FM 4-117

WAR DEPARTMENT

COAST ARTILLERY FIELD MANUAL

BARRAGE BALLOON

OPERATION OF MATÉRIEL AND EMPLOYMENT OF PERSONNEL

June 1, 1942

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TABLE OF CONTENTS

COAST ARTILLERY FIELD MANUAL

BARRAGE BALLOON

OPERATION OF MATÉRIEL AND EMPLOYMENT OF PERSONNEL

PART ONE

FUNDAMENTALS

CHAPTER 1

GENERAL

■ 1. SCOPE.—This manual is designed for use by barrage balloon units as a guide in the selection and training of personnel and the operation of matériel. The instructions given may be applied with slight modifications to any type of matériel used by barrage balloon units. Instructions given regarding operation of matériel will be confined, in general, to operation other than at the balloon sites. Instructions concerning the operation of matériel at balloon sites may be found in FM 4-108.

■ 2. REFERENCES.—This manual should be studied in conjunction with the references listed in the appendix.

■ 3. GENERAL PROBLEMS.—The mission of a balloon barrage is actually to destroy hostile aircraft which hit the balloon anchoring cables and attached lethal devices, and to present the psychological threat of destruction. In order that the barrage may accomplish its mission, barrage balloon units must keep balloons flying in sufficient numbers, in such patterns, and at such altitudes as to present the maximum probability of destruction. In addition to the maintenance, repair, and operation of barrage balloon matériel, barrage balloon units must make regular local weather forecasts, and must store and transport large quantities of inflation gas. It may also be necessary for units to generate inflation gas if commercial sources of supply are not available.

■ 4. MATÉRIEL.—*a.* Special matériel and supplies for a balloon barrage include the following:

(1) Balloons.
(2) Winches.
(3) Cables.
(4) Lethal devices.
(5) Inflation gas.
(6) Gas generating equipment.
(*a*) Semimobile or mobile hydrogen generating unit.
(*b*) Gas generating materials.
(*c*) High pressure manifold.
(7) Gas handling equipment.
(*a*) Cylinders.
(*b*) Inflation manifold.
(*c*) Inflation tube.
(*d*) Thimble and tie-off cord.
(*e*) Manometer and tube.
(*f*) Purity testing apparatus.
(8) Mooring and bedding-down equipment.
(*a*) Screw pickets.
(*b*) Ground cable.
(*c*) Ground rigging.
(*d*) Ground cloth.
(*e*) Sandbags.
(9) Boats and equipment for water-borne sites.
(10) Material for platform installations in marshy areas and shallow water positions; and material for installations on roof tops.
(11) Air blower and exhauster.
(12) Balloon nurse bags.
(13) Weather station equipment.

b. The communication equipment used for operational control of the balloons is standard and similar to that used by other arms.

CHAPTER 2

AEROSTATICS

SECTION I

BALLOON TYPES

■ 5. GENERAL.—Gas, being a compressible fluid, must expand on rising in the air to a region of lower atmospheric pressure, and must contract when lowered to a region of greater atmospheric pressure. In barrage balloons, some provision must be made for this expansion and contraction as the balloon is raised and lowered. In the present barrage balloons, both the ballonet and dilatable principles are used.

■ 6. BALLONET.—*a. Principles of operation.*—A cross section of the ballonet type balloon is shown diagrammatically in figure 1. The envelope is divided into two compartments, the upper compartment for gas and the lower for air. The two compartments are separated by a light fabric diaphragm, which is treated to render it impermeable to gas and air. The air compartment is provided with an air exhaust valve and an air scoop. The air scoop is equipped with a check valve which allows air to enter the air compartment, but prevents it from being exhausted through the air scoop. As the balloon rises and the gas expands, due to a decreasing atmospheric pressure, the diaphragm is forced downward by the expanding gas, and air is forced out of the air compartment through the air exhaust valve. The diaphragm is forced downward through positions 2 and 3 until all air is exhausted and the balloon is full of gas. The external shape of the balloon does not change. A gas safety valve is provided in the envelope of the gas compartment to relieve any additional gas pressure. The altitude at which the balloon begins to valve gas is known as the pressure height. When the balloon is lowered and the gas contracts, due to an increasing atmospheric pressure, the diaphragm is forced upward and the air compartment is again filled with air entering through the air scoop.

b. Internal gas pressure of ballonet balloons.—Some ballonet balloons are designed to operate with internal gas pressure sufficient to resist external wind pressure. These balloons also have gas-inflated fins, and internal gas pressure is required to extend the tail surfaces. Other ballonet balloons are designed to operate with practically no internal gas pressure, the internal gas pressure being just sufficient to

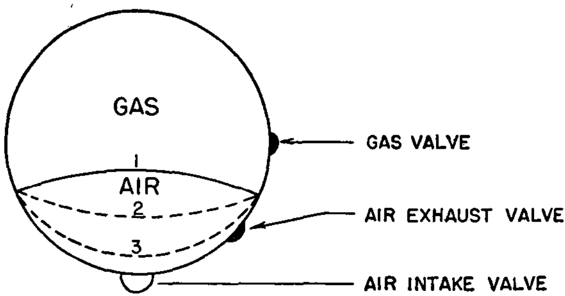


FIGURE 1.—Cross section of ballonet balloon.

maintain the shape of the balloon. The design of the latter balloon is such that it is not affected seriously by external wind pressures. This balloon has air-inflated fins.

■ 7. DILATABLE.—A cross section of the dilatable type balloon is shown diagrammatically in figure 2. This type balloon is rigged with elastic cords in the interior of the envelope. As the balloon rises and the gas expands, the cords are stretched and the balloon is dilated to the position indicated by the dotted lines. To prevent the balloon from bursting, a gas safety valve is provided to valve gas when a certain internal pressure is reached. The valve setting is determined by the strength of the fabric. When the balloon begins to valve gas, the pressure height of the balloon has been reached.

As the balloon is lowered and the gas contracts, the elastic cords draw the balloon back to the original shape. If gas has been valved, the original shape may not be recovered. Dilatable balloons need a sufficient internal gas pressure to resist external wind pressure. They also have gas-inflated fins, and require internal gas pressure to extend the tail surfaces.

SECTION II

VOLUME, PRESSURE HEIGHT, AND LIFT

■ 8. MINIMUM VOLUME.—*a. Definition.*—Minimum volume of a barrage balloon is the least volume to which the balloon may be inflated for safe operation. The minimum volume of

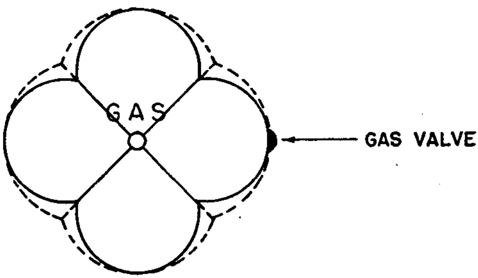


FIGURE 2.—Cross section of dilatable balloon.

balloons which require a certain internal gas pressure (dilatable balloons and some ballonet balloons) is the volume of gas needed to produce the required internal pressure. The minimum volume of ballonet ballons which require no certain internal gas pressure is the volume of gas required to give the balloon proper shape.

b. Methods for determining minimum volume.—Methods for determining whether a balloon is inflated to minimum volume will be described in various standing operating procedures issued for the different types of balloons in use. For dilatable balloons, the standard operating procedure will usually prescribe the minimum pressure to be maintained. The internal pressure needed for safe operation will be prescribed by the manufacturer, but it may be necessary to vary this pressure (as determined by experience) in accordance with the external wind pressures encountered in different regions. After a dilatable balloon is inflated to minimum pressure, the volume of gas in the balloon may be determined through use of methods similar to those described in paragraph 10. For ballonet balloons, the standard operating procedure may prescribe the number of cubic feet of gas required for minimum volume. This will be determined from data furnished by the manufacturer. If the number of cubic feet of gas is prescribed, the volume of gas in a balloon is determined by the weigh-off method described in paragraph 10*a*. For ballonet balloons, the standard operating procedure may also describe the position of the diaphragm when the balloon contains the minimum volume of gas. If this is done, a visual inspection of the diaphragm will disclose approximately whether the balloon is inflated to minimum volume.

c. Changes due to stretch.—As a balloon ages, the envelope and expansion cords (in the case of a dilatable balloon) will become permanently stretched, which will increase minimum volume. The standard operating procedure should prescribe the volume that should be allowed for stretch after a certain period of operation.

d. Minimum percent of fullness.—The minimum percent of fullness of a barrage balloon is the minimum volume divided by the gross volume of the balloon. As a balloon ages and stretch occurs, the minimum percent of fullness increases, since the volume of gas necessary to produce minimum volume increases more rapidly than does the gross volume.

■ 9. PRESSURE HEIGHT.—*a. General.*—The pressure height of a balloon is the altitude at which the balloon begins to valve gas. If a balloon ascends above pressure height, it will lose gas. Pressure height is affected by the percent of fullness of a balloon at the ground and by the atmospheric temperature.

b. Percent of fullness.—The percent of fullness of a balloon at the ground has a direct effect on the pressure height of the balloon For example, a balloon that is 60 percent full at the ground will have more room for the gas to expand before it begins to valve, and will therefore have a greater pressure height than would the balloon if it were 70 percent full at the ground. The percent of fullness of a balloon is determined by dividing the volume of gas actually present in the balloon by the gross volume of the balloon. The per-

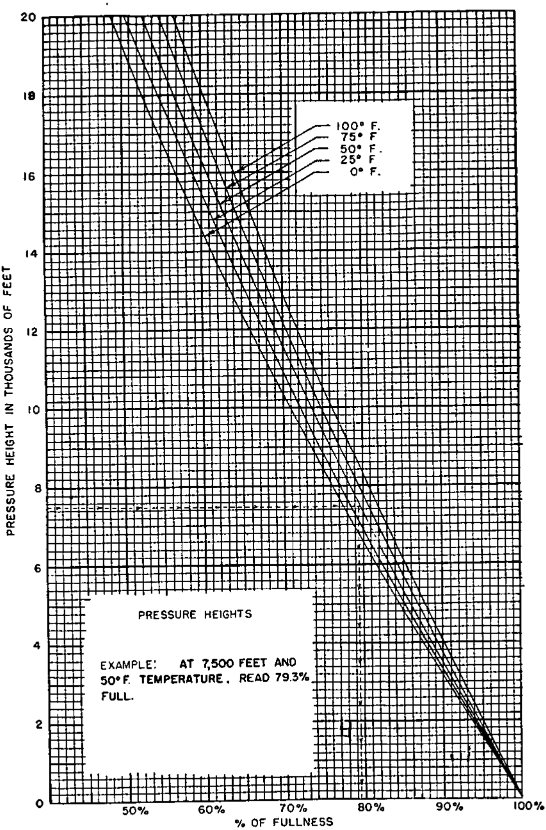


FIGURE 3.—Pressure height.

cent of fullness may also be determined by dividing the lift produced by the gas present in the balloon by the maximum lift, as shown in table I. A chart showing the pressure heights for various percentages of fullness is shown in figure 3. This chart is correct for any balloon.

c. Atmospheric temperature.—Gas expands more per unit increase in altitude at a low atmospheric temperature, than it does at a high atmospheric temperature. This is due to the fact that atmospheric pressure decreases more per unit increase in altitude at a low temperature than it does at a higher temperature. It follows, therefore, that for a given percent of fullness at the ground, the pressure height of a balloon will be less at a low atmospheric temperature than it will at a higher atmospheric temperature. For example, a balloon 80 percent full at the ground will have a pressure height of 6,600 at 0° F., and will have a pressure height of 8,300 feet at 100° F., as shown in figure 3.

d. Effect of raising a balloon above pressure height.—If a balloon filled to a certain percent of fullness is raised above pressure height it will valve gas, and will contain less than the original percent of fullness when returned to the ground. If the percent of fullness of the balloon upon being returned to the ground is less than the minimum percent of fullness prescribed for safe operation, the danger of break-away or damage to the balloon will be greatly increased. Figure 4 illustrates the effect of raising a balloon above its pressure height. In this case, the balloon was inflated to minimum volume, which was determined to be 79.3 percent of fullness at the ground. If it were permitted to ascend to 9,000 feet at 50° F., it would valve gas above its pressure height of 7,500 feet. When lowered to 1,400 feet it would be back to minimum percent of fullness, and when lowered to the ground it would be only 76 percent full, which would be less than the minimum percent of fullness. In the illustration, it is assumed that no change in atmospheric temperature occurred at the ground, and that superheat (sec. V) did not develop.

e. Effect of minimum percent of fullness on pressure height.—From the discussion above, it may be seen that the maximum pressure height at which a balloon may be flown with safety is governed by the minimum percent of fullness. If the balloon is filled with a greater volume of gas than the minimum percent of fullness, the pressure height will be reduced accordingly, but in no case should a balloon be flown above the pressure height for minimum percent of fullness. As a balloon ages and stretch occurs, the minimum percent of fullness is increased, and therefore the maximum pressure height at which the balloon may be flown with safety is

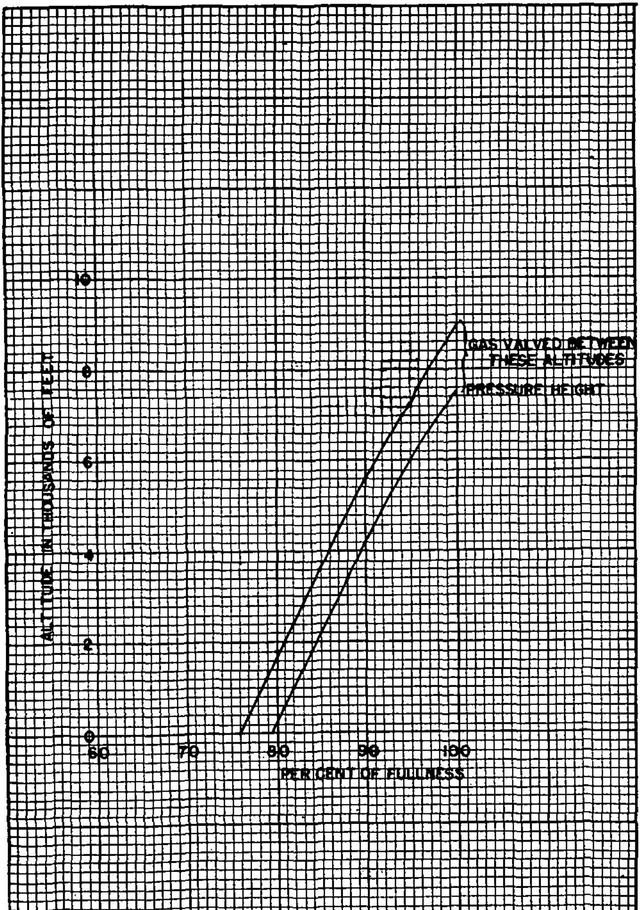


FIGURE 4.—Effect of raising a balloon above pressure height.

decreased considerably. This is particularly true of dilatable balloons.

■ 10. DETERMINING VOLUME.—Two methods of determining the volume of gas in a balloon are discussed below:

a. Weigh-off method.—The gross lift of a balloon may be determined by adding the weight of the balloon and ballast to the weigh-off (par. 12*a*). The volume of hydrogen in the balloon may then be computed through the use of the following formula:

$$V=\frac{81.24\,LT}{YP}$$

where V=volume of gas in cubic feet contained in the balloon.
L=gross lift of the balloon as determined by weigh-off.
P=atmospheric pressure in inches of mercury.
T=atmospheric temperature (absolute) in degrees Fahrenheit.
Y=gas purity expressed as a whole number, not as a percent.

The following formula is used to determine the volume of helium:

$$V=\frac{87.65\,LT}{YP}$$

This method is the most accurate available, but to avoid dynamic lift it is necessary that little or no ground wind (not more than 15 mph) exist when the balloon is weighed-off.

b. Groove depth method.—(1) By measuring the depth of the groove between two lobes of a dilatable balloon at a certain point and referring to the proper chart, the approximate volume of gas in the balloon may be determined. The point at which the measurement is to be taken is marked on the balloon and the chart is furnished by the manufacturer. The method of taking the measurement is shown diagrammatically in figure 5. As the balloon ages, the chart for volume as determined by groove depth becomes inaccurate due to fabric stretch, and a flat percentage correction is necessary.

(2) A method similar to (1) above has been proposed for ballonet balloons. In this method, the height of the diaphragm as shown diagrammatically in figure 6 is estimated

and reference is made to the proper chart to determine the approximate volume.

(3) The methods discussed in (1) and (2) above are only proposed methods, and more complete instructions may be contained in standard operating procedures issued for various balloons.

■ 11. STATIC LIFT.—Static lift is the lift produced by the gas in the balloon. Dynamic lift, produced by the kiting action of the balloon due to the wind, is not used to supplement static lift at the present time. To reach a given height, a balloon must be inflated with a sufficient volume of gas to lift the balloon, trim ballast, cable, lethal devices (if provided),

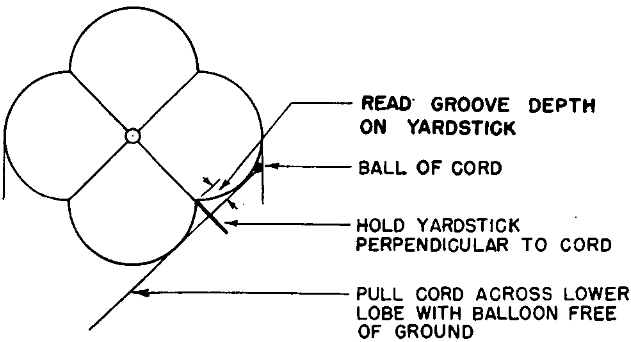


FIGURE 5.—Method for measuring groove depth.

and other appurtenances attached to the cable, to this height statically. (See lines 6 to 14, table I.) A free lift may also be added, (as determined by experience) to insure adequate cable tension for better flying performance and proper functioning of the lethal devices, and to compensate for changing atmospheric conditions, such as a drop in temperature. The number of cylinders of gas needed to produce the static lift required is determined by the methods discussed in section III. Since it is unlikely that all cylinders will be filled to the specified pressure, and since some valves may have leaked, it is always necessary to check the static lift of the balloon before ascension is made, either by weighing-off the balloon or by actually measuring the volume.

■ 12. CHECKING STATIC LIFT.—*a. Weigh-off.*—To check the lift of the balloon by the weigh-off, a number of sandbags equal in weight to the required net lift of the balloon are hung on the junction assembly grommets. Sandbags should weigh 33⅓ pounds each. If the wind is blowing, dynamic lift due to the wind may be partially eliminated by allowing the balloon to drift with the wind. If the balloon just lifts the sandbags, it is sufficiently inflated. Net lift required is the

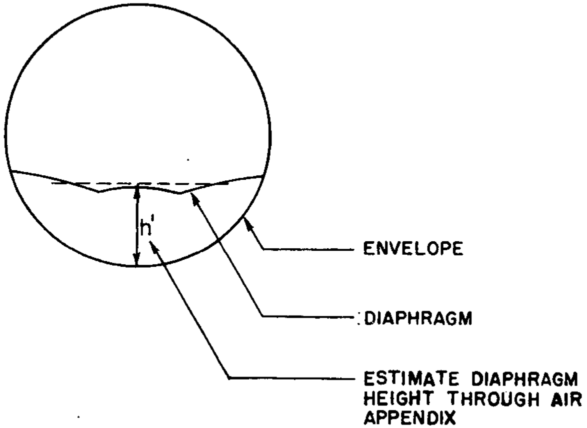


FIGURE 6.—Method for estimating diaphragm height.

sum of the weights of the cable for the altitude desired, the attached lethal devices, and other appurtenances, plus a free lift if desired. The net lift to be used will be greater than that required if superheat (sec. V) is present at the time of weigh-off, or if the minimum volume produces a greater lift than that needed to reach the required altitude. If the balloon will not lift the sandbags hung on the junction assembly grommets, the actual net lift may be determined by removing the sandbags one at a time until the balloon will lift those remaining. The sandbags remaining are then counted, and the number is multiplied by the weight of each sandbag to give the net lift. Sufficient gas must then be added to give the net lift desired. Gross lift is determined by adding the net lift to the weight of the balloon and trim ballast. If a tension meter is provided, the net lift may be more conveniently determined by attaching the balloon to the flying cable and reading the tension on the cable while the balloon is flying as close as possible to the ground. The tension reading will be equal to the net lift, except for any dynamic lift which may exist. In the absence of superheat it is preferable to check the balloon by weigh-off. This may be done any time between sunset and sunrise, after the superheat acquired during the day has disappeared.

b. Measuring volume.—If the balloon cannot be weighed-off satisfactorily due to the wind or other conditions, the lift may be checked by a method involving the actual measurement of the volume of gas in the balloon. The volume of hydrogen or helium required to produce the desired gross lift is first calculated by the use of the formulas given in paragraph 10*a*. The volume of gas in the balloon is then measured through use of some method similar to those discussed in paragraph 10*b*, and this volume is compared with the calculated volume required. If the volume of gas in the balloon is less than the calculated volume required, additional gas must be injected. If superheat is present when the volume is measured, a correction for the additional volume due to superheat must be made (see sec. V).

Section III

CALCULATING INFLATION AND WEIGH-OFF

■ 13. Appoximate Methods.—The following approximate methods may be used to determine the volume of gas needed to inflate a balloon if it is not desired actually to calculate the volume required. The results will not be as accurate as the results of calculations discussed later in this section, but will be definitely superior to guess work.

a. Dilatable balloon.—The principal requirement for inflation of a dilatable balloon is minimum pressure. If the balloon is inflated to minimum pressure, the lift will usually be greater than the lift required, and it will not be necessary to inject a volume of gas greater than that required to produce minimum pressure. An experienced balloon chief will usually know the approximate number of cylinders of gas required to give minimum pressure. After the balloon is inflated to minimum pressure, the net lift should be checked by weigh-off and more gas should be added if needed to produce the net lift required.

b. Ballonet balloon.—The approximate number of cylinders of gas needed to inflate a ballonet balloon may be determined by dividing the gross lift required (see lines 6 to 14, table I) by the average lift per cylinder. Lift of the gas contained in a standard hydrogen cylinder may be considered as about 13 pounds, and that of the gas contained in a standard helium cylinder, about 11.8 pounds. After the computed number of cylinders of gas have been injected, the balloon must be weighed off to determine whether it has sufficient lift. If the balloon will not lift the number of sandbags required, three cylinders of gas should be added for each sandbag that the balloon will not lift. Minimum volume must then be checked by a visual inspection of the diaphragm, as prescribed by the standing operating procedure in effect for the balloon. If the diaphragm is extended above the limits described, additional gas must be injected to produce minimum volume.

■ 14. CALCULATIONS.—*a. Gas requirements.*—The gas requirements of balloons are determined by the following factors:

(1) The balloon must contain a sufficient volume of gas to provide the static lift required to reach the altitude desired.

(2) The balloon must contain at least the minimum volume of gas.

(3) There should be as little gas in the balloon as possible at the ground, consistent with the above, in order that the pressure height will be as great as possible.

b. Form.—The number of cylinders of gas needed for inflation, and the weigh-off for checking the inflation, are calculated on lines 1 to 29 of table I. The pressure height for the percent of fullness to which the balloon is inflated is calculated on lines 30 to 34. If, in order to give minimum volume, the balloon is inflated to a greater volume than that required to reach H (line 8), the height attainable with the minimum volume of gas without valving is calculated on lines 35 to 41. All of the above calculations are made at the balloon site. Operating ceiling and the maximum altitudes for day and night flying without valving are calculated by higher headquarters on lines 42 to 58 of the form. These calculations are made before assigning H. The lift per cylinder of gas may be calculated on lines 59 to 64.

TABLE I.—*Inflation and ceiling calculations*

DATA AND LIFT

1.	P (atmospheric pressure)	*30.2* in. Hg.
2.	t (atmospheric temperature)	*40* °F.
3.	T (460 plus t)	*500°* F. Abs.
4.	dT (superheat)	*25°* F.
5.	Y (gas purity)	*98*
6.	Weight per 1,000 ft. of cable	*88* lb.
7.	w (cable weight per 1,000 ft. of alt.) (line 6 divided by .96)	*91.7* lb./ft.
8.	H (operating altitude)	*5,400* ft.
9.	Weight of balloon	*870* lb.
10.	Weight of ballast	*60* lb.
11.	Weight of lethal devices and other appurtenances attached to cable	*40* lb.
12.	Free lift	*150* lb.
13.	Cable weight $\left(\frac{\text{line 7} \times \text{line 8}}{1{,}000}\right)$	*495* lb.
14.	Lift required (sum of lines 9 to 13)	*1,635* lb.
15.	K (constant for calculating maximum lift) (for hydrogen, use 0.01231) (for helium, use 0.01141)	*0.01231*
16.	Balloon type	*Dilatable*
17.	V (gross volume)	*30,600* cu. ft
18.	L' (maximum lift at ground) $\left(\frac{PYKV}{T} = \frac{\text{lines } 1 \times 5 \times 15 \times 17}{\text{line } 3}\right)$	*2,230* lb.
19.	F_m (minimum percent of fullness)	*77%*
20.	Minimum lift (line 18 $\times$ line 19)	*1,717* lb.
21.	L (lift to be used) (enter line 14 or 20, whichever is greater)	*1,717* lb.

TABLE I.—*Inflation and ceiling calculations*—Continued

NUMBER OF CYLINDERS REQUIRED

22. l_o (lift per cylinder) .... *13* lb.
    (from line 64 or known)
23. Number of cylinders required for inflation *135*

$$\left(\frac{L}{Y\, l_o} \times 100 = \frac{\text{line 21}}{\text{lines } 5 \times 22} \times 100\right)$$

WEIGH-OFF

24. C (constant for superheat correction) *108*
    (for hydrogen, use .... 108)
    (for helium, use .... 116)

	Night	*Day*
25. L (enter line 21)	*1,717*	*1,717* lb.
26. dL (superheat correction) $\left(\frac{dT\,L\,C}{T\,Y} = \frac{\text{lines } 4\times21\times24}{\text{lines } 3\times5}\right)$	*0*	*95* lb.
27. Total gross lift (sum of lines 25 and 26)	*1,717*	*1,812* lb.
28. Weight of balloon and ballast (sum of lines 9 and 10)	*950*	*950* lb.
29. Weigh-off (line 27 less line 28)	*767*	*862* lb.

PRESSURE HEIGHT

	Night	*Day*
30. L (enter line 21)	*1,717*	*1,717* lb.
31. dL_s (superheat correction) $\left(\frac{dTL}{T} = \frac{\text{line } 4\times\text{line } 21}{\text{line } 3}\right)$	*0*	*86* lb.
32. L plus dL_s (sum of lines 30 and 31)	*1,717*	*1,803* lb.
33. F (percent of fullness) $\left(\frac{L \text{ plus } dL_s}{L'} = \frac{\text{line } 32}{\text{line } 18}\right)$	*77*	*80.9%*
34. Pressure height (enter chart with line 33)	*8,350*	*6,780* ft.

NOTE.—When either value of line 34 is less than line 8 and—

a. Line 21 is the same as line 20, the altitudes shown on line 34 are the maximum attainable without valving.

b. Line 21 exceeds line 20, a smaller value for H of line 8 should be determined; unless the first column, line 34, exceeds line 8 and attainment of H at night with sacrifice of day altitude is desired.

TABLE I.—*Inflation and ceiling calculations*—Continued

ATTAINABLE HEIGHT (OPTIONAL)

NOTE.—Excess lift (effective day and night) and superheat buoyancy (effective during the day) permit the following altitudes to be attained with the quantity of gas used without valving:

	Night	*Day*
35. Excess lift (line 21 less line 14)	*82*	*82* lb.
36. dL (superheat correction) (enter line 26)	*0*	*95* lb.
37. Total excess lift (sum of lines 35 and 36)	*82*	*177* lb.
38. Additional altitude $\left(\frac{1000 \times \text{line } 37}{\text{line } 7}\right)$	*895*	*1,932* ft.
39. H (line 8)	*5,400*	*5,400* ft.
40. Sum of lines 38 and 39	*6,295*	*7,332* ft.
41. Height attainable without valving (enter line 34 or line 40, whichever is smaller)	*6,295*	*6,780* ft.

OPERATING CEILING

42. Pressure height for F_m (enter chart with line 19)	*8,350* ft.
43. Superheat correction ($80\ F\ dT = 80 \times \text{line } 19 \times \text{line } 4$)	*1,540* ft.
44. Daytime pressure height for F_m (line 42 less line 43)	*6,810* ft.
45. F' for H (enter chart with line 8)	*84.5*%.
46. $L'\ F'$ (line 18×line 45)	*1,884* lb.
47. Lift required (enter line 14)	*1,635* lb.
48. Line 46 less line 47 (plus or minus)	+*249* lb.
49. $0.026\ L'$ (0.026×line 18)	*58.0* lb./ft.
50. w (enter line 7)	*91.7* lb./ft.
51. Sum of lines 49 and 50	*149.7* lb./ft.
52. Operating ceiling—H (plus or minus) $\left(\frac{L'\ F' \text{ less lift required}}{w \text{ plus } 0.026\ L'} \times 1{,}000 =\right)$ $\left(\frac{\text{line } 48}{\text{line } 51} \times 1{,}000\right)$	+*1,663* ft.
53. H (enter line 8)	*5,400* ft.
54. Operating ceiling (algebraic sum of lines 52 and 53)	*7,063* ft.
55. Superheat correction ($30\ F\ dT = 30 \times \text{line } 33 \times \text{line } 4$) (Use night percent of fullness; if unknown, use line 19 instead of line 33)	*578* ft.

TABLE I.—*Inflation and ceiling calculations*—Continued

OPERATING CEILING—Continued

56. Limited operating ceiling .... *6,485* ft.
(line 54 less line 55)
57. Maximum altitude to be assigned for inflation: Maximum altitude for night flying .... *6,485* ft.
58. Maximum altude for daytime flying .... *6,485* ft.

NOTE.—*a.* If line 54 exceeds line 42, enter line 42 in line 57 and enter line 44 in line 58.
b. If line 44 exceeds line 56, enter line 56 in lines 57 and 58.
c. If neither *a* nor *b* apply, determine line 41 (night flying) for inflation to minimum fullness and enter result in line 57; enter line 44 in line 58.

LIFT PER CYLINDER

NOTE.—If lift per cylinder is known, enter lift on line 22 directly. If lift is unknown use following lines, suitable for a cylinder of 1.528 cu. ft. capacity.

59. P' (gage pressure of cylinder) .... *2,000* lb./sq. in.
60. t' (temperature at which P' determined) .... *68°* F.
61. T' (460 plus t') .... *528* °F. Abs.
62. $\left(\text{For hydrogen: } 3.02\frac{P'}{T'}\right)$ $\left(\text{For helium: } 2.70\frac{P'}{T'}\right)$ .... *11.44* lb.
63. Constant .... *1.56* lb.
64. l_o (lift per cyl. for 100% purity) .... *13.00* lb.
(sum of lines 62 and 63)

c. Data and lift (lines 1 to 21).—Atmospheric pressure (P) and temperature (t) are furnished by the weather section of the barrage. (It is more desirable to read the temperature at the balloon site if a thermometer is available.) Superheat (dT) is determined as described in paragraph 19. Gas purity (Y) is determined by the gas workers, and is used in the form as a whole number and not as a percent. Thus, 98 percent purity is expressed by the number 98. Cable weight per 1,000 feet is furnished by the manufacturer, and the cable weight per 1,000 feet altitude is computed as shown on line 7. This computation takes cable sag into account. Operating altitude (H) is assigned by higher headquarters. The weight and type of balloon are painted on the nose of the balloon. The ballast is weighed when it is placed in the ballast pockets. Weight of lethal devices and other appurtenances attached to the cable is furnished by the manufacturer. Free lift may be added if desired (as determined by experience) to insure adequate cable tension for better flying performance and proper functioning of the lethal devices, and to compensate for changing atmospheric conditions, such as a drop in temperature. Cable weight for the operating altitude is determined by multiplying the operating altitude by the cable weight per 1,000 feet altitude, and dividing by 1,000. The sum of the weights of the balloon, ballast, lethal devices, free lift, and cable is equal to the gross lift required. Gross volume of the balloon is obtained from the manual for balloon operation issued by the manufacturer. Maximum lift at the ground (L') is determined by the use of the formula shown on line 18. Minimum percent of fullness (F_m) is determined by dividing the minimum volume (par. 8) by the gross volume. Minimum lift is determined by multiplying the maximum lift by the minimum percent of fullness. If the minimum lift is greater than the lift required, the minimum lift is used, since the balloon must be filled at least to minimum percent of fullness.

d. Number of cylinders required (lines 22 and 23).—The lift per cylinder of gas (l_0) may be known from information furnished by the battalion gas service section. If not known it may be calculated on lines 59 to 64. The pressure of the cylinder (P') and the temperature at which the pressure was measured (t') are determined by the gas workers at the inflation site. The temperature used must be the temperature at which the pressure was measured. Pressure and temperature readings should be taken on one out of every 12 cylinders (approximately), and the average lift per cylinder of this sample is used in making the calculation. If the cylinders are used within several days after being charged, the pressure and temperature at the time they were charged may be used. If facilities for measuring the pressure and temperature are not available, a lift of 13 pounds per cylinder of hydrogen and 11.8 pounds per cylinder of helium may be used. After the lift per cylinder has been determined, the number of cylinders required is determined as shown on line 23.

e. Weigh-off (lines 24 to 29).—To determine whether the balloon has sufficient lift after inflation, it must be weighed-off (par. 12*a*). If superheat (sec. V) is present at the time of the weigh-off, a correction for the additional lift due to superheat must be added to *L*, since the balloon must be inflated to fly with or without superheat. The correction for additional lift due to superheat (*dL*) is computed as shown on line 26. The weight of the balloon and ballast is subtracted from the total gross lift to give the net lift or weigh-off which the balloon should have in order to be sufficiently inflated. The night value is used whenever the balloon is weighed off in the absence of superheat.

f. Pressure height (lines 30 to 34).—Although the operating altitude (*H*) assigned by higher headquarters will normally be within the pressure height of the balloon, changes in atmospheric pressure, temperature, and gas purity since the operating ceiling was assigned, may have altered the volume of gas required for inflation, and therefore the pressure height will be altered. It is desirable, therefore, to determine the pressure height for the actual percent of fullness after inflation. If superheat is present, a correction for the increase in lift due to superheat must be added to *L*. This correction is calculated as shown on line 31. The percent of fullness is then determined as shown on line 33, and the pressure height for this percent of fullness is read from the chart shown in figure 3. At all times when superheat is not present, the night pressure height is used. If the pressure height for either day or night operation is less than the assigned operating altitude and line 21 is the same as line 20 (indicating that the balloon must be filled to the minimum percent of fullness), the pressure heights shown on line 34 are the maximum altitudes attainable without valving gas. If either value of line 34 is less than line 8, and line 21 exceeds line 20 (indicating that the balloon must be filled to more than the minimum percent of fullness), a smaller value for *H* must be determined and lines 13, 14, and 21 to 34 must be recalculated. Higher headquarters should be so informed. The new value for *H* may be determined on lines 42 to 58. If only the first column of line 34 is greater than line 8, *H* may be reached at night without valving gas, but altitude must be sacrificed in the daytime to conform with the pressure height shown in the second column, line 34.

■ 15. CALCULATING ATTAINABLE HEIGHT (lines 35 to 41).—If line 21 exceeds line 14 (indicating that the minimum percent of fullnes to which the balloon must be filled results in more lift than is required to reach *H*) the balloon will be able to support more cable than necessary to reach *H*. Superheat buoyancy also permits more cable to be lifted. The altitude attainable with the volume of gas used without valving may be calculated on lines 35 to 41. The excess static lift of the balloon is determined by subtracting the lift required to reach *H* from the lift produced by the minimum volume of gas. If superheat is present or will be present when the balloon is being flown, the additional lift due to superheat is added to give the total excess lift. The additional altitude attainable (ignoring pressure height) is determined by use of the formula shown on line 38. If the sum of *H* and the additional altitude is less than pressure height (line 34), this sum is the height attainable without valving; otherwise, the pressure height should be entered on line 41.

SECTION IV

OPERATING CEILING, LIMITED OPERATING CEILING, AND MAXIMUM ALTITUDES FOR DAY AND NIGHT FLYING

■ 16. GENERAL.—The operating ceiling of a barrage balloon is the maximum altitude to which the balloon will lift the anchoring cable and attached lethal devices and other appurtenances statically, and still maintain a cable tension at the winch equal to the free lift. It may or may not be greater than the pressure height for minimum percent of fullness. The limited operating ceiling of a balloon is the altitude for a certain volume of gas that cannot be exceeded at night because of lack of lift, and cannot be exceeded in the daytime when superheat is present because to do so would result in a loss of gas by valving, the altitude being the same for both day and night operation. The maximum altitudes which may be assigned for inflation and for day and night operation without valving gas are limited by the operating ceiling, and by the pressure height for minimum percent of fullness. A further discussion of limited operating ceiling and maximum altitudes for day and night flying will be found in section V.

■ 17. CALCULATIONS.—In order accurately to assign the altitude for inflation (*H*) and the altitudes for day and night flying to the various balloons in the barrage, higher headquarters must calculate the maximum altitudes which may be attained without valving gas and then make assignments which are within these altitudes. These calculations may be made on lines 1 to 21 and lines 42 to 58 of table I. To begin the calculations, a value must be assumed for *H* and entered on line 8. (A plus or minus correction for this assumed value will be determined later.) Lines 1 to 21 are completed as described in paragraph 14*c*, and lines 42 to 58 are completed as described below. Lines 42 to 44 are not necessary for calculating the operating ceiling, but are necessary for determining the maximum altitudes for day and night flying. The pressure height for minimum percent of fullness (F_m) is read from the chart shown in figure 3. If it is expected that superheat will be present during the day, a correction for the effect of superheat must be made as shown on line 43, and this correction must be subtracted from the pressure height for F_m. The percent of fullness (F') for the assumed altitude (H) is obtained from the chart shown in figure 3, and the lift for this percent of fullness is determined as shown on line 46. The lift required to reach *H* is subtracted from line 46 to give the excess lift, which is entered as a plus or minus quantity on line 48. If line 47 is greater than line 46, line 48 is negative. The amount that the assumed *H* must be increased or reduced to give the operating ceiling (operating ceiling minus *H*) is calculated as shown on lines 49 to 52. Line 52 bears the same algebraic sign as line 48. Line 52, when added algebraically to the assumed *H* will give the operating ceiling for the balloon. The limited operating ceiling may then be determined by correcting for superheat for daytime operation, as shown on lines 55 and 56. The altitudes to be assigned for inflation (H) and the maximum altitude for day and night flying are entered on lines 57 and 58 as follows:

a. If the operating ceiling exceeds the pressure height for F_m, the pressure height for F_m is assigned for inflation. The pressure height for F_m is the maximum altitude for night operation. The daytime pressure height for F_m is the maximum altitude for daytime operation when superheat is present.

b. If the daytime pressure height for F_m is greater than the limited operating ceiling, the limited operating ceiling or a lesser value may be assigned for inflation. The limited operating ceiling is the maximum altitude that may be assigned for day and night operation. The altitudes assigned for inflation and for day and night operation will be the same.

c. If neither *a* nor *b* above is true, which will be seldom (meaning that the limited operating ceiling is greater than the daytime pressure height for F_m and the pressure height for F_m is greater than the operating ceiling), the balloon should be inflated to minimum fullness and the altitude attainable for night flying must be calculated on lines 35 to 41. The maximum altitude for daytime flying will be the daytime pressure height for F_m.

■ 18. EFFECT OF ATMOSPHERIC DENSITY ON OPERATING CEILING.—As the atmospheric density at the ascension point decreases, the lift per unit volume of the gas in a balloon decreases, and therefore the operating ceiling is decreased. Density of the atmosphere decreases with altitude above sea level. Therefore, as the altitude of the ascension point above sea level is increased, the operating ceiling above the ascension point is decreased. Density of the atmosphere also decreases with an increase in temperature. Therefore, the operating ceiling of a balloon will be decreased in regions of prevailing high temperatures. Correction for atmospheric density is automatically made on the computation form, and no separate correction is necessary.

SECTION V

SUPERHEAT

■ 19. GENERAL.—*a. Determining superheat.*—Superheat is the increase in temperature of the gas in a balloon above that of the surrounding air due to the effect of the rays of the sun on the balloon fabric. It is expressed in degrees Fahrenheit. The amount of superheat present in a balloon may be measured by a thermometer in the balloon envelope, or may be estimated, based on experience and records of superheat acquired under the same or similar climatic conditions. Records of superheat acquired may be compiled by calculating the superheat by weigh-off and then recording the superheat, together with the atmospheric temperature. Superheat may be calculated by weighing-off the balloon with and without superheat, and then using the formula:

$$dT = D \cdot \frac{TY}{LC}$$

where

dT=superheat in degrees Fahrenheit.

D=the difference in weigh-off of a balloon when superheat is present and the same balloon without superheat.

T=atmospheric temperature (absolute) in degrees Fahrenheit.

Y=gas purity expressed as a whole number, not as a percent.

L=the gross lift of the balloon without superheat.

C=constant, which for hydrogen is 108 and for helium is 116.

b. *Superheat effects*.—An understanding of the effects of superheat is important in barrage balloon work. Due to the expansion of gas caused by the heating, the gas in a balloon will have greater volume and lift when superheat is present, but this volume and lift will disappear when superheat disappears. The additional lift and volume must be considered in checking the lift of the balloon by weigh-off or volume measurement methods. The additional volume will also affect pressure heights determined without taking superheat into account. Therefore, corrections for the effect of superheat must be made.

■ 20. SUPERHEAT CORRECTIONS.—*a*. *Weigh-off*.—To determine the weigh-off when superheat is present, the additional lift due to superheat must be added to the weigh-off calculated without superheat. This additional lift is determined by the formula:

$$dL = \frac{dT\ L\ C}{YT}$$

where

dL=the additional lift in pounds due to superheat.

dT=superheat in degrees Fahrenheit.

L=the lift of the balloon without superheat.

C=constant, which for hydrogen is 108 and for helium 116.

Y=gas purity expressed as a whole number, not as a percent.

T=atmospheric temperature (absolute) in degrees Fahrenheit.

b. Volume measurement.—To determine the volume of a balloon when superheat is present, the additional volume due to superheat must be added to the volume without superheat. This additional volume is determined by the formula:

$$dV=FV\ .\ \frac{dT}{T}$$

where

dV=the additional volume in cubic feet due to superheat.

FV=the volume of the balloon without superheat.

dT=the superheat in degrees Fahrenheit.

T=the atmospheric temperature (absolute) in degrees Fahrenheit.

c. Pressure height.—Since superheat causes expansion of gas in a balloon, the pressure height for a certain volume of gas will be reduced when superheat is present. In order that the balloon may be flown at the maximum altitudes without valving both day and night, certain compensations for the effect of superheat upon pressure height must be made. These compensations may be made by reducing the altitude of the balloon in the daytime when superheat is present, by reducing the volume of gas used for inflation (but not below minimum volume), or by a combination of the two.

(1) *Reduction in daytime altitude.*—This method is used when it is desired to attain the greatest altitude at night, but considerable altitude is sacrificed during the daytime when superheat is present. This method must be used whenever the operating ceiling is greater than the pressure height for minimum volume, because the balloon should not be inflated with less than the minimum volume of gas. In this case, the balloon is inflated to minimum volume and is flown at the pressure height for minimum volume at night. During the day when superheat occurs, the gas in the balloon will expand and the balloon must be lowered to the daytime pressure height for the minimum volume of gas. Daytime pressure

height is determined by subtracting a correction for superheat from the pressure height for minimum volume without superheat. The superheat correction is determined as follows:

$$\text{Reduction in feet altitude} = \frac{F\,dT}{KT}$$

where F=the percent of fullness at the ground without superheat.

dT=superheat in degrees Fahrenheit.

T=atmospheric temperature (absolute) in degrees Fahrenheit.

K=the change in air density corresponding to a change in altitude of 1 foot, expressed as a fraction of the ground density. For the range of altitudes encountered with low-altitude balloons, K=.0000245 to .000027.

For an average value of 50° F. and .0000245 for K, the approximate rule is:

$$\text{Reduction in feet altitude} = 80\,F\,dT$$

(2) *Reduction of gas content.*—When feasible, it may be more desirable to reduce the gas content of the balloon below the volume required to reach operating ceiling (but not below minimum volume) and fly the balloon at the same altitude both day and night. This altitude is known as the limited operating ceiling, since it cannot be exceeded at night because of lack of lift and cannot be exceeded in the daytime when superheat is present without valving gas. The amount of gas to be used for inflation is the volume required to lift the balloon to the limited operating ceiling without superheat. The limited operating ceiling is determined by first calculating the operating ceiling and then subtracting the superheat correction. The superheat correction is determined by the formula—

$$\text{Reduction in feet altitude} = \frac{F\,dT}{\dfrac{(K+w)\,T}{L'}}$$

where

F=the percent of fullness at the ground without superheat—

dT=superheat in degrees Fahrenheit.

K=the same as explained in (1) above.

w=the cable weight per foot of altitude.
L'=the maximum gross lift of the balloon at the ground.
T=atmospheric temperature (absolute) in degrees Fahrenheit.

Using average values for the above, an approximate rule is:

$$\text{Reduction in feet altitude} = 30\ F\ dT$$

The method described in this paragraph is applicable only if the limited operating ceiling calculated in this way is below the daytime pressure height for minimum volume.

(3) *Combined reduction in altitude and reduction in gas volume.*—It sometimes happens that the limited operating ceiling is above the daytime pressure height for minimum percent of fullness. In this case, the balloon could be lowered in the daytime as described in (1) above, but a greater daytime altitude without valving may be attained by a combination of the two methods described above. The balloon is inflated to minimum volume and is flown during the daytime at the daytime pressure height for minimum percent of fullness. The altitude attainable at night is determined on line 41 of table I.

■ 21. OTHER CONSIDERATIONS.—As shown in the preceding paragraph, a balloon may be filled with the minimum volume of gas and flown at the maximum height attainable with this volume of gas at night. In the daytime, when superheat is present, the additional lift produced by superheat may be used to lift the balloon above the altitude otherwise attainable with the volume of gas used. When superheat is used to produce this additional altitude during the day, it must be reasonably certain that the superheat will continue throughout the day. The appearance of clouds, which would reduce superheat, would cause a loss in lift and a consequent reduction in altitude. This would cause a sag in the cable, which if not removed, would impair the flying performance of the balloon and functioning of the lethal devices, and might cause the cable to become entangled in surrounding obstructions.

SECTION VI

OTHER EFFECTS ON LIFT

■ 22. LOSS OF GAS.—The lift of a balloon does not change materially between the ground and operating altitude (except for gain due to superheat), provided no gas is valved. In order to insure that the balloon will maintain its lift, and also to insure that the balloon will have minimum volume when lowered, every effort should be made to avoid valving gas by keeping the balloon within pressure height. Loss of gas by valving will not produce a loss in lift until the gas contracts as the superheat disappears or until the balloon is lowered to a region of greater pressure.

■ 23. SUPERPRESSURE.—Superpressure is the difference in pressure between the pressure of the gas in a balloon and atmospheric pressure. The amount of superpressure in a balloon reaches a maximum when the balloon is 100 percent full. Gas under pressure weighs more (has a greater density) than gas not under pressure, and therefore the useful lift per unit volume is less. It follows that a balloon with superpressure will have a smaller lift than the same balloon without superpressure. A superpressure of 3 inches of water will reduce the lift of a balloon less than 1 percent at 9,000 feet altitude. This effect is small enough to neglect in all barrage balloon work.

■ 24. HUMIDITY.—The lift of a balloon is determined by the weight of the air displaced. Humid air weighs less per unit volume than dry air, and therefore a balloon will have less lift in humid than in dry air. An increase of 50 percent relative humidity will decrease the lift of a balloon about 1 percent at the ground. This effect is small enough to neglect in all barrage balloon work. Constants in the equation given in this manual and the pressure height chart of figure 3 are based upon an average humidity of 60 percent at 50° F.

SECTION VII

TOPPING-UP

■ 25. GENERAL.—An inflated balloon may lose gas by valving or leakage through the envelope. This gas must be replaced if sufficient pressure and lift are to be maintained. Replacement of this gas is called topping-up. The volume of gas to be added is determined by weigh-off or volume measurement. In order to avoid the effects of superheat, balloons are ordinarily weighed-off and topped up between sunset and sunrise or when there is no superheat. If superheat is present, a correction must be made for the effect of superheat as discussed in section V.

■ 26. TOPPING-UP GAS.—As shown in the computation in table I, in some instances a balloon may have more than sufficient lift to reach a given altitude. In that particular illustration, the balloon has more than sufficient lift to reach the operating altitude of 5,400 feet, and the gas which produces the additional lift is needed only to maintain minimum volume. This balloon, with a minimum volume (*FV*) of 23,500 cubic feet, could be inflated with 22,400 cubic feet of hydrogen and 1,100 feet of marsh gas and still reach 5,400 feet. Hence, marsh gas would be very satisfactory for topping-up this balloon. If desired, the actual altitude attainable after marsh gas had been used for topping-up could be calculated on table I by entering on lines 5 the estimated purity of the gas in the balloon after topping-up. Coal gas may also be used as a topping-up gas. In localities where hydrogen is difficult to obtain, it may be practicable to resort to the use of marsh, coal, or other locally available gas for topping-up.

SECTION VIII

OTHER CONSIDERATIONS

■ 27. WHEN TO DEFLATE DUE TO LEAKAGE.—If a balloon is kept below pressure height so that no gas is valved, an excessive loss of lift indicates that gas is being lost through leakage. Gas leakage produces a decrease in pressure, which may lead to poor flying performance caused by inadequately inflated fins and nose-cupping. Therefore, the number of pounds of lift loss is an indication as to whether such erratic performance may be expected. When the lift loss becomes abnormally high, the balloon should be deflated, air inflated, inspected, and repaired. To determine when the balloon should be deflated, a record should be kept (preferably by the platoon chief) showing the pounds of lift loss of each balloon as determined by weigh-off. An example of such a record is shown below:

WEIGH-OFF RECORD BALLOON NO. ....

Date	Weigh-off after previous topping-up	Present weigh-off before topping-up	Lift loss	Remarks
	Pounds	*Pounds*	*Pounds*	
Feb. 1	600	567	33	
Feb. 2	600	600	0	Did not top-up.
Feb. 3	600	567	33	
Feb. 4	600	533	67	
Feb. 5	600	567	33	
Feb. 6	600	567	33	
Feb. 7	600	400	200	Believe gas valved.
Feb. 8	600	600	0	Value doubtful. Wind affected weigh-off.
Feb. 9	600	533	67	
Feb. 10	600	567	33	
Feb. 11	600	533	67	
Feb. 12	600	500	100	
Feb. 13	600	500	100	Recommend deflation.
Feb. 14	600	467	133	Deflation ordered.

It should be remembered that as a balloon ages and permanent stretch occurs, (particularly in a dilatable balloon) the pressure height for minimum percent of fullness is reduced, and the balloon must be lowered accordingly or gas will be valved and this record will be of no value.

■ 28. AERODYNAMICS.—*a. Angle of trim.*—The flying performance of a balloon is very dependent upon the attainment of the proper angle of trim, as prescribed by the manufacturer's specifications or by standard operating procedure. If the adjustment of the rigging is improper, so that the balloon will fly with less than the proper angle of trim, the balloon is sure to dive. On the other hand, if the adjustment of the rigging will permit the balloon to fly with more than the proper angle of trim, a high dynamic lift and great cable tension will result, and the danger of loss of the balloon due to cable breakage will be greatly increased. The rigging should be checked at every opportunity to insure that the balloon will fly with the correct angle of trim.

b. Kiting.—Dynamic lift due to kiting action of the balloon produced by the wind will ordinarily not be used to increase operating ceiling of the present balloons, except in special situations. Kiting may be used to advantage in areas of steady prevailing winds to maintain the altitude of a ballonet type balloon which is carrying heavy cable and does not require a certain internal pressure. In making use of kiting, the responsible officer should insure that the balloon lifts the extra cable payed out and does not drift away from the ascension point without increasing in altitude. A balloon especially designed to be lifted by the wind would have an extra large air chamber to provide for a greater pressure height.

CHAPTER 3

METEOROLOGY

SECTION I

INFLUENCE OF WEATHER ON BARRAGE BALLOONS

■ 29. WEATHER ELEMENTS.—The weather elements which must be considered in barrage balloon operations are lightning, wind, clouds, fog, ice, snow, rainfall, and sunshine.

■ 30. LIGHTNING.—Lightning tears and ignites balloons. Balloons have been destroyed under conditions when there was no actual lightning discharge to earth, and by strokes so weak that thunder was not heard on the ground. Experience has shown that there is great danger to balloons in lightning from all precipitating cumulo-nimbus clouds. It is essential for weather personnel supplying information to a balloon barrage to watch the development of cumulo-nimbus and cumulus clouds and give careful attention to reports of such clouds.

■ 31. WIND.—Large balloons should withstand a wind speed of at least 50 miles per hour. In the case of old balloons, rigging patches may tear off and the envelopes may rip at lower wind speeds. Gusty winds may cause balloons to yaw and dive. Such action may break their flying cables. A barrage normally contains balloons of all ages, and experience has shown that casualties may be caused by winds of 45 miles per hour, and balloons may be seriously endangered if the wind speed is 50 miles per hour or more. A rapid increase in wind speed or a squall is more dangerous than a steady wind. A wind of 25 miles per hour is dangerous when a balloon is being maneuvered near the ground, particularly on sites surrounded by obstructions which may damage the balloon fabric. If the balloons are kept flying until the wind at operating altitude is more than 50 miles per hour, serious losses may be incurred in attempting to bed down the balloons. It is necessary, therefore, to issue warnings when a wind speed of more than 40 miles per hour is expected. If balloons are flying during a surface wind of 20 miles per hour which is expected to increase, information about the possible later development of squalls, gales, lightning, and snow or icing conditions should be given as early as possible. This will enable the barrage commander to decide whether to bed down the balloons while it is still practicable to do so or to allow them to remain flying in the face of adverse conditions.

■ 32. CLOUDS.—The presence of stratus or strato-cumulus clouds is of tactical operational importance. If balloons project *above* a cloud layer they indicate the presence of a target to enemy bombardment aviation. The barrage commander must decide whether his balloons should or should not be hidden in the clouds. When the sky is less than six-tenths covered by clouds over the barrage area, the importance of concealing balloons in the clouds decreases. The weather section must keep watch for the development of stratus and strato-cumulus clouds. All available information as to height of the upper surface of these clouds, whether the information is obtained from aircraft observations or by other means, should be supplied to the barrage headquarters.

■ 33. FOG.—The considerations applying to fog are similar to those for stratus and strato-cumulus clouds. The barrage commander requires information as to when fog is expected, its vertical and horizontal extent, and the time it is expected to end. In dense fogs, balloons are ordinarily bedded down.

■ 34. ICE, SNOW, AND RAINFALL.—*a. Ice and snow.*—Glaze is the type of ice formation most seriously hindering balloon operation. The weight of the ice so formed may become sufficient to force the balloon to the ground. Actual inspection and tests of a balloon during and after a snowstorm revealed that the flight characteristics of the balloon were greatly affected by the snow. It was found that ice and snow had gathered in the corrugations of the fins, in the grooves, on the metal fittings, on the gas and air valves, and on the top surface of the balloon. Great difficulty was encountered in removing the snow. The tests showed the following:

(1) The balloon fabric may become brittle in temperature of 32° F. or less, and there is an increased danger of tearing the fabric.

(2) The load of snow that will accumulate on a balloon while it is on the ground or in flight in snowy weather will completely destroy trim and cause the balloon to be tail heavy.

(3) The weight of the snow will decrease the net lift of the balloon. If there is little wind to offset this decrease the balloon may lose altitude and drag the cable on the ground unless the winch operator is present at all times to take up any slack in the cable.

(4) The high angle of trim caused by the heavy tail of the balloon under ice and snow conditions may, in appreciable winds, result in a high aerodynamic lift and great cable tension. Under these conditions, the balloon will behave more nearly like a kite, and care must be taken to prevent the loss of the balloon due to cable failure.

(5) Due to the poor flying performance of the balloon under ice and snow conditions, it is essential that extreme care be taken in raising or lowering the balloon. The winch should be operated by an experienced operator. The allowable speed in raising or lowering the balloon is greatly reduced due to the following:

(*a*) Poor flying performance.

(*b*) Stiffness of the cable.

(*c*) Brittleness of the fabric.

(*d*) Slowness of the fabric to become adjusted to changes in pressure when the balloon is raised or lowered.

(6) When the balloon is flown under snow conditions, it is necessary to remove the ballast from the tail or adjust the rigging to compensate for the added weight of the snow on the fins. As the snow and ice melt and evaporate, it is necessary to haul down the balloon from time to time to readjust the trim. If this is not done, the tail will become lighter and poor trim will result.

(7) If the balloon is bedded down in any position other than with the nose into the wind, the accumulation of snow

on one side of the balloon will be greater than the other. This will cause the balloon to list when flying. The same will result if the sun melts the snow off one side of the balloon more rapidly than off the other side.

(8) Cold weather may cause both the gas and air valves to freeze open or shut regardless of whether actual moisture is present around the valves. Any valve frozen open or shut must be freed in order to permit proper functioning of the valve. Danger of valves freezing will be decreased if talc or a similar substance is used between the valve contacting surfaces.

(9) Snow blown by the wind may pile up in hard lumps in the air scoops, and may block the passage of air into air-inflated fins or into the air chamber of a ballonet balloon. The effect of this is most serious in ballonet balloons which do not require a certain internal pressure, since in these balloons the diaphragm must react quickly on even a slight change in gas volume in order to maintain the shape of the balloon.

b. Rainfall.—When rain is falling, the weight of the moisture absorbed by and collected on the fabric will be greater on the wide tail surfaces than it will on the nose, particularly of a dilatable balloon. This moisture will affect the angle of trim of the balloon. Rainfall may have a favorable effect on well-drained sites by decreasing the danger of fire during inflation and deflation.

■ 35. SUNSHINE.—Direct rays of the sun upon a balloon cause superheating of the gas within the balloon. A discussion of the effects of superheat may be found in section V, chapter 2. Bright sunlight also hastens the decomposition of neoprene, with the formation of hydrochloric acid. The acid causes deterioration of the fabric used in constructing the balloon, particularly the outer ply. Small drops of water on the balloon will concentrate the sunlight and increase this effect, which may cause the formation of small pinholes in the fabric.

■ 36. WEATHER REFERENCES.—Additional weather information may be found in TM 1–230 and 3–240.

SECTION II

WEATHER SECTION

■ 37. GENERAL.—The susceptibility of balloons to weather conditions makes it necessary that frequent local weather forecasts be made. The local forecasts must cover the area in which the barrage is operating, and must be made often enough to provide the barrage headquarters with all timely weather information, particularly the wind and lightning risks and whether or not moisture will be frozen on the balloons. It will be extremely unwise to rely on the more general Weather Bureau forecasts, and barrages will frequently operate in localities where such general forecasts are not available. For these reasons, a weather section is furnished each separate battalion and each barrage balloon group to provide the necessary forecasts. The weather section will also supply battalion and group headquarters with the atmospheric pressure and temperature readings for use in making aerostatic calculations, and will supply information as to the cloud ceiling and sky condition so that the barrage commander may determine the extent to which the clouds may be used to conceal balloons.

■ 38. PERSONNEL.—*a*. Each balloon barrage maintains a weather station unless the required weather information is available from other nearby sources. The personnel and equipment to operate a weather station are organic within each separate battalion. When several battalions operate a barrage, the personnel and equipment from the weather sections of the separate battalions may be combined to operate a group weather station.

b. The weather section of the separate barrage balloon battalion is a part of the headquarters battery. It is composed of the weather officer, who is responsible for the organization, training, and operation of the weather section. He advises the battalion commander on all matters pertaining to weather. He is assisted by the following enlisted personnel, according to the present tentative Table of Organization:

1 technical sergeant, meteorologist.
1 sergeant, meteorologist.
1 technician, 5th grade, clerk, weather.
1 private, clerk, weather.

3 privates, observers, weather.
1 private, chauffeur.
1 private, basic.

The weather officer will determine the distribution of duties among the enlisted personnel.

c. The weather personnel provided for the barrage control section of each barrage balloon group headquarters battery consist of—

1 master sergeant, meteorologist.
1 technician, 5th grade, meteorologist.
1 technician, 4th grade, clerk, weather.
2 privates, observers, weather.

■ 39. EQUIPMENT.—The equipment of the weather station consists of Signal Corps meteorological kits 6, 7, and 8, plus two weather teletypes. One teletype will carry schedule A weather information (hourly reports), and the other will carry schedule C information (all other weather information).

■ 40. OPERATION.—*a.* The weather station will operate on a 24-hour day, 7-day week basis. The weather section will be divided into watches arranged so that a forecaster will be on duty at all times. At least two men should be on duty during periods when adverse weather conditions are expected. The essential requirements of a balloon barrage weather station are the ability to issue accurate local weather forecasts from the basic weather information and to recognize the weather conditions as they appear.

b. All Weather Bureau teletype reports throughout the United States are based on eastern standard time. It is therefore necessary for the barrage weather station to base its operations on eastern standard time so that all weather information may be coordinated for issuance to barrage headquarters.

c. The following observations will be made by the weather section:

(1) Six-hourly map observations, four times daily; to be completed by 1:30 and 7:30 AM and PM, EST. These observations are used in the preparation of weather maps.

(2) Hourly observations, 30 minutes past each hour, for the purpose of maintaining a constant check on existing

weather conditions at the station and determining pressure and temperature for aerostatic calculations.

(3) Pilot balloon observations ("pibals") four times daily, to be completed by 10:00 and 4:00 AM and PM, EST. These observations are used to determine wind direction and velocity at various levels above the earth's surface.

(4) Special hourly observations as the weather requires.

(5) Special "pibals" as the weather requires.

d. All observations made by the weather section are for the use of the barrage, and will not be transmitted on the teletype circuit unless specifically authorized. All weather information will be transmitted to the command post of the barrage and to the command post of each battalion if the barrage is operated by more than one battalion.

e. The following maps and charts will be made at each weather station:

(1) Weather maps four times daily, beginning at 7:30 and 1:30 AM and PM, EST, and completed as soon as possible thereafter.

(2) Upper wind chart, two times daily, beginning as soon as possible after 6:00 AM and PM, EST.

(3) Adiabatic charts and Rossby diagrams, daily, from any available radiometrograph reports from nearby weather stations.

(4) Other maps and charts will be made at the discretion of the weather officer or at the direction of the commanding officer.

■ 41. WEATHER MESSAGE.—In general, the following types of weather messages will be issued by the weather station:

a. Eight-hour weather message.—Four 8-hour weather messages will be prepared daily so as to be delivered to the barrage and battalion command posts by 10:00 and 4:00 AM and PM, EST. The weather message will include a forecast of the wind and lightning risks and other weather conditions for the ensuing 8-hour period, and a report of the pilot balloon observation just completed.

b. Daily weather summary.—The daily weather summary will be issued at 11:00 AM daily, and will cover the weather for the period "tonight and tomorrow."

c. Special weather message.—If a previous message is found to be seriously in error or any weather phenomena has developed concerning which the barrage should be warned, a special message will be issued immediately. Special messages will also be issued to cover certain weather elements upon request by proper authority, and may be issued at any time.

■ 42. SUMMARY.—The following is a summary of observations made, records preserved, and information supplied by the weather station:

a. Observations made.

	Time completed
6-hourly map observations	7:30 and 1:30 AM and PM, EST.
"Pibals"	10:00 and 4:00 AM and PM, EST
Special "pibals"	As weather requires.
Hourlys	30 minutes past each hour.
Special hourlys	As weather requires.

b. Records preserved at station.

	Periods retained
6-hourly map observations	Permanently.
Hourlys and special hourlys	Do.
"Pibals" and special "pibals"	Do.
Barograph trace	Do.
Upper wind charts	1 year.
Weather maps	1 year.
Adiabatic charts	1 year.
Forecasts and special forecasts	1 year.
Teletype weather reports	3 months.

c. Information supplied.

	Time delivered
8-hour weather message	10:00 and 4:00 AM and PM, EST.
Daily weather summary	11:00 AM, EST.
Special forecasts	As required.
Hourlys	30 minutes past each hour.
Special hourlys	As required.
Other information	When requested.

SECTION III

FORM OF HOURLY OBSERVATIONS, PILOT BALLOON OBSERVATIONS, AND WEATHER MESSAGES

■ 43. HOURLY OBSERVATIONS.—Hourly observations made by the barrage weather station are reported to barrage headquarters in the following form:

Tyson 08305⊕ 30.05 45 N10

The station (Tyson) and the time on the 24-hour clock (0830) are given as shown. The figure 5 indicates the cloud ceiling in hundreds of feet. The symbol ⊕ indicates the sky condition. The symbols used are as follows: clear, meaning that the sky is less than one-tenth covered with clouds, ○; scattered clouds, meaning that the sky is one-tenth to five-tenths covered with clouds, ⦶; broken clouds, meaning that the sky is six-tenths to nine-tenths covered with clouds, ⦶; and overcast, meaning that the sky is more than nine-tenths covered with clouds, ⊕. The next group of figures 30.05 is the atmospheric pressure in inches of mercury. The figure 45 indicates the atmospheric temperature in degrees Fahrenheit. The letter N is the wind direction (expressed as one of the 16 points of the compass), and the figure 10 following the wind direction is the wind velocity in miles per hour.

■ 44. PILOT BALLOON OBSERVATIONS.—Pilot balloon observations made by the barrage weather station are reported in the 8-hour weather message in the following form:

Tyson 03 015022 025225 036035 etc.

The station and time of the observation on the 24-hour clock are given as shown. In the groups of six figures each that follow, the first two figures are the altitude in thousands of feet above the surface of the earth, the next two figures are the wind direction in hundreds of miles measured clockwise from north, and the next two figures are the wind velocity in miles per hour.

■ 45. WEATHER MESSAGES.—*a. Eight-hour message.*—The 8-hour message will be divided into three paragraphs, as follows:

(1) *Weather risk classification.*—A forecast of the weather risk classification will be given in each message. Classes of weather risks to balloons are shown in table II. If the classification for either wind or lightning is other than class I the probable time of the risk will be given and a word description will be included if applicable. If upper winds of 50 mph or more are expected, the elevation at which they are expected to occur will be given. For forecast purposes, a line squall will be defined as a front accompanied by surface winds of 25 mph or more.

(2) *"Pibal."*—A report of the "pibal" just completed will be given in the message in the form shown in paragraph 44.

(3) *Forecast of other weather elements.*—The following weather elements will be forecast in as near the order listed as proper wording will permit:

(*a*) Clouds and ceiling. (Large cumulus or cumulo-nimbus clouds will be mentioned by name).

(*b*) Thunderstorms and precipitation.

(*c*) Icing conditions and the altitude at which freezing is occurring.

(*d*) Obstructions to vision and visibility.

(*e*) Surface wind velocity and direction.

(*f*) Front and time frontal passage is expected.

(*g*) Temperature, if decided change is expected.

TABLE II.—*Classes of weather risks to balloons*

Class	Definition
Lightning I	Lightning risk very slight, or there is no lightning risk.
Lightning II	It is expected that over the actual region of the barrage there will be large cumulus clouds which may develop into cumulo-nimbus clouds, but that there will be no actual lightning in the meteorological vicinity of the barrage.
Lightning III	There is practical certainty that cumulo-nimbus clouds will be over the barrage area and lightning has been observed in the meteorological vicinity of the barrage.
Wind I [1]	All wind conditions except those under wind class III.
Wind III	Wind at ROH is 50 mph or more; or line squall risk exists.

[1] There is no wind class II corresponding to lightning class II.

b. Form.—A sample forecast, illustrating the form to be used, is given below:

Camp Tyson, Tenn. April 1, 1942, 10:00 AM to 6:00 PM.
Weather class III from 1:00 PM to 6:00 PM.
Thunderstorms after 1:00 PM.

Tyson 09 013212
023514
033722
043625
053515

High scattered to broken clouds with large cumulus and cumulo-nimbus forming at 2,000 to 4,000 feet by 1:00 PM. Thunderstorms with light to moderate rain after 1:00 PM. Visibility more than 12 miles except lowering temporarily during rain. Wind SW 8 to 12 mph increasing to 25 to 30 mph during thunderstorm.

c. Weather summary and special messages.—(1) *Summary.*—The daily weather summary will cover expected weather for the period "tonight and tomorrow" in a general way. An example of a daily weather summary is given below:

Camp Tyson, Tenn. April 1, 1942.

Tonight and tomorrow—Clear tonight, lowest temperature about 35°. Increasing cloudiness during day tomorrow with light rain during afternoon. Wind south 6 to 10 mph.

(2) *Special weather message.*—The form for a special message will vary considerably depending on circumstances, but in general should follow the form of other messages.

PART TWO

PERSONNEL

CHAPTER 1

SELECTION

■ 46. IMPORTANCE.—Barrage balloon units require a large percentage of highly-trained specialists. In order that the training program may produce the greatest possible results, it is highly important that the men who are to be trained as specialists be carefully selected.

■ 47. QUALIFICATIONS.—*a. General.*—Previous knowledge and experience in similar or related fields is often the most reliable basis upon which selection of men to be trained for certain positions may be made. If a sufficient number of men with previous knowledge or experience is not available, then those men possessing the desired mental and physical capabilities for the various positions should be chosen for training. Various tests should be devised for the purpose of discovering the capabilities desired.

b. Balloon chiefs.—Men selected to be trained as balloon chiefs must possess initiative, a sense of responsibility, and the ability to handle men. They should be capable of grasping the fundamentals of aerostatics, meteorology, and map reading. Prospective assistant balloon chiefs must have the same qualifications.

c. Winch operators.—Winch operators should be mechanically inclined, and should have a mechanical background. Manual dexterity and coordination are principal prerequisites. Previous experience in the handling of machines or motor vehicles is desirable.

d. Gas workers.—Gas workers should have a basic knowledge of the chemistry and physics of gases, and should have practical working knowledge of machinery. Previous experience with gas or gas producing and compressing apparatus is desirable.

e. Riggers.—Men selected to be trained as riggers should be able to read blueprints and should be manually adept.

f. Communication workers.—Telephone operators should have good hearing and should be able to speak clearly and correctly. Telephone and teletype maintenance men should know the rudiments of electricity and should have had experience with electrical equipment. Teletype operators should be able to type at least 30 words per minute, using the touch system.

g. Weather station personnel.—Men selected to be trained as weather station personnel should have a basic knowledge of physics. They should have a fair knowledge of mathematics and some ability as draftsmen.

CHAPTER 2

TRAINING

SECTION I

INDIVIDUAL TRAINING

■ 48. GENERAL.—The training of personnel is divided into two phases; individual training, and unit or crew training. In the first phase, individuals are trained in the technique of their individual duties. In the second phase, the men of a unit learn to work together as a team. The responsibility for the training of personnel lies with the officers who command the various units. General information on training plans and methods of instruction may be found in FM 21-5.

■ 49. INDOCTRINATION OF PERSONNEL.—Each man in a barrage balloon organization must become imbued with the fact that barrage balloons are an effective means of defense against hostile aircraft. Demonstrations of effectiveness may not be possible under training conditions, but the use of barrage balloons under war conditions has amply demonstrated their effectiveness. All personnel must be constantly indoctrinated by the instructors to have confidence in their arm.

■ 50. BALLOON CHIEFS.—The balloon chiefs require careful training in order to command their units properly. Balloon chiefs must be thoroughly familiar with the work pertaining to the inspection, care, and maintenance of the balloon, and its operation, maneuvering, bedding down, and mooring under all conditions. They must know in detail the work of every man in the crew and possess the ability to instruct them. They must keep records at the balloon sites. Their training should include the subjects listed below:

a. Aerostatics.—The balloon chief should understand and be able to explain—

(1) Static lift of the balloon and how it varies with atmospheric conditions.

(2) Methods of determining lift required and weigh-off.

(3) Necessity for maintaining minimum volume and flying the balloon within pressure height.

b. Aerodynamics.—Balloon chiefs should understand aerodynamics sufficiently to enable them to make the proper adjustments to the angle of trim of a balloon and to react properly to phenomena involving dynamic lift, weaving, listing, and diving of a balloon.

c. Meteorology.—Balloon chiefs should understand the general formation of the atmosphere and how various kinds of weather affect the operation of balloons.

d. Map reading.—Balloon chiefs must have a sufficient knowledge of map reading to—

(1) Guide their units to a position indicated on a map, or to a position for which the map coordinates are given.

(2) Determine whether a road is too steep for vehicles to climb.

e. Winches.—Balloon chiefs should know enough about the operation and functioning of the winch to supervise its operation and routine maintenance.

f. Local defense.—Balloon chiefs command their squads in action against local attacks by ground troops. They should be thoroughly schooled in the principles of organizing a position for local defense, including defense against parachute troops and mechanized units.

■ 51. ASSISTANT BALLOON CHIEFS.—The training of the assistant balloon chiefs should include enough of the details of each job to enable them to understand and explain it. The assistant balloon chiefs are second in command at a balloon site. They are responsible for the functioning of the crew on one side of the balloon during the time it is being maneuvered by a balloon crew. They should be trained to take over the duties of the balloon chief, should this become necessary.

■ 52. WINCH OPERATORS.—Operators selected should be given theoretical instruction to enable them to understand the functioning and correlation of the various parts of the winch. As a first step in practical training and explanation they should be taught the mechanics of starting, running, and stopping the winch engine. Intensive practical training in handling the balloon with the winch and cable should be started as soon as possible for the purpose of giving the operators experience in handling the balloon under various conditions of wind and weather. Through practical training, the operators must learn the best procedure to follow during emergency conditions, such as how to handle a diving balloon. Operators must be taught how to maintain the winch and how to make the repairs they are permitted to make at the site. Since winch operators also assist the gas workers, they should have a fundamental knowledge of handling hydrogen.

■ 53. CHIEF GAS WORKERS.—The chief gas workers (sergeants) should be taught the prescribed methds of—

a. Inspecting and adjusting gas and air valves.

b. Reading manometers, and inspecting and adjusting manometers and fittings.

c. Preparing and maintaining required records concerning supply and consumption of gas.

d. Testing gas for purity.

e. Handling hydrogen, including safety precautions and action in case of emergency.

f. Handling lethal devices and attaching and detaching them from the cable.

■ 54. GAS WORKERS.—*a. Inflation and topping-up.*—It is important that gas workers be given sufficient instruction and drill to make them proficient in the operation of equipment during inflation and topping-up. They should become especially familiar with the safety precautions required in handling hydrogen and should be taught to observe these precautions.

b. Maintaining proper pressure.—The maintenance of pressure within some balloons is of primary importance since ease of handling these balloons in the air is largely dependent upon it. It is important that the training of gas workers concerning the use of pressure instruments and the procedure used in checking pressure be thorough and complete. Gas workers should be taught how to improvise a manometer if this becomes necessary. They should be taught the prescribed method of—

(1) Attaching and detaching the manometer and taking readings.

(2) Maintaining proper pressure within the balloon.

(3) Installing and detaching air scoops, air valves, and gas valves.

(4) Operating and caring for the inflation tube, inflation manifold, and gas cylinders.

c. Testing gas for purity.—Purity of hydrogen in a balloon must be tested regularly in order to insure that the gas is not below 85 percent purity. Hydrogen must also be tested for purity at the time of generation and a purity sample is taken from each lot of cylinders used for initial inflation. Gas workers must be thoroughly trained in the methods of conducting the various tests for hydrogen purity and the operation of equipment involved.

d. Handling lethal devices.—It is the duty of the gas workers to handle all lethal devices at the balloon site and to attach and detach these devices from the cable. They should be thoroughly trained in the technique of handling lethal devices.

■ 55. RIGGERS.—Platoon and battery riggers should be trained in the care and maintenance of all rigging, internal and external, and the care, maintenance, and patching of balloon fabric. It is incumbent upon instructors to instill in the minds of these men the importance of their work. Constant practice in cordage, fabric repair, and other phases of their work is necessary for riggers to develop the proficiency required. Riggers should be taught the prescribed method of—

a. Determining if a balloon is properly rigged.

b. Making various knots, hitches, splices, and servings.

c. Repairing and maintaining all rigging.

d. Maintaining and patching balloon fabric.

e. Making various types of patches and stitchings.

f. Inspecting rigging and envelope.

g. Forming eyes in and splicing cable.

■ 56. TELEPHONE OPERATORS.—Suggested methods of training telephone operators are found in FM 4–115, and instruction in the general procedure for efficient telephone operation as given in FM 24–5 should be included.

■ 57. Weather Section.—Personnel of the weather section must be able to prepare and read weather maps with speed and accuracy. Constant practice in this type of work is the chief means for training these men. They must also receive instruction in methods of operating the various instruments used in the weather station.

■ 58. Chauffeurs.—While the majority of enlisted men today have had some experience in driving an automobile, nevertheless they should first be taught the difference between a passenger car and the truck they are to operate. Suggestions for training chauffeurs will be found in FM 4–115. Care and maintenance of motor vehicles should be included in the training. Suggestions may be found in FM 25–10.

■ 59. Other Crew Members.—The individual training of other members of the barrage balloon squad and crew should include enough practical work in cordage to enable them to perform efficiently the duties of mooring the balloon and placing it in flight. If possible, every man should be taught to operate the winch and telephone and to read the manometer. Every member of a balloon squad will perform duty as a sentry at the balloon site, and the proper performance of sentry duty will require that the sentry answer the telephone, receive and record messages, read the manometer, and often operate the winch. As rapidly as possible, every man in a balloon crew should be trained to perform all duties necessary at a balloon site.

Section II

UNIT OR CREW TRAINING

■ 60. Teamwork.—The purpose of unit or crew training is to develop teamwork in order that the men will be able to work together efficiently. Teamwork is based on the belief that the team task can be accomplished, on the knowledge that the leadership is competent, and in mutual confidence.

■ 61. Method.—If proper individual training has been given, the most important factor in unit training is practice. Practice must be provided at regular intervals, and should cover all the situations the unit is likely to encounter in the field.

■ 62. SECURITY AND PROTECTION.—Balloon sites may be subjected to various forms of attack, such as by parachute troops, mechanized forces, small naval craft, landing parties, and saboteurs. Balloon squads should be taught to be constantly on guard against parachute troops and saboteurs. The ground should be organized for defense at each installation, and the squads should be taught how the defense is to be conducted in event of an attack. The squads should also be given training in defense against mechanized units. (See FM 5–30, FM 100–5, and Training Circular No. 19, W. D., 1942.) In the event of a land or airborne attack in force, the defense plan for the tactical area in which a balloon barrage operates may provide for the abandonment of barrage balloon operations and the occupation of ground defense stations by barrage balloon personnel coordinated with respect to other ground units in the same tactical area. Balloon sites close to hostile air attack objectives should be provided with shelters to protect the balloon crews during air bombardment.

CHAPTER 3

INSPECTIONS

■ 63. GENERAL.—*a.* Barrage balloon inspections are made by the balloon unit commanders of all ranks or by members of their staffs. All balloon sites in a battery are inspected by an officer at least once a week. All sites need not be inspected the same day, nor is it necessary that a specific day in each week be set aside for inspection. Such training inspections as may be desired are conducted concurrently with the barrage balloon inspections.

b. Technical inspections of the condition and functioning of matériel pertaining to the Ordnance Department, the Signal Corps, and the Army Air Forces are made periodically by designated representatives. Battery commanders should follow closely the progress of these inspections, and should bring to the attention of the inspector deficiencies which cannot be corrected locally.

c. Tactical and training inspections are a function of command and are utilized to produce battle efficiency. Tactical inspections are inspections of the actual solution of tactical, supply, and communication exercises by tactical units and individuals. Training inspections comprise observations of the scheduled drills, exercises, assemblies, and conferences. Detailed information on tactical and training inspections is included in AR 265–10.

d. During the training period of a barrage balloon unit, frequent administrative inspections conforming to the provisions of FM 22–5 and FM 4–120 (with suitable modifications) will be held.

e. When operating under war conditions, the personnel comprising barrage balloon units are dispersed and the assembly of units for inspection purposes will be impractical. However, regularly scheduled formal inspections of sites and installations must be made to insure high sanitary standards in connection with latrines, garbage disposal, food handling, and drinking water; to promote a neat appearance of personnel and of their uniforms and equipment; to determine the state of preservation and thoroughness of maintenance of matériel; and to verify the proper maintenance of records, reports, and logs.

■ 64. INSPECTION AT A BALLOON SITE.—*a*. This paragraph deals with the formal inspection of the balloon squad and and balloon matériel at a balloon site. Modification of the procedure herein outlined may be prescribed by the inspecting officer.

b. During the entire inspection the sentry on duty continues to perform his regular duties.

c. The balloon squad is formed under arms by the balloon chief in a single rank, 15 paces in front of the nose of the balloon and facing the left side of the balloon. On the approach of the inspecting officer, the squad is called to attention and the balloon chief reports to the inspecting officer. After the men have been inspected in ranks as prescribed in FM 22–5, arms are stacked. At the command: 1. INSPECTION, 2. POSTS, given by the balloon chief, the squad members take posts as shown in the following table. Assignment of men to positions is made previously by the balloon chief.

Squad member	*Post*
Balloon chief	Accompanies inspecting officer.
Assistant balloon chief	Takes post near telephone and displays records, reports, and logs.
Chauffeur	Takes post at his motor vehicle.
Gas worker	Procures the inflation manifold, inflation tube, and the manometer and displays them for inspection near the gas cylinders.
One crewman	Assists gas worker.
Winch operator	Takes post at winch. Removes winch assembly cover, opens hood and tool box cover, and starts winch engine. Procures blower and places it near the winch where it may be inspected when the winch is inspected.

One crewman	Assists winch operator.
Two crewmen	Take posts, one on each side of balloon bed, to perform any task near the balloon and bed requested by the inspecting officer.
Two crewmen	Procure and display all service and repair kits at the balloon site.
Sentry	Continues to walk his post.

d. Inspection of quarters, mess facilities, latrines, and other housekeeping facilities may be made following the inspection at the balloon site, or the inspection may be made at a different time.

PART THREE

OPERATION OF MATÉRIEL

CHAPTER 1

HYDROGEN GENERATING PLANT

SECTION I

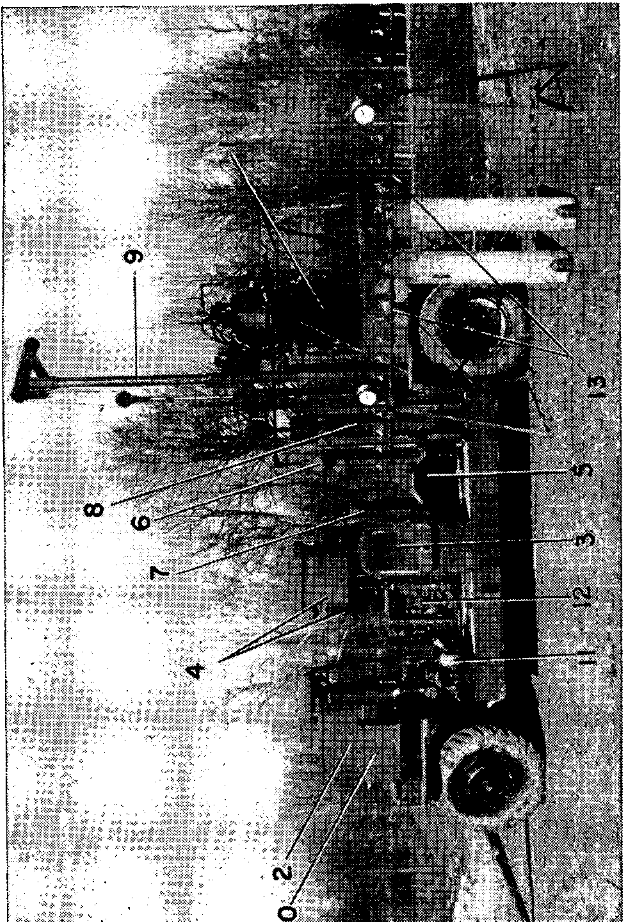
EQUIPMENT AND OPERATION

■ 65. GENERAL.—Large quantities of inflation gas must be made available to the balloon barrage in the field. Barrages will frequently operate in isolated localities and at great distances from commercial sources of hydrogen, making supply from these sources extremely difficult. The use of central generating plants will generally be found impractical, due to the amount of transportation required and the time required to make the inflation gas available to units in the field. Therefore, each barrage balloon battalion is furnished with semimobile equipment for gas generation when necessary. Safety precautions to be observed in generating hydrogen are discussed in section II, chapter 2. Maintenance and repair of the hydrogen generating plant are discussed in paragraph 104.

■ 66. EQUIPMENT.—*a. General.*—The high-pressure hydrogen generating plant now in use is mounted on a trailer and may be towed to its location in the field by a tractor. It is a self-contained apparatus and is capable of continuous operation under its own power.

b. Parts of the hydrogen generating plant.—The parts of the hydrogen generating plant are shown in figure 7.

(1) *Generators.*—The generators are constructed of drawn seamless steel tubing, the outside diameter of which may be from 14 to 20 inches, and the height of which may be from 6 to 8 feet. Due to the high reaction temperature, the



1. Generators.
2. Soda mixing tank.
3. Power unit.
4. Cooling unit.
5. Caustic pump.
6. Sludge separator.
7. Moisture separator.
8. Drying cylinder.
9. Hoist.
10. Water storage tank.
11. Auxiliary water pump.
12. Air compressor.
13. Manifold.

FIGURE 7.—Hydrogen generating plant.

generators are equipped with hollow water-cooled heads, and have water jackets about the walls. Connections are so arranged that the caustic inlet line, generator purge line, hydrogen outlet line, and sludge outlet line may be led into the upper portion of the generator. A removable can, in which lump ferrosilicon is placed, fits within the generator so that the generator will not be damaged if the reaction materials solidify during operation.

(2) *Soda mixing tank.*—The soda mixing tank is a container in which the caustic solution is prepared. In it is a power-driven agitator which aids in the preparation of the solution. Beneath the mixing tank, and connected to it with proper valves, is a storage reservoir for the caustic solution. The caustic pump suction line is attached to the storage reservoir, so that mixing and pumping may be carried on simultaneously.

(3) *Power unit.*—The power unit is an internal combustion gasoline engine. Reduction gears reduce the power take-off speed to 300 rpm. The clutch is of the friction disk type, and is hand controlled. The engine supplies power for the caustic soda tank agitator, cooling fan, water pump, caustic pump, and a small air compressor. Sufficient power is generated to run the plant and accessories continuously under maximum load conditions.

(4) *Cooling unit.*—The cooling unit consists of steel coils immersed in water. The hot gas passing through the coils is reduced in temperature. The water is cooled by a radiator and power-driven fan.

(5) *Caustic pump.*—The hydraulic piston type caustic pump is of high strength steel and is capable of pumping liquids at a pressure of 3,500 pounds per square inch, although 2,500 pounds per square inch is the maximum pressure encountered in the hydrogen generating plant.

(6) *Sludge separator.*—The sludge separator is a chamber of extra heavy steel pipe construction. It traps any sludge which may be carried out of the generator by the hydrogen gas.

(7) *Moisture separator.*—The moisture separator is a chamber of extra heavy steel pipe construction. It removes

liquids which have been condensed from the hydrogen in the cooling coils.

(8) *Drying cylinder.*—The drying cylinder is an extra heavy steel cylinder filled with potassium hydroxide. It removes all remaining water vapor from the hydrogen.

(9) *Hoist.*—The generating plant is equipped with a pneumatic hoist for removing the generator head and the inside container.

(10) *Water storage tank.*—The water storage tank is used for storing plain water for use in mixing the caustic solution.

(11) *Auxiliary water pump.*—The auxiliary water pump is a centrifugal type pump which is used to pump water from local sources of supply, such as lakes and streams.

(12) *Air compressor.*—The air compressor is used to compress air for operating the pneumatic hoist, operating the sludge valves, and engaging and disengaging the caustic pump gears.

(13) *Manifold.*—The manifold is used for transferring gas from the generating plant into a number of cylinders simultaneously. Empty cylinders can be engaged to the manifold and full cylinders can be disengaged without shutting off the flow of gas from the generating plant. The manifold is equipped with gages for measuring the pressure of the gas in the cylinders. It is not attached permanently to the generating plant.

■ 67. Reaction Materials.—*a. Ferrosilicon.*—(1) Ferrosilicon is an intimate mixture of silicon and iron, and usually contains small amounts of other elements as impurities. It is made in an electric furnace by fusing a mixture of sand, carbon, and iron or iron oxides, and is hard and brittle. It may be obtained with varying amounts of silicon, but the high-pressure hydrogen generating plant uses a mixture containing 85 percent silicon in 2-inch lump size. Ferrosilicon is shipped and stored in metal containers of 100-pound capacity.

(2) Ferrosilicon and sodium hydroxide should never be stored together where there is any possibility that they will become mixed through the breaking of one or more packages. Such a mixture would create a fire hazard.

b. Sodium hydroxide or caustic soda.—(1) Caustic soda is a white solid obtained in flake form for hydrogen generation. It will absorb moisture from moist air. When it is dissolved in water, a large amount of heat is produced. Caustic soda solution is extremely alkaline.

(2) Caustic soda is supplied in metal, airtight containers of 100- or 400-pound capacity, and should not be exposed to the atmosphere. Containers should be opened only as the material is required.

(3) Caustic soda is extremely corrosive, either in the solid form or in solution. Severe skin burns or blindness may result from contact with it. Wool and leather clothing is severely attacked by it.

(4) Caustic soda should always be stored in a dry place under cover.

c. Water.—(1) Water for the caustic solution may be taken from any adjacent lake or stream or may be hauled to the generating plant. A small gasoline-operated water pump is part of each hydrogen generating plant. A water storage tank is built in the forward end of the plant.

(2) Water for the cooling system may be obtained from the same sources as the water for the caustic solution. Extremely muddy water may tend to clog lines and reduce pump operating efficiency, and should not be used.

■ 68. METHOD OF GENERATING HYDROGEN.—*a. Reaction and general process.*—(1) The ferrosilicon process for producing hydrogen depends on the reaction between silicon, sodium hydroxide (caustic soda or NaOH), and water, resulting in the formation of sodium silicate (water glass) and hydrogen. The chemical equations for the process are:

$2NaOH+Si+H_2O=Na_2SiO_3+2H_2$ (iron acts as a catalyst); and $Si+3H_2O=H_2SiO_3+2H_2$ (NaOH acts as a catalyst).

(2) The sodium silicate formed by the reaction and the small particles of iron will settle to the bottom of the generator, and may be removed by purging the generator through the purge valve. Sodium silicate, or water glass as it is commonly termed, is a heavy, viscous fluid. The greater the quantity of water contained in the water glass, the more fluid

the substance. In the absence of water, it becomes very hard and the later addition of water will not dissolve it.

b. Conditions affecting rate of reactions.—(1) *Temperature.*—As the temperature rises, the rate of reaction increases. Since the reaction itself gives off heat, the total yield of hydrogen may actually be decreased by a sufficient increase of temperature; therefore, the temperature is a very important factor. The heat of the reaction causes the temperature to rise at an increasing rate until it reaches a maximum which depends on the pressure.

(2) *Concentration of sodium hydroxide solution.*—The reaction is slow with a weak solution. As the concentration is increased, the rate of reaction is increased until a solution of 35 to 40 parts of sodium hydroxide to 100 parts of water is reached.

(3) *Amount of ferrosilicon.*—The rate of reaction is directly proportional to the amount of ferrosilicon present at any time. The rate of reaction decreases as the ferrosilicon in the generator is consumed.

(4) *Size of ferrosilicon lumps.*—The rate of reaction is very rapid if small particles or lumps are used. If the ferrosilicon is too fine, the rapid reaction fuses the lumps into a solid mass that will not be reached by the caustic solution. This mass may destroy the inner cylinder. If the lump size is too great, the reaction will not be rapid enough. Maximum size of the lumps should be 2 inches and the minimum size ½ inch in diameter.

(5) *Silicon content of ferrosilicon.*—The greater the percentage of silicon present in the ferrosilicon, up to a maximum of 90 percent silicon, the greater will be the speed of reaction.

(6) *Amount of sodium silicate.*—As the reaction proceeds, the quantity of sodium silicate in the generator increases unless it is removed. This sodium silicate will settle to the lower portion of the generator, and if not removed will retard the chemical reaction.

c. Operation of high-pressure hydrogen generating plant.—(1) *Charging the generator.*—(*a*) The generator head is removed, and the inside container is filled manually with ferrosilicon. The container may or may not be removed from the generator for this purpose. The head is replaced and all connections made preparatory to the actual run.

60

(*b*) The caustic soda solution is prepared in the soda mixing tank. The solution should contain approximately 2.5 pounds of sodium hydroxide per gallon of water.

(*c*) Steel hydrogen cylinders are connected to the manifold for the storage of the hydrogen gas produced.

(*d*) In order to purge the system of air once operations are begun, the drain valves beneath sludge separator, moisture separator, and drying bottles are opened.

(2) *Initial steps for operation.*—(*a*) The caustic pump is placed in operation, with the caustic inlet valve of the generators open.

(*b*) The air in the generator is "bled" off through the purge line by the intermittent "cracking" of the purge valve.

(*c*) The caustic inlet valve is closed when the solution covers the ferrosilicon. This can be determined by the amount of moisture given off when the purge valve is opened.

(*d*) Water jacket valves are opened to allow the flow of water about the sides of the generators.

(*e*) When the generator pressure reaches 2,000 pounds per square inch, as indicated on the pressure gage, the hydrogen outlet valve is "cracked" to permit the flow of gas from the generators through the remainder of the generating plant.

(*f*) After 15 to 30 seconds of operation, during which time the system has been purged of air, the drain valves are closed in the following order: sludge separator, moisture separator, and drying cylinder.

(3) *Hydrogen gas production.*—(*a*) The hydrogen gas outlet valve is operated so as to maintain a pressure of 2,250 to 2,500 pounds in the generator.

(*b*) The sludge outlet valve is "cracked" intermittently to remove the sodium silicate (water glass) formed. The sludge settling to the lower portions of the ferrosilicon container will impede or prevent the reaction in that region.

(*c*) If the pressure falls off, additional caustic solution must be added. The level of caustic should be maintained at the dip pipe depth, as determined by "cracking" the purge line valve.

(*d*) All drain valves in the system should be opened at approximately 20-minute intervals to remove all accumulated matter.

(*e*) Each group of hydrogen cylinders connected to tne manifold should be filled to a pressure greater than the final desired pressure, since subsequent cooling of the gas will reduce the pressure to normal storage pressure. The pressure to which the cylinders should be filled is determined by the formula:

$$P' = \frac{PT'}{T}$$

where

P' = the pressure to which the cylinders should be filled.

P = the final desired pressure.

T' = the temperature (absolute) of the gas when the cylinders are filled.

T = the prevailing atmospheric temperature (absolute).

(*f*) Operations will be continued until insufficient ferrosilicon is present in the generator, as indicated by the failure of the generator to produce sufficient gas to give the required pressure.

(4) *"Blowing down" or shutting off gas generation in order to recharge the generator.*—(*a*) The valves are adjusted so that water from the storage tank may be carried by the caustic pump and line to the generator.

(*b*) The hydrogen gas outlet valve is closed.

(*c*) As water is pumped into the generator, the pressure in the chamber is "bled" through the sludge outlet valve.

(*d*) When the generator is filled with water, the water is allowed to stand so as to dissolve all the remaining sludge within the generator. The ferrosilicon not consumed is left in a clean condition and is used again.

(*e*) The generator drain valve is opened to allow all water within the generator to be drained.

(*f*) The generator head must be removed manually and preparations begun for recharging.

(*g*) If the generator is not recharged, all material left in the generator should be covered with water to prevent it from hardening.

(5) *General instructions for operations.*—(*a*) The apparatus will usually include two generators, though future designs may increase that number. Connections are arranged so that the generators may be operated independently and simultaneously.

(*b*) Charging and operation of the generators should be staggered so that production of hydrogen gas from at least one chamber will be continuous.

(*c*) Safety valves are arranged to relieve any excessive pressure which may build up within the system before the strength limit of the material is reached.

(*d*) In case of emergency, pressure from either generator may be released through the sludge outlet, hydrogen outlet, or generator drain lines.

SECTION II

FIELD LOCATION

■ 69. GENERAL.—*a*. The high-pressure hydrogen generating plant, assembled on a trailer unit, will be towed to the desired location.

b. The actual ground site must be level, within reasonable limits.

c. Nearby lakes or streams are desirable in order to eliminate the necessity of hauling water for operation.

d. A natural setting which will lend to camouflage is desirable.

e. Good transportation facilities must be available, due to the great quantities of charging materials necessary for large-scale operations and to the great number of cylinders which must be moved in and out.

f. The generating plant should be as centrally located as possible within the units it is to serve.

g. Although it is not absolutely necessary, a 10- by 10- by 10-foot pit should be dug into which the sludge from the sludge outlet valve may be discharged. Since the sludge issues from the valve under high pressure, it may spray over the personnel, generating plant, and nearby buildings and equipment, unless discharged into a suitable pit. The caustic and sodium silicate contained in the sludge are known to cause damage to window glass, clothing, and painted surfaces. The sludge from the sludge outlet valve may be led into the pit by means of a pipe furnished with the generating plant, or by an improvised shield made of sheet metal.

SECTION III

PERSONNEL

■ 70. SELECTION.—Men to operate the high-pressure hydrogen generating plant should be carefully chosen. Those chosen must be familiar with the handling of tools, and must be technically inclined so as to readily acquire knowledge of the operations. They should not be afraid of working about a high-pressure and high-temperature apparatus, but should respect the danger that may be present if the equipment is improperly handled.

■ 71. SIZE OF CREW.—A crew sufficiently large to operate a high-pressure hydrogen generating plant with two reaction chambers consists ordinarily of eight men. A crew will be able to operate the plant for a shift of 8 hours. If the plant is operated only during the hours of daylight, and sufficient men are available, it is recommended that the daylight period be divided between two shifts. Three crews will be needed to operate the plant on a 24-hour basis. Duties of the crew members will include—

a. One man per generator (two to a plant) to handle the caustic inlet valve, sludge outlet valve, and hydrogen outlet valve.

b. One man to mix the caustic solution and maintain a constant supply of the solution on hand.

c. One man in charge of the power plant, caustic pump, and all connecting apparatus.

d. Two men to connect empty hydrogen cylinders to the manifold for filling, to disconnect filled cylinders, and to test the valves for leakage by applying soapy water with a brush.

e. Two relief men who will be capable of taking over any job on the apparatus as well as aiding where help is needed.

■ 72. EQUIPMENT FOR PERSONNEL.—*a. Tools.*—A complete set of tools, including crescent, socket, pipe and special wrenches, pliers, hammers, etc., will be furnished with each apparatus and must be stored in the case provided. Since certain tools are specially designed for the hydrogen generating plant and are not in the normal line of supply, extreme care must be taken to prevent loss or damage to them.

b. Spare parts.—Each battalion should maintain in the field an assortment of spare parts, including high-pressure valves, bolted flange unions, bolts, nuts, and any parts which operation experience proves to be necessary.

c. Clothing.—(1) Each man will be provided with non-woolen coveralls, or some like garment on which there are a minimum number of flaps which might snag on the equipment.

(2) Each man will wear rubber footgear, preferably rubber overshoes or boots.

(3) Each man mixing the caustic solution will be provided with rubber gloves, the length of which will be sufficient to protect his wrists and lower forearms.

(4) Each generator operator will be provided with extra-heavy canvas gloves.

(5) All remaining personnel will be provided with canvas gloves.

(6) All personnel will wear close-fitting hats or caps to eliminate scalp irritation from caustic fumes.

(7) All personnel will be provided with goggles, which must be worn whenever the plant is in operation. This rule must be stressed, because all operators have a tendency to remove goggles whenever possible, contrary to instructions.

SECTION IV

GAS PURITY

■ 73. GENERAL.—Gas must be tested for purity in order to determine its lifting power. The purity of hydrogen gas in a balloon must ordinarily be checked daily in order to insure that an explosive mixture is not present. Each crew or shift operating the hydrogen generating plant must check the purity of gas produced at least once during the shift. Several methods for testing gas purity have been devised. The principles of these methods are discussed below.

■ 74. METHODS OF DETERMINING GAS PURITY.—*a. Army effusion method.*—The Army effusion apparatus is an apparatus for determining the difference in time required for equal volumes of air and the gas tested to pass through an orifice under the same pressure. The ratio between the air time and gas time is determined, and from that the purity (for hydrogen) may be found in the chart in TM 1–315. A detailed description of the method of operating this apparatus may be found in TM 1–315.

b. Absorption method, using alkaline pyrogallol.—Alkaline pyrogallol will absorb the oxygen from a mixture of hydrogen and air. To make this test a certain volume of hydrogen is exposed to alkaline pyrogallol. When the oxygen is completely absorbed, the volume remaining is measured. The decrease in volume is equal to the volume of oxygen originally present. A detailed description of the apparatus required for this test and the method of operation may be found in TM 1–315.

c. Absorption method, using ammonia-copper solution.—The principle for this method is the same as described above, except for the absorption medium. A detailed description of the method may be found in TM 1–315.

d. Other methods.—Other methods of testing gas purity, which make use of other physical or chemical properties of the gas involved, are now being considered and may be adopted as experience shows their capabilities.

CHAPTER 2

SAFETY PRECAUTIONS IN MANUFACTURING AND HANDLING HYDROGEN

SECTION I

GENERAL

■ 75. CHARACTERISTICS OF HYDROGEN.—*a.* Hydrogen gas is colorless, odorless, and tasteless and cannot be distinguished from air except when containing impurities which may give it a slight odor or color. An element of danger is always present with hydrogen gas because of its inflammable and explosive nature when mixed with oxygen or air. Hydrogen is very inflammable under all conditions encountered in practice, and is easily ignited. Ignition may be caused by an open flame, static sparks, sparks from the use of ferrous metal tools, heated exhaust pipes or manifolds of gasoline engines, etc. The hydrogen flame is intensely hot and when burning at moderately low pressure is pale blue or colorless and rather difficult to see, especially in the sunlight. When the gas is burning at relatively high pressure, the flame becomes yellow because of the heating of particles of sodium always present in the air, and not because of the intrinsic properties of the flame. Under certain conditions, mixtures of hydrogen and oxygen or hydrogen and air, when ignited, are very explosive. The explosion is caused by the rapid propagation of the flame through the mixture, no additional oxygen being necessary to support the combustion of the hydrogen in the mixture.

b. Air alone contains sufficient oxygen to produce an explosive mixture in a hydrogen-filled balloon when the purity is lowered to 74 percent. Diffusion of oxygen through balloon fabric is more rapid than that of nitrogen. Therefore, if a balloon has been inflated for some time and the only source of impurities is diffusion through the fabric, the percentage of oxygen in the balloon is likely to be high. To allow for this oxygen enrichment, it is recommended that hydrogen-filled balloons be deflated when the purity is lowered to 85 percent.

c. The bases for most precautions when using hydrogen are—

(1) To keep sources of ignition a safe distance away from any volume of hydrogen regardless of its purity.

(2) To keep the purity of any volume of hydrogen used above explosive limits.

d. While an absence of accidents is likely to give a false sense of confidence, it is impossible to be too careful and the necessary precautions must always be observed.

■ 76. IGNITION.—*a. Prevention.*—A certain amount of impurities is present in the balloon at all times, and therefore the danger of fire or explosion may be present. The following general fire-preventive measures should be observed at the balloon bed, hydrogen generating plant, hydrogen cylinders, and nurse bags:

(1) No fire or other source of ignition must be permitted within a distance of 150 feet. The winch should not be operated within 150 feet of a hydrogen-filled balloon.

(2) A specific smoking area should be designated at a distance of at least 150 feet away.

(3) The sentry on duty should at all times enforce fire prevention regulations.

(4) Signs should be erected to denote the limits of the danger and smoking areas.

(5) All animals should be kept away from installations as a precaution against static electricity.

(6) Wool outer clothing should not be worn by members of a balloon crew, gas generating detail, or cylinder handling detail, since the wool may create static sparks capable of igniting the hydrogen. If wool clothing is worn, cotton coveralls should be worn as an outer garment. Cotton caps or some other head coverings should be worn.

(7) Extreme care must be exercised during inflation, topping-up, and deflation of the balloon, as during these maneuvers the danger of igniting the hydrogen is increased.

b. Action in case of fire.—In case of fire at a balloon site or other installations listed above, the following action should be taken:

(1) The person who first observes the fire will call: FIRE. Other persons in the vicinity will repeat the call until it is certain that all are aware of the fire.

(2) All gas cylinder valves will be closed immediately.

(3) If, in the judgment of the balloon chief or other man in charge, it is possible to extinguish the fire, he will order all available men to combat the blaze.

(4) If at any time, in the judgment of the balloon chief or other man in charge, personnel will be seriously endangered by remaining at the site, he will order all personnel out of the danger zone by the command: ABANDON SITE. Other personnel will repeat the command until it is certain that all are aware of the order.

(5) When the site is ordered abandoned, everyone should clamp his hand over his nose and mouth if there is a possibility of breathing in flames, close or cover his eyes if this does not interfere with getting away, run at least 100 feet, fall forward, and crawl on his stomach until out of the danger zone.

(6) If burning fabric falls upon him, an individual should roll over and over in order to remove the fabric or put out the fire. If he attempts to remove the burning fabric with his hands he is likely to damage his hands and fail to remove the burning fabric.

Section II

MANUFACTURE

■ 77. Precautions.—The following precautions should be observed in operating the high-pressure hydrogen generating plant, and in handling materials and equipment used in hydrogen generation:

a. Air should be flushed from the generator and lines at the start of operation and before any gas is used, by opening the drain valves beneath the sludge separator, moisture separator, and drying bottle.

b. Care must be exercised to keep all joints and connections gastight.

c. A careful periodic check must be made for leaks in all lines by applying a soapy water solution with a brush. A match should never be used to test for leaks.

d. Men working at the generating plant should be protected by goggles, rubber gloves, and preferably by rubber clothing. They should wear rubber-soled shoes. It is advisable for the men to rub a light coating of boric acid ointment on their hands and faces.

e. White lead, red lead, or any materials containing linseed oil should not be used in making repairs to the generator. Glycerin and litharge mixed to the consistency of a thin paste should be used.

f. Ferrosilicon should be shipped in airtight drums and stored in dry, well-ventilated compartments.

g. Ferrosilicon and sodium hydroxide should not be stored together in such a way that a mixture may result from damaged or broken containers.

h. Tests for the purity of the hydrogen produced should be made at least once by each shift working at a generating plant.

i. If generation is carried on indoors the building should be well ventilated. The engine should be provided with a flame arrestor on the exhaust system and rubber caps on the spark plugs and ignition system to avoid the possibility of igniting any hydrogen-air mixture which may exist within the building. To avoid producing sparks, all personnel using tools on metal equipment should be warned not to strike metal to metal. Brass, or other nonsparking tools should be used.

j. A first-aid kit containing plenty of absorbent cotton, boric acid ointment, and a saturated solution of boric acid should be kept at the generator. Vinegar or acetic acid may also be supplied. This kit should be inspected at least once each week and contents replenished if necessary. A bucket of clear water should also be kept on hand.

k. Caustic that gets on the skin or clothing of individuals operating the hydrogen generating plant should be removed immediately with clear water, either by submerging the affected area in water or dousing it with water. The skin and eyes should then be treated with boric acid solution. Vinegar or acetic acid may be used on the skin, but should not be used in the eyes. The affected area should not be rubbed. Persons with eye burns should be taken to the hospital immediately for treatment to prevent adhesions.

l. A carbon dioxide type fire extinguisher and a supply of sand should be available for use in case of fire.

m. Before an attempt is made to repair a high-pressure line, the pressure should be removed from the line.

SECTION III

HANDLING, STORING, AND TRANSPORTING CYLINDERS

■ 78. IDENTIFICATION OF CYLINDERS.—*a*. Army hydrogen cylinders are painted with a standard olive drab paint, or are galvanized, with the neckbands and caps painted olive drab. The word HYDROGEN is painted on the cylinder body.

b. All Navy hydrogen cylinders are painted black with a white band around the middle.

c. Commerical hydrogen cylinders are usually painted black. Sometimes, though very rarely, they are painted red.

■ 79. PRECAUTIONS.—In handling gas cylinders the following precautions will be observed:

a. Because of high pressure, cylinders must always be handled with care. They should never be dropped or subjected to heavy jars. This also applies to empty cylinders. Dangerous, or even fatal accidents easily result when high-pressure cylinders receive heavy or sudden jars or blows.

b. Cylinders will never be exposed to fire or heat. They should be protected from the direct rays of the sun if the temperature is above 90° F. by means of suitable covering, such as a tarpaulin or foliage.

c. The valve protecting cap will be kept in place at all times except when inflation is in progress or when the cylinders are being filled.

d. Standard size gas cylinders should always be handled by two men. One man should handle each end of the cylinder, and they should avoid striking the cylinder caps and possibly causing a leakage of gas or an explosion.

e. Cylinders will be stacked in groups of not more than 60 cylinders, and not more than 6 tiers high. Groups should be not less than 10 feet apart.

f. The cylinders will be stacked upon dunnage. Each cylinder of the bottom row should be securely chocked with wood blocks so that no rolling or sidewise movement is possible.

g. Each stack of cylinders will be grounded at all times. This is done by grounding an uninsulated copper wire which is placed between the first and second tier of cylinders while the cylinders are being stacked.

h. As the cylinders are stacked, the valve outlets will be pointed downward with all the valves on the same side of the stack.

i. In order properly to connect the inflation manifold hose to the valves of the bottom tier of cylinders, a trench 6 inches wide and 6 inches deep will be dug directly underneath the line of valves; or the bottom row may be stacked with the valves pointed to one side.

j. When preparing to discharge a cylinder, all connections and joints will be cleaned of dirt, grit, and foreign materials with a brush before making the connections. Care should be exercised to see that all joints are gastight.

k. Cylinder valves will be opened slowly and progressively to prevent them from being clogged (frozen) because of accumulated frozen moisture, and to guard against flash firing of small particles of foreign matter which may have accumulated in the valve opening.

l. When the gas is exhausted from a cylinder, it will be labeled at once by means of the letters MT marked with crayon or chalk.

m. The cylinder valve of an empty cylinder will be kept closed to prevent air from entering the cylinder.

n. The valve of a gas-filled cylinder will not be opened unless it is attached to a manifold hose or a pressure gage, or unless it is necessary to discharge a damaged cylinder.

o. Any cylinder which fails to discharge, is exposed to fire, dented by rough handling, or suspected of being defective will be marked DEFECTIVE and returned, together with a full explanation.

p. Repairs to valves will not be made in the field. Tightening of the gland nut to prevent leakage is permissible. Any valve which cannot be opened by hand will be marked DEFECTIVE and the cylinder returned. A wrench will never be used on a valve.

q. Cylinders will be tested for leaks immediately after charging, and on every occasion when the valve is opened and closed without completely discharging the cylinder. The method of testing for leaks is to apply soapy water plentifully with a small paint brush to the gland of the valve stem, the gas outlet, the valve body and safety plug, and where the valve screws into the cylinder.

r. If leakage is found at the gas outlet the cylinder will be connected to a manifold and the valve opened and closed rapidly. A quick partial turn is all that is required. If the above action does not stop the leak, the cylinder should be discharged into a balloon as soon as possible.

s. If leakage is found where the valve body screws into the cylinder, the leaky cylinder will be discharged into a balloon as soon as practicable. No attempt should be made to tighten the valve body.

t. If, as a result of an accident, the condition of a cylinder is considered dangerous, and a gas service officer is not immediately available to inspect it, the cylinder will be grounded and discharged into the open air by partially opening the valve.

u. In case of fire, carbon dioxide extinguishers will be used. Ordinary fire extinguishers will not extinguish hydrogen issuing under high pressure.

■ 80. STORING AND TRANSPORTING CYLINDERS.—Cylinders will be stored in a shed that has free ventilation. This prevents the accumulation of hydrogen in the event of a leaky valve. When cylinders are shipped by railway car, motor truck, or boat they should be securely chocked to prevent undue motion, and should be placed in well-ventilated compartments. Hydrogen will not be shipped in closed boxcars.

SECTION IV

INFLATION

■ 81. PRECAUTIONS.—The following precautions should be observed when inflating a balloon with hydrogen gas:

a. The ground cloth and inflation tube should be thoroughly wetted.

b. All air must be completely exhausted from the balloon.

c. All connections in the inflation system from the gas cylinders to the balloon must be inspected for leaks before the inflation starts.

d. The inflation tube should be rolled up to force out all air, attached to the manifold, rolled out flat, and attached to the balloon appendix. The appendix should not be twisted when the thimble and inflation tube are attached.

e. When inflation starts, each gas cylinder valve should be opened very slowly until there is a good flow of gas. Before removing a manifold hose, the valve should be opened fully to make certain that all gas is exhausted from the cylinder.

f. The inflation tube must not be allowed to become kinked or twisted while a balloon is being inflated. If there is a wind, the tube should be secured to stakes.

g. The electric bonding must be grounded during inflation.

h. When inflation is completed, the appendix must be tied off before the inflation tube and thimble are removed.

i. If inflation takes place inside a building, ample ventilation must be provided.

j. All precautions to prevent igniting the hydrogen gas must be observed.

SECTION V

DEFLATION

■ 82. GENERAL.—When the purity of hydrogen within a balloon falls below 85 percent, the balloon must be deflated. Except when rain is falling or the ground is wet from rain, dew, or surface water, deflation should take place between sunset and sunrise. Balloons that do not have a valve at the tail are normally deflated by pulling the rip cord. Balloons having a valve at the tail are deflated by removing the valve and allowing the gas to escape through the valve orifice. During this operation, the nose of the balloon should be held down so that the orifice is always at the highest point on the balloon. Balloons having a valve in the side of the envelope near the tail may also be deflated by this method. The orifice is kept at the highest point by rolling the balloon on its side as deflation progresses.

■ 83. PRECAUTIONS.—The following precautions should be observed when deflating a hydrogen-filled balloon:

a. Ground cloths and the surface of the balloon around the rip panel, or around the valve, must be wet down before the deflation starts.

b. Electric bonding should be grounded before deflating.

c. More than one opening at a time should not be permitted in a balloon that is being deflated, as more than one opening will permit a surge of air through the balloon, and a dangerously explosive mixture of hydrogen and air will result.

d. When deflating a balloon through the valve orifice, a wet blanket or other large cloth should be held over the valve while it is being removed. A wet cloth is then inserted into the orifice so as to hang approximately half in and half out of the balloon, and left there until the balloon is completely deflated.

e. Caution should be used when rolling up a deflated balloon because of the danger of gas pockets in folds of the fabric. All gas must be removed from the folds of the fabric.

f. No attempt should be made to hasten deflation by walking on the fabric.

g. All equipment and all personnel not required for the deflation will be not less than 200 feet up wind from the balloon bed.

h. All engines within 200 feet of the balloon should be stopped, and all precautions to prevent igniting the hydrogen gas should be observed.

i. Under no conditions should the blower be attached to the appendix to deflate a hydrogen-filled balloon.

SECTION VI

TYPICAL ACCIDENTS

■ 84. GENERAL.—*a*. An observation balloon was deflated in a tent hangar. While some of the crew were rolling the balloon, other men walked on the balloon in woolen socks, pushing little pockets of gas toward the valve opening with their feet. Result—an explosion. Three men were killed, 30 men were hospitalized for severe burns, and the balloon and hangar were destroyed.

b. To hasten the deflation of a free balloon, the appendix and valve were both opened at the same time. A little pop was heard, and then a flame rapidly consumed the balloon.

c. During inflation a man crawled under a balloon to straighten the appendix. As he touched the metal thimble a spark jumped from his hand to the thimble, causing a fire.

d. One man dropped a full hydrogen cylinder while moving it. The valve was snapped off. The cylinder thrashed around crazily, finally plunging through a wood wall.

e. A machinist removed the cap from the check valve of the caustic pump on a hydrogen generator while pressure was on the line. The check valve in the main line gave way, causing caustic to be blown into the face of the machinist.

f. A workman tapped a high-pressure gas cylinder with a hammer in passing. The cylinder exploded, killing the workman.

CHAPTER 3

HELIUM PURIFICATION PLANT

■ 85. General.—Since the supply of helium is limited, it will not ordinarily be used to inflate balloons in a barrage. However, it is used to inflate balloons used for training purposes. Diffusion of air through the balloon fabric reduces the purity of helium in a balloon, thereby decreasing the lift. When it becomes necessary to deflate a helium-filled balloon, due to low gas purity and insufficient lift or other reasons, the helium is purified and reclaimed through the use of a helium purification plant. Hydrogen-filled balloons of low gas purity are deflated by allowing the gas to escape into the atmosphere, and no attempt is made to reclaim the hydrogen.

■ 86. Principles of Helium Purification.—The principal impurities likely to be found in helium gas are oxygen and nitrogen. Oxygen, nitrogen, and helium will liquefy at −182°, −196°, and −268° C., respectively, at the pressures developed in the helium purification plant. Therefore, the oxygen and nitrogen may be liquefied and drained off, leaving the purified helium. The helium purification plant contains an air cycle and a helium cycle. The purpose of the air cycle is to produce liquid air, which in turn produces a sufficiently low temperature to liquefy the oxygen and nitrogen impurities. The purpose of the helium cycle is to provide means for separating the impure helium into liquid impurities and gaseous purified helium, and for removing the impurities.

■ 87. Helium Purification Plants.—Two types of helium purification plants are now in use. One type is mounted on a railway car, and is referred to as helium purification plant, car No. ( ). Car No. 1, now in use, is capable of purifying 5,000 cubic feet of helium per hour. The other type is mounted on a trailer, and is referred to as mobile helium purification laboratory, type B–1 (originally type A–3). This laboratory is capable of purifying 1,500 cubic feet of helium per hour. An explanation of the principles of operation of these plants and instructions for operation may be found in A. C. Technical Order No. 16–1–5, December 1, 1941.

■ 88. PERSONNEL.—*a. Helium purification plant, car No. 1.*— The recommended size of crew for operating this plant is six enlisted men, including the technical sergeant who is in charge of the operation. The other five men are employed as follows: one man to operate the air compressor, one to operate the helium compressor, one to operate the control panel, and two men to attach the source of impure helium to the helium compressor and to attach the manifold to cylinders for collecting the purified helium. Due to the heat in the air compressor room, the air compressor operator may alternate with the helium compressor operator, or may be relieved by the sergeant in charge.

b. Mobile helium purification laboratory, type B–1.—The recommended size of crew for operating this laboratory is seven enlisted men, including a technical sergeant who is in charge of the operation. The other six men are employed as follows: one man in the compressor room to operate the air and helium compressors, one man to operate the control panel, two men to attach the source of impure helium to the helium compressor and to attach the manifold to cylinders for collecting the purified helium, and two men to handle the helium cylinders. Due to the heat in the compressor room, the compressor operator may alternate with the control panel operator, and may also be relieved by the sergeant in charge.

CHAPTER 4

AIR INFLATION, INSPECTION, AND DEFLATION

■ 89. GENERAL.—Before a balloon is delivered to a balloon site for use, it must be air inflated and inspected. Air inflation and inspection is ordinarily accomplished by the service platoon of the barrage balloon group or separate battalion. Initial gas inflation of a balloon is ordinarily accomplished at the balloon site, and should not be attempted unless the balloon has been previously inflated, inspected, and repaired if necessary. Instructions covering gas inflation and deflation at the balloon site may be found in FM 4–108.

■ 90. AIR INFLATION.—*a. Facilities and equipment needed.*—If possible, the balloon should be air inflated and inspected inside a building of suitable size and accessibility. If a suitable building cannot be obtained, the air inflation may be accomplished in the open on a balloon bed in a central and easily accessible location. Equipment needed for air inflation includes an inspection lamp, blower, inflation tube, and thimble and elastic tie-off cord. An auxiliary lighting unit is also needed if no other source of electricity is available.

b. Procedure.—(1) In the discussion that follows, it will be assumed that the inflation is conducted in the open. The balloon box is placed on the down-wind side of the bed at the edge of the ground cloth. The ground cloth must be carefully swept. The top of the box is removed, the canvas liner is laid back, and the waterproof container opened. The box is then turned over on the side, so that the top of the box faces the bed. Crew members from opposite sides then carefully grasp the fabric at intervals of a few feet and carry the balloon onto the bed. The lobes, fins, and folded fabric are spread so that the balloon lies flat on the bed. All parceling is removed from the ropes and fittings and saved for rewrapping.

(2) After the balloon is unfolded and parceling removed, the crew members extend the mooring and handling lines to the sides and attach sandbags to them. The air blower is procured, inspected, and given a test run. The gas and air valves

are procured and installed. The inflation tube is attached to the appendix and to the blower by means of thimble and elastic tie-off cords. Riggers inspect the external rigging, as described in paragraph 91. Crew members place a row of sandbags across the envelope one-third of the balloon length away from the appendix in order that the balloon being inflated may be more easily controlled. If sandbags are not available, a number of crew members with shoes removed may be directed to stand on the balloon, or a rolled-up ground cloth may be used. Crew members who will walk on the balloon fabric must remove their shoes or wear special shoe coverings prescribed by standing operating procedure to prevent damage to the fabric.

(3) After preparations for air inflation are completed, the air blower is started. Care should be used to insure that fumes from the engine exhaust are not sucked into the fan and blown into the balloon. As the inflation proceeds and air fills the envelope, crew members move the sandbags placed across the balloon away from the appendix. Sandbags are attached to the first bridles or to the catenary curtain grommets as inflation proceeds. The crew members adjust the handling and mooring lines on their respective sides of the balloon, and when inflation has proceeded to a point where sandbags attached to the lines are being dragged along the ground, crew members will be directed to tie the handling and mooring lines through the screw picket eyes. When a balloon is air inflated inside a building, it is not necessary to hang sandbags on the bridles or catenary curtains, or to tie down the handling and mooring lines.

(4) Inflation will proceed until the entire balloon and gas-inflated fins are well filled. The inflation tube is disconnected from the appendix and the appendix is closed. In the case of a ballonet balloon, the air chamber must be filled with sufficient air to allow an inspector to move about under the diaphragm. The air chamber is not inflated until after the gas chamber has been air inflated and inspected.

■ 91. INSPECTION.—*a. Initial external inspection.*—While the balloon is being air inflated, the riggers will inspect all seams and finger patches on the outside of the balloon for signs of defective cementing. All of the rigging is also inspected to see that the balloon is properly rigged according to the manufacturers' specifications, or according to marks locating the positions of the knots on the rigging. All splices and servings are inspected for imperfections. Fabric will be inspected for signs of chafing by the rope rigging, which may have occurred while the balloon was packed.

b. Initial internal inspection.—This inspection is conducted by the riggers for the purpose of locating any holes or tears in the balloon envelope and fins. One or more riggers enter the balloon through the appendix with an inspection light. When the light is turned off the inspector will be able to locate all holes in the fabric upon a thorough inspection of the interior. If the balloon is inspected inside a building it will be necessary to use a bright light on the outside of the envelope and each panel must be inspected carefully. The inspector will mark each hole by circling it with a red pencil or chalk. The entire envelope is inspected in this manner. The balloon may be turned over on its side for inspection of the bottom. The fins are inspected from the inside through an opening between the envelope and fins. Care must be exercised by the men in the balloon, so that the fabric will not be damaged. They must enter the balloon with their shoes removed, or wear special shoe coverings prescribed by standard operating procedure. All of the patches made as a result of the original inspection are made on the inside of the envelope.

c. Inspection of ballonet diaphragm.—One rigger will enter the gas chamber with an inspection light and another rigger will enter the air chamber. By prearranged plan, the inspectors will progress from one end of the diaphragm to the other. When a hole or tear is found, the inspector under the diaphragm will hold his finger against the diaphragm at that point, while the other rigger will circle the spot with red pencil or chalk.

d. Inspection for storage.—The balloon will be air inflated and inspected as described above. The fabric will be cleaned of all foreign matter and oil. Benzol will be used to remove oil from neoprene-treated fabric. An excessive amount should not be used, as benzol may damage the seams. Fabric must be thoroughly dried, and it is advisable to sprinkle talcum powder on the envelope if it is believed that the storage will be of long duration. All rope rigging will be carefully inspected, and any worn or damaged ropes will be replaced. All dirt or foreign matter will be removed from the ropes, and they must be thoroughly dried.

■ 92. AIR DEFLATION.—If the balloon is to be deflated by man-power, the valves are first removed. The appendix is then held open and the crew members roll the entire envelope up tightly toward the appendix, while the lines are released from pickets as deflation proceeds. If an exhauster is used, a metal tube is attached between the appendix and the exhauster. The balloon is deflated and lies spread upon the bed.

■ 93. PACKING.—After the balloon has been deflated the parts of the rigging that may damage the fabric are wrapped in parceling cloth. All handling and mooring lines are properly coiled and tied. Starting from the tail, the balloon is folded and is placed in the packing case. When placing the balloon in the case, the balloon should be lifted and not dragged over the edge of the case, so the fabric will not be damaged. The metal parts are replaced in their original packings and securely fastened. The canvas and waterproof packing are folded over the balloon and the waterproof packing is cemented shut. The top of the case is screwed on tightly.

CHAPTER 5

TRANSFERRING HYDROGEN FROM ONE BALLOON TO ANOTHER

■ 94. GENERAL.—The following instructions for transferring hydrogen from one balloon to another are to be complied with whenever it is necessary to deflate one balloon and inflate another at the same site. This operation should not be undertaken in high winds and should be done only when the purity of hydrogen is 90 percent or more. In the following instructions, the balloon to be deflated is referred to as *A* and the one to be inflated as *B*.

■ 95. PROCEDURE.—In dry weather this operation should be done between sunset and sunrise. The ground cloths and the junctions of the inflation tubing are liberally wet down. The purity of the gas in *A* is taken. If the purity is 90 percent or more, the procedure is as follows:

a. *A* is transferred to a temporary screw picket bed just ahead of and to the windward of the permanent bed so that *A* lies with the nose into the wind and affords some protection to *B* during the first stages of inflation. If possible, *A* should be placed on lower ground than *B* to assist inflation. On very inclosed sites, *A* may be placed on either side of and parellel to *B*. The air-inflated stabilizers of *A* are furled. *A* is trimmed so that the end of the balloon containing the inflation appendix is as high as possible on the bed.

b. *B* is laid out on the permanent bed with the nose into the wind and prepared for inflation in the usual way.

c. The inflation appendixes of *A* and *B* are connected by inflation tubing, usually two lengths. All junctions should be securely tied to prevent leakage. The junction of the two inflation tubes should be grounded by a grounding rod attached to the metal thimble. For this purpose one end of a copper wire may be inserted between the thimble and the tube, and the other end of the wire attached to a rod or pipe driven into the ground.

d. If *A* is of the ballonet type the air should be exhausted from the ballonet.

e. Sandbags are to be hung from the catenary curtain of *A*, starting from the end of the balloon opposite the inflation appendix.

f. When *A* has been deflated to a point where the pressure within the balloon is no longer sufficient to force gas into *B*, crew members commence rolling up *A*, starting at the end opposite the inflation appendix. They should roll the balloon as tightly as possible, and take care not to allow gas to blow back into the rolled portion. As the balloon is rolled up, handling and mooring lines are released as reached.

g. When *B* starts to inflate, the gas entering the balloon is controlled by placing a row of sandbags or a rolled-up ground cloth across the envelope. The sandbags or ground cloth are gradually moved away from the inflation appendix as inflation progresses.

h. Throughout the process of rolling up *A*, the inflation appendix should be kept as high as possible above the ground to prevent the appendix or inflation tube from being kinked or twisted.

i. When *A* is sufficiently deflated, 12 to 14 men are distributed around the balloon and the remaining gas is expelled by folding inward from all sides toward the inflation appendix.

j. When all gas has been transferred, the inflation appendix of *B* is tied off and a purity reading is taken. If *B* is a pressure-type ballonet balloon, the ballonet is filled with air. *B* is topped-up if necessary.

CHAPTER 6

MAINTENANCE AND REPAIR

■ 96. GENERAL.—Minor repairs to barrage balloon matériel may be made at the balloon site by the balloon squad under supervision of the platoon rigger. Major repairs to cable, rigging, fabric, winches, hydrogen-generating plants, and automotive equipment are made by the service platoon of the barrage balloon group or separate battalion.

■ 97. CABLE.—Steel cables must be inspected frequently for signs of rust, corrosion, broken wires, or chafed surfaces. Rust must be removed. When a cable shows signs of corrosion or chafing at the cable terminal assembly, a sufficient length must be cut from the end of the cable to allow an unworn portion of the cable to be inserted in the assembly. Cables will ordinarily be protected by a light coating of oil, or by other cable preservatives which may be tested and approved from time to time. Cables which are likely to be exposed to salt water should be impregnated with a mixture of linseed oil and lampblack, or with any other tested and approved mixture which will serve to prevent corrosion. The admiralty splice is used in splicing balloon cable. The proper method of making this splice is described in Army Air Forces Specifications No. 98–25515.

■ 98. CORDAGE.—*a. Maintenance.*—Ropes will be inspected frequently for signs of wear, and will be replaced if necessary. Exposure to rain and frost causes ropes to deteriorate. Whenever possible, wet ropes should be laid out in such a manner as to insure rapid drying. Frozen ropes break easily, and should not be used until they have been thawed out. Rope which has been exposed to water or to the elements should be thoroughly dried before it is stored. Ropes should be kept free from sand and grit, and should not be permitted to come in contact with acids. Broken or deteriorated ropes are replaced with new ropes when available.

b. Repair.—Broken ropes are repaired by splicing if necessary. Either a short or long splice may be used, but a short splice will result in an enlargement of the rope at the point of the splice.

■ 99. FABRIC MAINTENANCE.—Great care must be taken to prevent damage to balloon fabric. It should not be allowed to come into contact with sharp or uneven surfaces, and should not be allowed to rest on the ground or any other surface unless a clean ground cloth has previously been laid. No one should be allowed to walk on the fabric unless he removes his shoes or wears special shoe coverings prescribed by standard operating procedure. The neoprene-treated balloon fabric is more resistant to the deteriorating action of oils and greases than rubberized fabric; nevertheless, care should be taken to prevent the fabric from being exposed to oils and greases. The life of balloon fabric may frequently be extended by coating it with a type of dope manufactured and authorized for that purpose. Doping, either internal or external, may overcome deterioration of the fabric and decrease permeability. It is preferable to apply the dope on the inside of the balloon.

■ 100. FABRIC REPAIR.—*a. General.*—Holes up to 12 inches in diameter may be patched. If holes are larger than 12 inches, it is generally advisable to replace the entire panel. Patches are applied by stitching and cementing. Small patches require no stitching. Stitches used are the baseball stitch, back stitch, and saddler's stitch. Stitching by hand requires a correctness of execution which may be attained only through constant practice and infinite care and patience. The cement used is neoprene cement. The cement should not be applied in direct sunlight or in a dusty or humid atmosphere. Neoprene cement is highly inflammable, and should be kept away from sources of ignition. The fumes from the cement are dangerous to breathe for any length of time, and are also explosive. Therefore, the cement should not be used in an enclosed space without proper ventilation. Fabric selected for patches should be of the same diagonal as the fabric of the panel to be repaired, and should be of the same color if possible.

b. Deflated balloon.—(1) Large holes are repaired by applying a filler patch. The edges of the hole are trimmed evenly so that a piece of fabric may be cut to fit the hole exactly. The patch is started by cementing a piece of fabric over the hole on the inside of the envelope and stitching it with the saddler's stitch. This piece of fabric should overlap the hole at least 3 inches on all sides. The hole is then "filled" with a piece of fabric that has been cut the same size and shape as the hole. This piece of fabric is cemented to the inside patch. The hole is then covered from the outside by a piece of fabric cemented to the envelope and filler. The outside patch should overlap the hole at least 2 inches on all sides.

(2) Small holes may be repaired by simply cementing a piece of fabric over the hole, allowing the patch to overlay the hole sufficiently on all sides. If possible, the patch should be applied from the inside of the balloon.

(3) Tears are replaced by first bringing the edges of the tear together by means of a baseball stitch. The tear is then covered with a piece of fabric cemented to the inside of the envelcpe. If the patch is rectangular in shape, the corners should be rounded.

(4) Holes larger than 12 inches in diameter are usually repaired by replacing the entire panel. The old panel must first be removed. This is done by soaking the cement loose with benzol (applied with an oilcan) and gradually working the edges of the panel away from the adjoining panels. The cement remaining on the envelope is removed by erasing it with a piece of raw rubber. The surfaces of the envelope where cement is to be applied are washed lightly with benzol. The required number of coats of cement (according to manufacturer's directions) are applied to one of the long edges of the hole and to the corresponding edge of the new panel. The cement must be worked thoroughly into the fabric. Cement is applied to only one edge at a time, and the panel is cemented to this edge before additional cement is applied. After the cement is applied, a line is marked ½ inch from the edge of the panel to be used as a guide line. Two men are required to cement the edge of the panel to the envelope. One man starts from each end and works toward the center for about 18 inches. The men then thoroughly roll the surfaces cemented together before proceeding further. During these operations, the remainder of the cemented

surfaces are prevented from becoming stuck together inadvertently by a piece of cheesecloth placed between them. The cheesecloth is removed as the cemented edges are pressed together. After the 18 inches at each end are rolled, the fabric is stretched by pulling from the ends. Weights are placed on the portions already cemented together. This process is repeated until the center of the panel is reached. The remaining three edges of the panel are cemented in place in the same manner. The panel must then be allowed to dry for 12 hours before tape is applied. The cemented edges of the panel and the uncured neoprene side of the tape must be washed lightly with benzol. The required number of coats of cement are then applied to the seams. Cement is not applied to the tape. Guide lines 1⅛ inches apart are marked on the envelope. The tape is applied 18 inches at a time and is rolled thoroughly. Both the outside and inside of the seams must be taped. To permit the repairmen to enter the balloon to tape the inside seams, the balloon is inflated with air. After the operation is completed, the cemented area is powdered with soapstone. In cementing, it is extremely important that the surfaces be rolled thoroughly to force out air bubbles and distribute the cement evenly. In the application of benzol, an excessive amount should not be used, since it will wash the neoprene out of the fabric.

(5) A rip section that has been pulled out is ordinarily repaired by replacing the entire panel in the manner described in (4) above. The new panel may be obtained from the manufacturer with the rip section in place. If the new panel is not available, it is possible for an experienced repairman to use his own judgment and replace the rip section in the old panel.

c. Inflated balloon.—Small holes are repaired by cementing a patch over the hole on the outside of a balloon. Stitching of tears is practically impossible. The edges of tears should be joined quickly to prevent the escape of gas. This may be done by cementing a patch of fabric over the tear or by cementing bands of fabric across the tear. Either of the above should then be covered by a larger patch. The edges of this patch should be covered with a band of fabric to help prevent further tearing.

88

■ 101. WINCH MAINTENANCE.—*a. Inspections.*—In addition to the daily inspections performed by the winch operator at the balloon site, the following inspections by the battery engineer officer are necessary to insure proper maintenance. (The instructions contained in this paragraph refer to the type A–9 winch, but may be applied, with modifications, to other types of winches which may be adopted.)

(1) After each *50 hours* of operation—

(*a*) Thoroughly clean engine.

(*b*) Inspect clutch for 1 inch free travel of pedal.

(*c*) Inspect winch gear case for leaks.

(*d*) Inspect transmission for leaks and check bellhousing bolts for tightness.

(*e*) Check water pump for leaks.

(*f*) Inspect and tighten engine mounting support bolts.

(*g*) Adjust fan belt tension and replace belt if worn.

(2) After each *100 hours* of operation—

(*a*) Clean magneto cap and inspect timing contacts.

(*b*) Clean carburetor inlet screen.

(*c*) Check ignition timing.

(*d*) Clean and adjust spark plugs.

(*e*) Tighten all wiring connections and check for chafing.

(*f*) Remove and clean gasoline strainer screen.

(3) After each *150 hours* of operation—

(*a*) Inspect winch mounting bolts for tightness.

(*b*) Check cylinder compression.

(*c*) Clean cooling system thoroughly and remove all rust and sediment.

(*d*) Clean gasoline strainer screen, remove and clean sediment trap, and blow out fuel line.

(*e*) Check spooling device chain drive for tightness and make necessary adjustments.

(4) After each *200 hours* of operation—

(*a*) Check and adjust valve clearances.

(*b*) Inspect radiator hose and replace if deteriorated.

(*c*) Check and tighten bolts attaching unit to base.

b. Lubrication.—The more important points of lubrication and the methods are given below. More detailed instructions will be found in the lubrication chart furnished by the manufacturer.

(1) *Engine crankcase.*—Check and fill to proper level as required. Drain and refill every 100 hours of operation.

(2) *Water pump.*—Give grease cup three turns every 75 hours of operation. Refill if needed.

(3) *Fan.*—Remove plug and fill hub with engine oil every 75 hours of operation.

(4) *Air cleaner.*—Wash in gasoline and dip in light engine oil every 100 hours of operation or more frequently if air is abnormally dusty.

(5) *Transmission.*—Fill to level plug opening every 100 hours of operation. Drain, flush with light oil, and refill every 250 hours of operation. Use high-grade mineral gear oil. In winter use SAE 90, and in summer use SAE 140.

(6) *Winch gear case.*—Fill to level plug opening every 100 hours of operation. Drain and refill every 250 hours of operation. Use high-grade mineral gear oil. In winter use SAE 90, and in summer use SAE 140.

(7) *Clutch release bearing.*—Grease with pressure gun every 75 hours of operation. Use No. 5 cup grease.

(8) *Clutch release shaft.*—Grease with pressure gun every 75 hours of operation. Use chassis lubricant.

(9) *Clutch release transfer lever.*—Grease with pressure gun every 75 hours of operation. Use chassis lubricant.

(10) *Clutch pedal.*—Grease with pressure gun every 75 hours of operation. Use chassis lubricant.

(11) *Spooling device.*—Grease with pressure gun every 75 hours of operation. Use chassis lubricant.

(12) *Storage drum.*—Grease left-hand bearing with pressure gun, using chassis lubricant, and place a few drops of engine oil on right-hand bearing every 75 hours of operation.

(13) *Spooling device idler.*—Grease with pressure gun every 75 hours of operation. Use chassis lubricant.

(14) *Lead-off gear.*—Grease with pressure gun every 75 hours of operation (three fittings). Use chassis lubricant.

(15) *Lower right cable sheave.*—Grease with pressure gun every 75 hours of operation. Use chassis lubricant.

(16) *Spooling device upper guide rod.*—Place a few drops of oil along rod every 75 hours of operation.

(17) *Magneto.*—Place a drop of engine oil on contact lever pivot and grease cam follower with high-pressure grease every 100 hours of operation.

(18) *Service brake pedal shaft.*—Grease inner end with pressure gun, using chassis lubricant, and place a few drops of engine oil on outer end every 100 hours of operation.

(19) *Clutch linkage.*—Place a few drops of engine oil on clevis pins and other moving parts every 75 hours of operation.

(20) *Governor control linkage.*—Place a few drops of engine oil on clevis pins and other moving parts every 75 hours of operation.

(21) *Clutch pilot bearing.*—Grease with pressure gun every 250 hours of operation. Use No. 5 cup grease.

■ 102. LUBRICATION OF VEHICLES.—*a.* Vehicles should be lubricated according to instructions issued by the manufacturers in the handbooks pertaining to the vehicles. Methods of lubrication and types of lubricants are given in FM 25–10.

b. The proper grease and oil as recommended in the handbooks for the vehicles should be used for each fitting. The mixing of different brands of oils and greases should be avoided.

c. In cases where no lubrication chart or instructions are available, the instructions for a vehicle of similar type should be used.

■ 103. COMPRESSORS.—*a.* All types of compressors must be kept clean at all times. Care must be taken to see that no dust, dirt, grit, or foreign matter of any kind is allowed to enter the compressor. Dirt of any kind will collect with the oil to form a gummy mass which will eventually impair the proper functioning of the machine. All parts should be protected from rust, particularly when the compressor is not in use. Parts which are not painted should be coated with grease or vaseline.

b. When the compressor is not in use, the water should be drained from the cooling system. The intercoolers and water jackets should be washed out thoroughly at least once a month to prevent formation of a deposit, which will retard the flow of water through them.

c. All valves should be examined at least every 2 weeks while the compressor is in use, and before it is placed in service after a period of idleness. If a valve is leaking and the valve seat requires the removal of only a small amount of metal to prevent leakage, it is advisable to lap the valve on the seat. If a valve or valve seat is pitted or otherwise distorted to any extent, the seat should be replaced and the seating face of the valve should be refaced. In each case the valve should be properly lapped on the seat. When regrinding is necessary, fine emery and glycerin should be used. The valve and valve seat should be wiped clean after lapping.

d. A heavy grade, high flash point oil is used for lubrication of compressor cylinders. Care must be taken to see that the proper amount of oil circulates through the compressor. Intercooler passages should be blown out occasionally to avoid accumulation of oil carried through from the cylinders with the flow of gas. An excessive amount of oil should not be used for the lubrication of journals, crank pins, and guides. If oil is allowed to collect on these parts, dust may be drawn in with the oil and cause unnecessary wear.

■ 104. HYDROGEN GENERATING PLANT.—The pipe used on the high-pressure hydrogen generating plant is extra heavy with extra heavy fittings. Outside diameter of the pipe is the same as for standard pipe, but the wall thickness is much greater, making the inside diameter much smaller. From the outside, high-pressure pipe can be distinguished from other pipe by the larger, more bulky fittings, and the maximum pressure it will carry is usually marked on the pipe. When high-pressure pipe is replaced, care must be taken to insure that no standard pipe is used, since it will not withstand the pressures encountered in the high-pressure system. High-pressure pipe must always be cut with a hacksaw, and not with a pipe cutter. Any remaining bur must be removed from the inside of the pipe so that it will not decrease the pipe opening. Threads must be carefully made so as to insure maximum strength and to prevent possible leaks at the joints. Longer threads must be made on high-pressure pipe and the pipe must be screwed farther into the fittings than in standard pipe work. When a high-pressure globe valve is used, the valve should be placed so that the pressure is on the under side of the valve away from the valve stem packing; otherwise, the pressure would be against the packing at all times. The pressure should always be removed from a line before it is repaired or adjusted. Care should be taken at all times to insure that fittings and pipe are not subjected to excessive strain from the wrenches. If the threads will not come loose at a joint without excessive strain, some form of heat may be applied if the generating plant has been purged of all hydrogen. In making up new connections, a mixture of glycerin and litharge may be used. A compound containing white lead, red lead, or linseed oil should not be used. If glycerin and litharge are not available, the connection may be made without them, and any small leaks which may occur may be peened out with a small punch and light hammer.

APPENDIX

LIST OF REFERENCES

FM 4–107, Organization, Tactics, and Technique, Barrage Balloon.
FM 4–108, Service of the Balloon and Balloon Equipment, Barrage Balloon.
FM 4–115, Operation of Matériel and Employment of Personnel, Antiaircraft Searchlight Units.
FM 4–120, Formations, Inspections, Service, and Care of Matériel.
FM 5–30, Engineer Antimechanized Measures.
FM 21–5, Military Training.
FM 22–5, Infantry Drill Regulations.
FM 24–5, Signal Communication.
FM 25–10, Motor Transport.
FM 100–5, Operations.
TM 1–230, Weather Manual for Pilots.
TM 1–315, Hydrogen.
TM 1–325, Aerostatics.
TM 3–240, Meteorology.
AR 265–10, Tactical and Training Inspections.
Air Corps Technical Order No. 16–1–5, December 1941.
Air Corps Specifications No. 98–25515.

INDEX