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AIRPLANE PARACHUTES.

By Lieutenant Mazer.

From "Bulletin Technique," August, 1924,

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Introduction.- The "Bulletin Technique," of March, 1919, gave the results of tests and studies made up to that date in connection with airplane parachutes. This work has been continued and the object of the present "Bulletin" is to supply information in regard to:

1. The various theoretical considerations on which the study and improvement of the parachutes was based and the experiments through which it is possible to verify and compare the progress made (Chapter I).

2. The types of parachutes existing at the present time both in France and in other countries (Chapter II).

3. The various performances at the two meets held in 1923 (Chapter III).

4. The present status of the difficult problem of adapting the parachute to the airplane, of the belt which fastens the parachute to the passenger and, lastly, the storage of parachutes.

* From "Bulletin Technique," August, 1924.

Chapter I.

Theoretical Considerations.

Fundamentally, the parachute consists of a "sail," from which the user is suspended by means of a certain number of cords uniformly distributed about the periphery of the parachute. It is known that the speed with which a body falls through space is uniformly accelerated. When any resistance, which is a function of the velocity, is opposed to the attraction of gravity, the body falls with a constant vertical speed, as soon as this resistance has attained a value equal (though of contrary sign) to the weight of the body.

The object of the sail is to create this resistance. As soon as it opens, the pressure of the air causes it to assume its true shape, usually that of a dome, with a more or less pronounced curve and a central opening or vent, which allows the air to escape and prevents the sail from tearing while unfolding. This dome offers a vertical resistance which is an increasing function of the velocity of descent. A moment arrives, therefore, at which the resistance is equal, and directly opposed, to the weight of the passenger. Normal conditions are then established. Theoretically, this velocity depends only on the area of the parachute, but the speed at landing, which is the most important from a practical point of view, depends on two factors, the area of the parachute and the rapidity with which it unfolds, since the normal speed is less, the more quickly it has been established.

Unfortunately, the experiments, made for the purpose of expressing the phenomena in figures, are very difficult and, in designing a parachute, more reliance is placed on methodical experiments and successive trials (both with respect to the form and dimensions of the sail) than on calculation. Various models of reduced size have nevertheless been studied in the laboratory with the object of ascertaining the best form to be given to the parachute. After this is decided, the resistance of the sail may be calculated in the manner described later on.

A method of calculation will also be given, by means of which the area may be plotted and the effect of the weight of the sail on the velocity of descent taken into account. The chief qualities required for a good parachute will be discussed, as also the different modes of operation of the parachutes now in use. Lastly, the means possessed by the "Service Technique" for the experimental investigation of the characteristics of a parachute (laboratory and flight tests) will be discussed.

I. Shape of Parachutes.- When the study of airplane parachutes was first begun, the question of the shape of the sail was not considered. The first airship parachute was in the form of a spherical dome and was made of gores or sectors of silk and provided with a vent collar. In their first tests, the experimenters in this field were content with reducing or increasing the diameter at the bottom and the curvature of the dome.

As regards the calculation of a parachute (plotted from the meridian), we will see that a sail was obtained which was very nearly balanced while descending. It is in this form that the parachute "Galbé" (Chapter II, Sect. 1, B) was constructed. Experiments made since then, however, have demonstrated the importance of the shape of the sail and, with this in mind, the "Service Technique" has made a series of tests, the results of which have led to the following conclusions:

1. Tests of accelerating the velocity of descent by expanding the vent prove the existence of a region of minimum pressure at the center of the section of resistance.

2. Tests of acceleration by removing the peripheral ring show the existence of a circular region of minimum pressure at the edge of the section of resistance.

3. Various tests with auxiliary or "pilot" parachutes show the existence of a region of zero pressure above and toward the center of the supporting surface, as well as below and at the center, if this surface is convex.

4. The same tests show that below and toward the edge of the supporting surface there is a very deep eddy zone.

From these indications it was concluded that the lines of air filling the vertical cylinder formed by the descent of a parachute approximated the course indicated in Fig. I.

In order to make better use of the air lines thus displaced, our first thought would be to construct a parachute in the form of an inverted cone (Fig. 2). This form imparts greater stability but a prohibitive speed of descent.

A trumpet-shaped parachute was then made, but the shock of opening was too great and the stability insufficient. Moreover, it either did not open completely, or did not remain open, the forces acting on the sail to expand it doubtless counterbalancing those forces which, on the contrary, tended to crease the sail toward the center (Fig. 3). Owing to structural difficulties and the fear that it might not open, this sail was not considered suitable for use on airplanes. On the other hand, experiments with reduced models made it seem probable that the spherical shape offered the most resistance to descent.

For all these reasons and because simplicity of design and certainty of operation outweigh all other considerations, the "Service Technique" returned to the use of either dome-shaped parachutes, or those in the form of an oblate spheroid. In an endeavor to distinguish between these two forms, the sustaining power of each parachute was calculated by putting

$$P = KSV^2 \quad \text{and} \quad K = \frac{P}{SV^2} ,$$

K being a numerical coefficient, supposed to be established for a given form: P, the weight of the load; V, the speed of descent. Calculations with respect to existing parachutes show, however, that the value of K varies and depends chiefly on the quality of the fabric. With light and permeable fabrics, K is small, but it increases with dense and heavy fabrics.

In short, it is not yet possible to give any exact laws relative to the best forms. The most satisfactory method is therefore the experimental and it is absolutely necessary, to make numerous tests in order to judge of the value of any given type of parachute.

II. Determination of Tensions on the Sail of a Parachute.- The appearance of long tears in the fabric was noticed in certain cases, these being due to excessive tensions at the moment of opening. The "Service Technique" was therefore led to calculate the tensions affecting the sail of the parachute, basing this on the well known mechanical properties of deformable surfaces.

In the following, we have considered the only practical case, namely, the one in which the surface of the sail is a surface of revolution.

Let us take a parachute, in which

D is the diameter;

P, the suspended weight;

2α, the angle at the apex of the cone formed by the suspension lines;

n, the number of suspensions lines;

R, the radius of the base of the cone.

If we consider a meridian, on assuming that the pressure is constant at all points of the sail and equal to $\frac{P}{\pi R^2}$ and that the projection on the normal at M of the tensions along a small rectangle, cut out about M, is equal to the pressure forces of this rectangle, we will find that the maximum and minimum tensions tx, ty, are related according to the equation

$$\frac{tx}{\rho x} + \frac{ty}{\rho y} = \frac{P}{\pi R^2},$$

ρx ρy being the principal radii of curvature of the surface at M (Fig. 4).

We will obtain a second relation between tx and ty by assuming that the projection of the tensions normal to the parallel of M (radius r), on the axis of the parachute, counterbalances the pressure applied on the dome intersected by this parallel, which gives us

$$2\pi \; r \times ty \times \cos\alpha = \frac{P}{\pi R^2} \times \pi r^2$$

and (2)

$$ty = \frac{P \; r}{2\pi \; R^2 \; \cos\alpha} \quad \frac{P\rho x}{2\pi \; R^2}$$

these formulas being well known to aeronauts.

If we liken the surface of the sail to a sphere, we will have

$$\rho x = \rho y = \rho,$$

in which case

$$tx = ty = \frac{P\,\rho}{2\pi \; R^2}, \qquad (3)$$

this tension being relatively very weak.

For a value P = 300 kg shock of opening and a relatively small base radius of 3.5 m, we will find a tension of less than 15 kg per meter. Therefore, in a well-constructed parachute the sail will never be the weak point. In spite of this fact, the program of the contests (as well as the specifications for parachutes in all countries of the world) require the relatively high strength of 300 kg per meter of the fabric. This is due to the three following reasons:

a) The maximum value of the tensions may vary to a considerable degree, as soon as the surface of the parachute is no longer spherical and particularly if puckers are produced in it.

b) The strength of such thin fabrics decreases rapidly with the least deterioration.

c) In case of a tear, a local deformation is produced, which tends to spread very rapidly, unless there is a considerable margin of safety.

Therefore, in the case of airplane parachutes which have to support a considerable weight with a relatively small number of lines, the maximum tensions are produced in the region of the points of attachment. The sail itself, as we have seen above, is never subjected to very great stresses.

III. Calculation of a Parachute - Rough estimate.- We will give the means of finding by calculation:

1. A logical shape for the sail of a parachute;

2. The effect of any variation in the weight of the fabric, of which the sail is made, on the velocity of descent.

A) Plotting the meridian.- In this calculation, it is therefore assumed that the fabric has been so manufactured as to transmit the pressure of the air to the prolongations of the suspension lines and arranged to follow the meridians (Fig. 5).

Each suspension line is subjected to a stress

$$t = \frac{P}{n \cos\alpha} .$$

According to what has already been established, it is with this stress that the factor of safety of the entire parachute is calculated. This stress is transmitted to the meridians of the parachute, which are then subjected to this tension t and also to the stresses originating in the fabric.

Formula (3) gives us

$$p \times \rho = t,$$

ρ being the radius of curvature at A.

If, at A, the distance of the two meridians is $\frac{2\pi r}{n}$, the value of p (for the point A, total of unit pressures on the length $\frac{2\pi r}{n}$) will be (the unit pressure being $\frac{P}{\pi \frac{D^2}{4}}$)

$$p = \frac{4\,P}{\pi\,D^2} \times \frac{2\,\pi\,r}{n} = \frac{8\,P\,r}{n\,D^2},$$

whence we have

$$\rho = \frac{\frac{P}{n\cos\alpha}}{\frac{8\,P\,r}{n\,D^2}} = \frac{D^2}{8\cos\alpha\,r} .$$

This formula, by means of which the stable form of the meridian may be plotted, shows that:

1. The curve of the parachute is independent of the suspended weight P;

2. It is a function of the angle of opening of the suspension lines α;

3. For two parachutes of diameter D and D_1, such that $D_1 = K\,D$, the same curve represents the parachute D

with the scale 1 and the parachute D_1 with the scale 1/K, the curve being therefore independent of D.

If we take the fabric between any two meridians, A_1 and A_2, Fig. 6 /then $d = \frac{2 \pi r}{n}$, the distance between them. If, at this point, the fabric has a length l greater than d, it curves inward, under pressure, in an arc of a circle having a radius ρ. By reason of symmetry, the unit pressure is, in fact, the same at all points of a parallel and accordingly its radius of curvature is constant.

B) Correspondence of weight and velocity of descent.- The sail being determined, it may be assumed that, for the same fabric and the same arrangement of the parachute, the weight is proportional to the surface area

$$\pi = h\,S. \qquad (1)$$

On the other hand, if P is the weight of the load and V the velocity of descent, we will have

$$P = K\,S\,V^2 \qquad (2).$$

If we differentiate the two equations, we obtain

$$d\,\pi = h\,d\,S \qquad\qquad d\,\pi = h\,d\,S$$

$$KV^2\,d\,S + K\,2\,S\,V\,d\,V = 0 \qquad\qquad V\,d\,S + 2\,S\,d\,V = 0$$

If we eliminate π, S and dS from these four equations, we obtain

$$d\,V = \frac{K}{2\,h\,P}\,V^3\,d\,\pi.$$

If we take, as our basis, the S.T.Aé. parachute now in use,

$$h = 0.125 \text{ and } K = 0.086.$$

If P = 80 kg, the variation of descent corresponding to a variation of weight of 50 grams, is

$$d\,V = -\,0.00022\,V^3,$$

or, for a velocity of	5.5 m/s,	3.65 cm;
" " "	5.0 "	2.75 ";
" " "	4.5 "	2.00 ";
" " "	4.0 "	1.4 ";

For a silk parachute of the same shape as the S.T.Aé., K would be the same (approximately h = 0.085) and we would have, for the same variation of weight,

for a velocity of	5.5 m/3,	5.5 cm;
" " " "	5.0 "	4.1 ";
" " " "	4.5 "	3 ";
" " " "	4.0 "	2.1 ".

By means of these calculations, the constructor is enabled to produce a parachute which, owing to its shape, is subjected to the minimum shock of opening, since it represents the curve of equilibrium of the fabric under the pressure of the air while descending. He may also obtain a velocity of descent with which any increase in the weight of the sail would cause a maximum diminution of this velocity.

IV. Qualities Required for a Parachute.- The conditions which a properly calculated parachute must satisfy are as follows:

1. Certainty of opening;

2. A shock not exceeding three times the load at the moment of opening;

3. Low velocity of descent, less than 5 meters per second.

1. Opening.- It has been proved by experiment that, under normal conditions, an ordinary parachute, which has been correctly folded, always opens. In France, the S.T.Aé. has discarded all automatic opening devices involving additional weight or the introduction of metal parts capable of tearing the sail and of causing fatal accidents, in case of failure of the opening mechanism.

2. Stress.- The shock produced at the moment when the sail opens may be dangerous to the user of an airplane parachute. In certain types, the tension resulting from it may be from five to six times the weight suspended from the parachute (tension measured by means of the ball dynamometer, described later on in discussing the qualities of parachutes).

Experiments made with animals ("Bulletin Technique" of March, 1919) have shown that this tension cannot exceed three times the weight without becoming dangerous. It is true that certain aeronauts, including a German parachutist, have recently withstood shocks of the order of 420 kg.

By means of measurements taken with the special ball dynamometer, it has been discovered that the magnitude of this shock depends chiefly on the shape of the parachute, on the rapidity with which it opens, and on the speed of the airplane.

3. Velocity of descent.- The velocity of descent depends, for a given load, on the size and shape of the sail. An average velocity of descent of 4.5 m/s is equivalent at landing, to a free drop of about 1 meter.

These are the properties required of a well-constructed parachute in order that it may be employed on airplanes with every guaranty of safety. They are not found together, however, on all the parachutes now in use. The parachutes all open, but the manner in which they are used and their method of opening, vary.

V. Different Classes of Airplane Parachutes.- We will divide the parachutes used in aviation into several classes according to their mode of operation.

1. Lift-off.- The parachute, in opening, pulls the aviator from his airplane (Pégoud). This type has no practical value. Its installation would require much special construction, which is impossible on airplanes with more than one seat. The method, which consists in being pulled overboard by the parachute, may, nevertheless, be used with an ordinary folded parachute. The aviator is certain, in this case, of leaving the airplane with his parachute open, but he runs the risk of catching on the tail of the airplane, a risk which may be avoided by starting the process of opening the parachute at the end of one of the wings.

2. Jump.- The aviator jumps from the airplane. Here again two cases must be considered.

a) Automatic opening.- The parachute, or its container, is opened either by means of a line connected with the breakable cord and attaching the rider to the airplane, or by a small auxiliary ("pilot") parachute, or by any other suitable device for utilizing the force of the fall. This method of automatic opening has been used, as will be seen, on the majority of French parachutes (S.T.Aé., Robert, Ors, Blanquier, Tinsonnier, Cormier), the English Calthrop or Guardian Angel, etc.

b) Opening controlled by the aviator.- By pulling a small "rip-cord" at the end of which there is a "pull-ring" the rider is able to release the parachute. These two methods each have their advantages and disadvantages.

The first method, which requires no action on the part of the aviator after he has jumped, was, for this reason, preferred in France for a long time. The breaking of the rip-cord in consequence of the line catching in the rider's belt or on the tail of the airplane may cause a failure to open.

The second method, preferred by the American army, has now been adopted in France. It allows the aviator great liberty of motion and enables him to jump from any part of the airplane and to choose the side to jump from, which is indispensable in certain cases, as in a tail spin, etc. The lift-off method is thus rendered possible. On the other hand, it requires more composure.

If the aviator should pull the rip-cord before jumping, the parachute, opening too soon, might catch on the tail of the airplane and tear. (A tear in the sail is not always fatal, however.) The opposite risk need not be feared, for a delay in opening can not be considered dangerous, since a human body must drop approximately 200 meters before attaining a speed of descent of 200 km per hour.

In consequence of the necessity, on commercial airplanes, of several passengers leaving by the same exit in case of danger, and in order to eliminate the breakable cords, this last method has been adopted for the latest French parachutes.

Even in the case of parachutes having the same mode of operation, the shock of opening and the velocity of descent may vary. The determination of these two qualities in the different types is not easy, as we shall see later.

VI. Investigation of the Qualities of a Parachute.- The form of the sail being determined and its resistance calculated, we still have to verify the required qualities and the mode of operation of the different types of parachutes.

This is the object of the tests, which may be placed in two distinct categories.

1. Laboratory tests;
2. Flight tests.

1. Laboratory tests.- Before every flight test, the follow-

ing operations are performed in the laboratory:

a) Weighing the parachutes;

b) Measuring them. This consists in placing the parachute in a container of known volume, which is then filled with very fine dry sand. The parachute is taken out and the volume of sand necessary to finish filling the case is measured. The figure found is equal to the volume of the parachute.

c) Testing the strength of the fabric, the suspension lines and their attachments to the sail. These tests are made in the usual manner with testing machines:

1. Test-pieces, 1 meter long by 50 centimeters wide, are cut from the fabric of the parachute. The breaking loads in the direction of the warp and of the filling are determined and the elongation and weight per square meter are then calculated.

2. Braided cords, whose strength is known and is given in the catalogs, are generally used for the suspension lines.

3. As we have seen in Section II, the point of maximum tension is where the suspension line is fastened to the sail. A sample of this fastening is made and the load which causes it to break is measured by the testing machine. This breaking load defines the factor of safety.

<u>2. Tests made in flight</u>.- All the properties of a parachute may be determined by descents from captive balloons or airplanes. The most important are:

a) Rapidity of opening;

b) Velocity of descent;

c) Maximum shock of opening;

d) Factor of safety;

e) Stability

The S.T.Aé. equipped a Potez limousine IX (Fig. 7) for these tests. A trap-door 0.51 m by 0.48 m was made in the floor of the cockpit. Above this trap-door, fastened between the two upper longerons of the fuselage, there is a bar of aluminum covered with ash, 1.03 m in length and 4 cm in diameter.

The 80 kg rubber dummy, equipped with parachute harness and pack, is suspended by a cord attached to the cross-bar above the trap-door and is released by cutting the cord. To open the pack, the breakable cord or the snap hook-knife is attached to a line which is also fastened to the suspension bar. According to the length of this line, the pack is opened in a longer or shorter time after the dummy has been released from the airplane. The altitude at which this takes place is recorded by a barograph. The speed of the airplane, when dummy is released, is recorded by the T. L. speed indicator, both these instruments being connected with an electric circuit.

a) Rapidity of opening.- There are two methods of ascertaining this: (1) By means of a stop-watch which records the time elapsed between the release from the airplane and the opening of the parachute; (2) With the Debrie motion-picture gun-camera which simultaneously photographs a watch and the parachute, thus recording on the film all the phases of the descent.

b) Velocity of descent of the parachute.- The mean velocity of descent of a parachute falling from a known altitude of H meters in a period of time T and opening at an interval of time θ after a drop of h meters, is

$$V = \frac{H - h}{T - \theta}$$

H can be determined very accurately with the aid of a barograph, if the pressure at the ground and the temperatures, both at the altitude H and at the ground, are known. T and θ are taken by an observer with a stop-watch having two hands, or by a motion-picture camera.

The height h is difficult to measure in tests on airplanes, but an approximate value is obtained by the following method. It is assumed that the parachute is released from a fixed point and that it descends vertically in still air. (Though these are not the actual conditions, it has been shown by experiment that the differences are negligible.)

The motion at first is comparable to a free drop which the opening of the parachute gradually curbs. The acceleration γ (which, at the beginning of the drop, is equal to that of the weight g) diminishes, becomes zero, then negative, then returns very quickly to zero and the parachute assumes its normal speed of descent.

Let us construct the curve representing the acceleration as a function of the time (Fig. 8).

We know the origin of the coordinates: $t = 0$; acceleration = g horizontal tangent.

The lowest point corresponds approximately to the moment of opening θ and the value of acceleration at this point is given us by the impression made by the ball dynamometer. If this impression corresponds to an acceleration - ng, the total acceleration, to which the parachute is subjected, will be $g - ng$.

By comparing the representative curve of acceleration between the instants o and θ to a parabolic arc of unknown degree p,

$$\gamma = g\left(1 - n \frac{tp}{\theta p}\right). \qquad (1)$$

From this equation we deduce the velocity of descent,

$$V = g\,t\left(1 - \frac{n}{p + 1}\;\frac{tp}{\theta p}\right), \qquad (2)$$

and the distance fallen,

$$e = \frac{gt^2}{2}\left[1 - \frac{2\,n}{(p + 1)\,(p - 1)}\;\frac{tp}{\theta p}\right] \qquad (3)$$

At the moment that $t = \theta$, the velocity is nearly that calculated (V). Since the approximate value of V_o is known, this enables us to obtain p.

$$V_o = g\theta\left(1 \frac{n}{p + 1}\right)$$

$$p + 1 = \frac{n\,g\,\theta}{g^{\theta} - V_o}$$

By substituting θ for t in equation (3), we have

$$h = \frac{g\,\theta^2}{2}\left[1 - \frac{2\,(g^{\theta} - V_o)^2}{g\,\theta\,[(n + 1)\,g^{\theta} - V_o]}\right]$$

$h = \theta \left(\frac{5\ e\ (n - 1) + 2\ V_o}{n + 1}\right)$. θ = time before opening, in tenths of a second; $F = 80\ \eta$ = shock of opening in kg; V_o = approximate velocity in m/s = $\frac{\text{altitude of test}}{\text{total time of descent}}$.

By taking into account the practical values of the different factors: $A = 2$, $V_o = 5$, $n > 3$, $g = 10$, this formula, when simplified, becomes

$$h = \theta \left(\frac{5\ \theta\ (n - 1) + 2\ V_o}{n + 1}\right),$$

θ being computed in seconds and V_o being the approximate value (H/T) of the velocity of descent.

If, for example, we take the Ors parachute which participated in the last contest, then $H = 300$; $T = 51.3$, $\theta = 4.3$, $n = \frac{415}{30}$ (approximately), $V_o = \frac{300}{51.3} = 5.85$ m,

$h = 4.3\ \frac{5 \times 4.3 \times 4 \times 2 \times 5.8}{6} = 70$ meters, and the calculated velocity $\frac{H - h}{T - \theta} = 4.90$ m.

The difference between the approximate and calculated velocities is about 1 meter per second, which is not negligible.

Formula (5) has been put in the form of an abacus (Fig. 9).

c) Maximum shock of opening.- This is measured by a Lenoir dynamometer, placed between the point of attachment of the parachute and the load. When the parachute unfolds, the steel ball strikes a calibrated bar. The shock is measured by the diameter of this impression. The bars are copper. The diameter of the impression is measured by a gage. Fig. 10 gives the area in square millimeters, plotted against the diameter in millimeters.

In order to ascertain the shock of opening, the area obtained by a given index is multiplied by the curve (Fig. 11). We know that the shock is equal to the surface multiplied by a coefficient or index. The latter is not constant, but varies with the diameter of the impression. The variations of this index are determined by preliminary tests.

The following table gives, without any calculation, the correspondence between the diameter of the impression and the maximum shock or stress on opening.

Table Giving the Stresses in kg as a Direct Function of the Impression.

Diameter of impression in tenths of a mm	Stress in kg	Diameter of impression in tenths of a mm	Stress in kg
10	59.0	26	349.0
11	71.0	27	373.0
12	84.0	28	397.5
13	97.5	29	422.5
14	112.0	30	448.0
15	127.5	31	473.5
16	144.0	32	500.0
17	151.0	33	527.0
18	179.0	34	553.5
19	198.0	35	581.5
20	217.5	36	608.5
21	238.0	37	636.5
22	259.0	38	665.0
23	281.0	39	693.0
24	302.5	40	722.0
25	325.5		

d) The maximum stress being obtained, it is divided by the number of suspension lines, in order to ascertain the stress e, to which each line is subjected. The maximum stress E, which causes the fastening to break is determined in the laboratory.

The safety factor is the quotient of:

$$\frac{\text{Maximum breaking stress}}{\text{Maximum stress supported}} = \frac{E}{e}$$

The maximum shock of opening must be reduced as much as possible, so as to avoid accident. The force resulting from a shock or blow is given by the formula

$$F = M \frac{dv}{dt} ,$$

in which dv = variation of speed and dt = variation of time.

It has been attempted to diminish this shock by modifying the different terms:

By increasing dt (German and Italian parachutes);

By decreasing dv by the addition of parachutes in tandem (Holt and Tinsonnier).

These terms cannot be modified easily. The method which has given the best results consists in absorbing a part of the shock by shock-absorbers (See Chapter III, "General Conclusions").

e) Stability.- It is important for the descent to be uniform without too pronounced oscillations which might greatly increase the speed of landing.

The oscillations may be reduced:

1. By varying the diameter of the vent. The vent, which was made small at first (0.20 m), may be greatly enlarged without any disadvantage. Nevertheless, since it opens out with difficulty, it may be advantageously divided into several small vents.

2. By changing the length of the suspension lines. The

tests hitherto made seem to show that long suspension lines produce very strong oscillations, while, on the other hand, short lines tend to draw the edges of the sail inward and thus reduce the effective area, thereby increasing the rate of descent. For this reason, the length usually adopted is equal to, or slightly greater than, the diameter of the sail.

3. By the action of the rider himself. By hanging his entire weight on one group of suspension lines, the rider can make the parachute glide slightly in the desired direction. This operation is not at all dangerous with a well-designed parachute. One edge of the sail may be drawn clear to the center, but it will spread out again, as soon as the tension is removed from the lines. The parachute may be prevented from rocking, by pulling on the lines when an oscillation is at its maximum.

Conclusion.- The importance of making flight tests may thus be seen. The "Service Technique" is continually improving its methods of measurement in experiments, so as to be able to make as great progress as possible in the comparative study of the performance of parachutes. In order to improve the measurement of the rapidity of opening and velocity of descent of parachutes, the altitude at which they are launched must be known as exactly as possible. Since the maximum shock of opening depends, among other factors, on the speed of the airplane, the latter must also be known with the maximum approximation. At the Villacoublay annex, the barograph and speed indicator, on the airplane used for launching parachutes, are connected with an electric circuit. By breaking the circuit at the moment that it drops, the dummy inscribes on the diagrams the altitude and speed of the airplane.

The "Service Technique" is trying to improve still further the use of the motion-picture camera, by means of which the mode of operation of the parachute may be correctly ascertained. It has been learned in this way that, when opening, the upper part of the parachute bulges first, this spreading afterwards to the entire sail. The importance of the vent in the first phase of opening may therefore be understood.

The maximum shock of opening is measured, at the present time, by the ball dynamometer, but it may perhaps be best not to accept as infallible, the figures given by this instrument. The speed with which the impression is made modifies the relation between the force and the diameter of the impression. Moreover, the pull on the dynamometer is exerted along some axis which can not be known and which varies in each case. It follows that the stresses produced at different speeds and under different conditions might not, perhaps, be recorded accurately. The "Service Technique" is about to adopt a new mode of measurement of these stresses, in order to ascertain whether the results are similar in all cases.

When all of these methods of measurement have been perfected, we will have all the means necessary for measuring the performances of parachutes and, as the result of systematic experiments, for the construction of as safe a parachute as could be desired, under the most different conditions with respect to speed and load

These methods of testing have been applied in the calculation of the performances of the different models enumerated in the following chapter.

Chapter II.

We will now discuss the various types of parachutes used at the present time in France and in other countries. The data at our disposal with respect to foreign parachutes is by no means complete and there is a certain amount of doubt as to the performances of these parachutes, either because they are already old, or because they have not been tested by known methods.

We have given the chief characteristics of each parachute, described the pack in which each is contained, the manner of folding adopted when used on airplanes and their mode of operation. The performances of each type are given in a table. As a matter of information, we will first discuss the experiments made in 1919.

I. Summary of "Bulletin Technique" No. 22.- The tests made at Chalais Meudon, Saint Cyr and Villacoublay, were discussed in the "Bulletin Technique" No. 22, April, 1919.

A) The "Service Technique" first tried to adapt to airplanes the parachute used on balloons, which gives every guaranty of safety, both owing to its manner of opening and its velocity of descent. The experiments made with it on airplanes gave good results, but this model was not adopted for the following reasons;

a) Its weight (12 kg);

b) Its bulk;

c) Risk of not opening, owing to its position on the airplane;

d) Difficulties attending its installation in the fuselage (Fig. 12).

B) Galbé Parachute (Fig. 13).- This showed less satisfactory behavior in the air than the ordinary parachutes. Its use was abandoned, owing to its velocity of descent.

C) Parachute with spherical sail (Fig. 14).- Parachute 6.9 m in diameter when open, depth 1.05 m, obtained by reducing the scale of the balloon parachute, its performances being comparable with those of the latter. Nevertheless, the diminution of area resulted in perceptibly increasing the shock at the moment of opening.

The principal results obtained with the various types of parachutes, are as follows:

	Time to open			Rate of descent			Shock of opening		
	max.	min.	mean	max.	min.	mean	max.	min.	mean
	sec.	sec.	sec.	m	m	m	kg	kg	kg
Galbé parachute Diameter at opening 5 m Geliot P1 fabric (90 g per m²)	3	2	2.4	7.14	5	6.07	407	291	340
Geliot P2 fabric (75 g per m²)	4	2	3	7.14	5	6.07	440	291	352

Table (continued).

	Time to open			Rate of descent			Shock of opening		
	max.	min.	mean	max.	min.	mean	max.	min.	mean
Spherical Diameter at opening 6.90 m Vent: 0.4 m Fabric 90 g per m²	3.4	1.4	2.4	5.56	3.67	5	407	300	337
Balloon parachute Spherical Diameter at opening 10.24 m Vent: 0.5 m	5	3	4	4.75	3.35	4	250	175	220

Other experiments on airplanes, made at Villacoublay with a German parachute (Fig. 15) and a parachute of 6.9 m, gave the following results, which are faulty, particularly as concerns the excessive shock of opening.

	Rate of descent			Shock of opening		
	max.	min.	mean	max.	min.	mean
	m	m	m	kg	kg	kg
Spherical parachute, diameter at opening: 6.9 m; depth: 1.05 m	5	4	4.50	600	346	473
Spherical parachute, diameter at opening: 6.9 m; depth: 1.05 m				404	313	358
German parachute, diameter at opening: 5.8 m; depth: 2.24	6	5.20	5.60	372	176	274

The following are the principal types now in use:

II. S.T.Aé. 1919 Parachute.- The 1919 type (Fig. 16) is very satisfactory. The parachute opens slowly, which lessens the shock. More than six hundred descents were made with a dummy without accident. This parachute is, therefore, very safe, strong and easily managed. The manner of folding and launching has been described in a special report (Instructions in the use of the airplane parachute of the S.T.Aé. 1919 type).

Characteristics.- This parachute is made of English cotton weighing 60 grams per square meter. It is 6.6 m in diameter and 2.6 m deep. It is provided with twenty suspension lines 7.3 m in length by 4 mm in diameter (each line having a tensile strength of 130 kg) and a central landing cord 11.4 m long. The suspension lines and central cord are joined below in a 10 mm served loop, to which are attached two lines 0.7 m in length carrying the snap hook-knives for the belt.

Pack.- The parachute is folded into a pack of coarse canvas, where it is held by four weak springs. A cord runs across the top, being attached at one end to the airplane and at the other end to the vent of the parachute by a breakable cord. On each side of the pack there are two small cords furnished with snap hook and serving to attach the parachute to the straps of the belt.

Folding.- The so-called "umbrealla" method of folding should be used (Fig. 17). This must be performed with the utmost care, since, if the sail is folded badly, it will not work properly.

It must be folded in the following manner:

1. Stretch the parachute and its rigging on a canvas with the gores lengthwise. Pass two suspension lines into the slit made for this purpose at the bottom of the pack.

2. Straighten out the rigging.

3. When the parachute and the suspension lines have been stretched out, draw the fabric away from the latter, so that it forms only one large fold, A B C, between two consecutive lines. When the operation of folding has been completed, the fabric must be outside the suspension lines.

4. Coil the rigging very carefully in a figure 8 at the bottom of the pack.

5. Grasp the sail and place it in the pack in zigzag layers. It makes no difference if the material is crumpled.

6. The point of intersection of the vent of the parachute and the central cord is attached by a double 15 cm breakable cord to the cord of the cover of the pack.

Operation.- During the experiments, certain improvements in connection with the fastening cords, were made in the original model. The cord connecting the user to the parachute was furnished with a snap hook-knife, by means of which the observer or the machine-gunner could very quickly free himself from, or attached himself to, the parachute. The fastening system was still further simplified by eliminating the two 0.6 m cords and replacing them by a metal cable connected with the belt.

The S.T.Aé. fastened the bottom of the pack securely to the assembling loop of the suspension lines. During a trial, the tearing of this seam had prevented the device from opening (See Fig. 18). The cord, which is attached at one end to the airplane and at the other to the parachute by a breakable cord, was increased in length from 4 to 7 meters, so as to prevent the parachute from catching on the tail of the airplane. The S.T.Aé. 1919 model is excellent, but a little heavy and bulky for light airplanes. The further efforts of experimenters should therefore be devoted to effecting a reduction in weight and volume.

III. S.T.Aé. 1922 Model.- A silk parachute was made for pursuit and combat airplanes. This was a reduced model of the S.T.Aé. 1919 type.

Sail.- Usual S.T.Aé. 1919 shape; reduction of linear dimensions in the ratio of 10 : 9 (19% reduction of area), which gives

Diameter at opening	6.12 m
Height of dome	2.34 m
Length of suspension lines	6.57 m
Same number of suspension lines 20	

Materials.- Light, strong silk (not more than 40 grams per square meter).

The 2.5 mm cords are made of hemp and have a breaking strength of 65 kg.

The landing cord is hemp and is 10.25 m in length.

During the experiments, the suspension lines were lengthened and strengthened and the vent diminished in size.

The time taken to open averages 4.8 seconds. The velocity of descent is about 5.6 meters per second.

Pack.- The pack, which is made of coarse canvas, has the following dimensions:

Height, 60 cm; width, 34 cm; thickness, 10 cm.

The pack is of such height that, when the wearer is sitting, it rests on the airplane seat without pulling on his shoulders. It is closed by a cord which passes through a series of rings on the four flaps of the pack (Fig. 19).

Folding.- The umbrella method described above is again used here.

Operation.- Two snap hook-knives, connected with the rip-cord are attached to the breakable cord which keeps the pack closed. A pull by the rider cuts the cord which passes through the closing rings of the pack. The parachute opens under the action of the air. The opening may thus be effected automatically with the rip-cord attached to the airplane, or controlled by the rider. The experiments with this parachute were very satisfactory.

IV. Ors Parachute (Fig. 20) - Characteristics.- The Ors 1922 parachute is made of French silk. It is of the type known as the "flattened spherical" (or "oblate spherical") with sixteen suspension lines. It is 9 meters in diameter and has a 15 millimeter vent. One of its characteristics is a device called a "draft tube," consisting of a series of strong light hoops a, in any number desired (ten in the 1922 model), arranged one above the other between the loop, which forms the connection of the suspension lines, and the opening of the apex of the "parachute dome."

These hoops are connected with one another by the small lines b, the top hoop being attached to the central cord (landing cord) and the lower to the connecting loop. An auxiliary disk c, measuring 0.4 meter in diameter and made of light cloth, is connected with the central cord by lines of suitable length and is outside of, and separate from, the body of the parachute. This disk, which is inflated by the air as soon as the pack is opened, stretches the fastening cords and, drawing the main parachute forcibly from the pack, assures its operation.

Pack.- The pack has a central portion, which constitutes the bottom and in which the suspension straps of the harness are fastened. Triangular pieces extend from the edges of this central portion and these are provided with loops at the top and are so arranged as to lie side by side when they are folded over the parachute placed at the bottom of the pack. A cord runs through these loops in such a way as to hold the ends of the triangle together and thus close the pack.

Folding.- In order to place the parachute in its pack, the suspension lines are fastened by fours to the cane hoops forming the draft tube. The sail is folded like an umbrella. This method of folding must be performed by very expert persons, which is a great disadvantage from a military point of view.

Operation.- This parachute is either attached to the airplane or is controlled directly by the user. The latter pulls a cord, and this operates a "guillotine" release which cuts the cord closing the pack. The opening of the pack is greatly facilitated by rubber bands. The small auxiliary or "pilot" parachute causes the main parachute to take the most favorable position for opening and the air rushes into the "draft tube" and pushes out the sail by spreading the suspension lines which, under the stress, break their yarn fastenings and unfold.

V. Cormier Parachute (Fig. 21) - Characteristics.- Cotton parachute with spherical sail and central landing cord. Area about 40 square meters. It has sixteen gores, 3.4 m in length by 1.22 m base; a vent with a diameter of 0.16 m; a central cord of 10.50 m. The sixteen braided hemp suspension lines are 7 m long and 5 mm in diameter.

Pack.- In the first type made, the strong canvas pack was attached underneath the fuselage and closed by a breakable cord which was broken by a second cord (rip-cord) attached to the rider.

Folding.- The suspension lines are folded accordion-fashion in fourteen small sheaths attached to the inside of the pack. This device prevents tangling of the lines. The fabric is folded accordion-fashion inside the pack. The back pack, which is of a new type, is 55 cm in diameter and 20 cm thick.

VI. Blanquier Parachute (Fig. 22) - Characteristics.- This consists of a spherical sail with a supporting area of 44 m² (cotton), twenty suspension lines and two inverted cones formed by the union of four straps held apart at the center by a semirigid ring or hoop. One of these cones is folded in the supporting surface. The other is arranged to receive the suspension lines and prevents them from becoming tangled. The hoop at the edge of the sail facilitates the entrance of air.

Pack.- This is formed by two rubber disks reinforced by the straps for closing the pack. At the center of each of these disks, which are about 90 cm in diameter, there is a 45 cm hole. The edges of these holes are sewed together and the ends are folded towards the center and fastened by means of a small cord. The case, thus obtained, is 45 cm in diameter and may be opened on both sides.

Folding.- The parachute is placed between the two disks and the pack is opened by means of a rip-cord connected with the breakable cord. This parachute may be employed as follows:

1. Under the airplane.- The parachute is then attached by means of small cords running through the rings of the pack. The ends of the suspension lines toward the ground are fastened by a 3 m life-line to the user or to the load.

2. Fastened on the back.- Autocratic opening, when fastened to the airplane; or opening controlled by the user.

3. As seat.

Operation.- The cord (landing cord) which connects the vent formed by the two inverted cones with the suspension ring is also provided with a so-called "acceleration ring." By simply bearing the weight on this ring while falling, it is possible to change the velocity of descent and also to flatten the sail when landing.

VII. Robert Parachute (Fig. 23) - Characteristics.- This parachute, called the "Providence," is composed of a flat circular sail of Japanese silk, 8.5 m in diameter. The sail has 24 gores, stitched together and each provided with a line sewed into the seam. At the center there is a vent 6 cm square, crossed by two cords, by means of which the parachute may be hung up for drying or inspection.

In order to prevent the suspension lines from becoming tangled and to facilitate the folding and unfolding of the parachute, the inventor covered with cloth the twelve triangles formed by the converging ropes, from which the suspension lines start (Fig. 33). Each of these triangles is 2.5 m long and 1.05 m at the base. In folding the parachute, each triangle is folded accordion-fashion on its base.

The twelve suspension lines are assembled in two groups on two rings attached to the belt. This device enables the rider to vary the velocity of descent by pulling on one of the groups.

Folding.- There are two methods of folding.

1. "Pumpkin" folding.- The parachute is spread out on the ground and rolled from the edge toward the center, the triangles being first folded accordion-fashion at the rim of the sail.

2. "Umbrella" folding.- This is the method most generally used, as it is simpler and more rapid.

Pack.- The Providence parachute may be placed in a pack s, shaped like a flattened pumpkin, 45 cm in diameter by 10 cm in thickness. It is closed by a breakable cord passing through a series of rings fastened to the bands of the pack. The pack is opened by breaking this cord. Two snap hooks, in one of which there is a cutting blade, are adjusted for this purpose. The hook with the blade cuts the closing cord and the other hook draws out the cord from the rings.

This parachute can either open automatically (attached to the airplane), or it may be opened by the rider. A small auxiliary or pilot parachute assists the main parachute to open quickly.

The constructor has made five parachutes of different characteristics.

VIII. Froidure Parachute (Fig. 24) - Characteristics.- Square parachute 2 meters on a side with an area of 66.7 m ; made of French silk. An auxiliary parachute. 1/30 the size of the main parachute, assures the opening of the latter.

There are eight suspension lines, made of 10 mm braided cord and 8 meters long. The center cord is made of three No. 5 strands not laid and capable of withstanding a stress of 202 kg. This cord is so adjusted as to give to the open parachute the form of four hemispherical pockets. Each pocket has a square vent at the center, so that the total aperture is 300 cm².

Folding.- The parachute is spread out on the ground with the suspension lines on top. The corners of the square are folded four times on themselves, care being taken not to leave the suspension lines in the folds of the sail. This operation is repeated with the square thus obtained and is continued until the parachute is a compact mass, care being taken to keep the suspension lines and their point of attachment outside of the folds of the sail. The suspension lines are coiled in a figure eight at the bottom of the pack.

Pack.- This is of the "pack-on-back" type and is made of strong canvas with a rigid rim and a hole at the top for the strap which is at the end of the suspension lines. The pack is closed by a cap edged with an elastic band which is fitted to the rim of the pack. The auxiliary parachute is attached by cords at four points of the elastic border of the pack cover. In unfolding, this parachute causes the cover to come off and pulls the main parachute from the pack.

IX. Tinsonnier Parachute (Fig. 25).- Characteristics.- Parachute with flat sail of English cotton 8.75 m in diameter, area 60 m² and twelve gores. At the edge of every two gores, flexible whalebones are held in place by the circumference strap. A round central vent prevents eddies at the upper part of the parachute and maintains the negative pressure above the sail. There are twelve hemp suspension lines and a central landing cord. The fastening of the former is formed by a cotton patch reinforced at the center by a double fold of crossed cotton. A small, wound cord, of the same kind as the suspension lines, is attached to the loop of this fastening and the other end is spread on top of the first panel, so as to distribute the stress over a larger portion of the sail.

Folding.- The parachute is folded like an umbrella in the upper part of a pack, which is fastened to the back of the wearer. When the sail is completely folded, it is encircled by the last whalebone, the purpose of this being to accelerate the opening.

Pack.- The pack is shaped like a box, the cover and bottom being similar and one fitting into the other. The two parts are joined by eight breakable cords. A slit in the lower part of the pack allows the passage of the connecting loop at the end of the suspension lines.

The cover of the pack is connected by a cord with a point on the airplane. When the breakable cords give way, the suspension lines come out first alone, since the sail is retained by the last whalebone. As soon as the sail emerges, the pockets formed by the whalebones create a draft and assure the opening of the parachute. The velocity of descent may be varied by manipulating the central cords.

XII. German Parachutes - Heinecke Parachute.- The Heinecke parachute consists of the following parts:

1. The parachute proper (Fig. 26), comprising: 22 gores (a),

and 22 suspension lines (b), which are joined in two retention cables (c), 1 central cord (d), 3 communication or breakable cords (e), the closing wires (f) and the opening or unfolding cord (g). It has an area of about 40 square meters.

2. The belt (i) and 2 hooks (k).

3. The pack (h).

Folding.- The parachute is spread lengthwise on the ground. The 22 suspension lines are so arranged that they cannot get tangled. The 22 gores are then so arranged that one-half lie on one side and the other half on the other side, the eyelets, one over the other, with the folds outside (Fig. 27).

The 2 retention cords are then drawn across the opening of the pack in such a manner that their ends project about 30 cm from the opening (Fig. 28). The suspension lines are then coiled in the pack (Fig. 29) and the sail is placed on top in the shape of a fan. The folds must lie on one another accordion-fashion (Fig. 29a).

The pack is then closed by running the longest of the two closing wires (Fig. 30f) through the 12 rings of the upper opening of the pack, commencing at the center.

When the upper part of the pack is thus closed, the other part is closed in the same manner by means of the shorter closing wire (Fig. 30ff). The 3 breakable cords are then placed on top, beside the sail, almost at the center of the opening. The pack is now covered and makes a comfortable seat.

Employment.- The belt is put on, the parachute is placed on the airplane seat, the wearer sits on it, and the two hooks are adjusted in the oval rings of the belt. The rip-cord is carefully attached to some point inside the airplane. The belt is so made that it cannot slip and the jump may be made either feet or head foremost. After each descent the three breakable cords must be replaced. These must be of unequal lengths, about 50, 55 and 60 cm. They are attached to the landing cord and to the rip-cord, but under no circumstances to the cross-cords of the vent.

The central landing cord serves to regulate the velocity of descent. Individual instruction in its use is absolutely necessary. By giving a slight pull on this cord, the vent is narrowed, the result being to reduce the rate of descent. On the other hand, by pulling it harder the parachute will fall more rapidly, which is necessary when exposed to enemy fire. The central cord also serves to gather together and refold the parachute after the descent.

Holt Parachute, so-called "autochute".- In this parachute a new principle is found in the form of a variable retarding mechanism which controls the opening of two pilot parachutes and which is started by the aviator immediately before jumping. This device eliminates the necessity for any action after jumping. Under certain circumstances, indeed, the rider might be unable to pull a release cord during descent. Moreover, the parachute pack forms part of the jacket of the wearer, which does away with the discomfort of the haversack.

There are three parachutes arranged in tandem (Fig. 31):

a) Auxiliary pilot;

b) Main pilot (or shock-absorbing pilot);

c) Main parachute.

The auxiliary pilot is not essential and is made as light as possible, since it is not subjected to any severe stress. Its function is to insure the position of the main pilot, so that the latter will inflate as quickly as possible. It is provided with an opening (called a "positive" opening). Even if it should not open, the main pilot would inflate by itself, although more slowly, since it is very compact and comparatively heavy.

The pack forms part of the jacket of the aviator and, consequently, there are no projections which might catch on the airplane, or interfere with the movements of the aviator, either while piloting or in leaving the airplane hurriedly. As soon as the aviator is seated, the entire weight of the parachute rests on the seat. The two pilot parachutes are released by a retarding mechanism which is started by drawing out a pin. This mechanism is made of non-oxidizable steel and silver-plated brass, so that no lubrication is needed. If the retarding device fails to function, the parachute can still be released by the rider himself, by drawing out a second, short-circuit, pin. The device may be used in three different ways:

a) When the aviator is expert, the pin is attached to a cord fastened to the other end of the seat and just long enough to enable the user to climb out of his place so as to jump. When there are several passengers on the airplane under the guidance of an experienced aviator, the cords may be grouped at a point at which he can control them. In either case, the delay will be increased to about two seconds or two seconds and a half.

b) But without doubt the best manner of employing the retarding device (and which would probably be used by any experienced aviator) is to dispense entirely with the cord. The aviator will get into position to jump and will then draw out the pin of the retarding system which will be so adjusted as to delay opening for one-half second, or one second at the most. Even if he forgets to pull out the pin before jumping he can remove it, or the short-circuit pin, after jumping.

c) If the aviator prefers, instead of dispensing with the cord, he may have one longer than those for the passengers, so that he may move all over the airplane and jump from any point. When he moves, he must hold the cord in his hand, so that it may not be jerked accidentally.

d) If the airplane is at a low altitude, the aviator, immediately after jumping, may pull out the short-circuit pin and by this means entirely eliminate the delay. While the main parachute is being released from its pack, it is falling at a rate which depends on the supporting power of the main pilot, diminished by:

1. The force necessary to release the main parachute from its pack (a force which may be considered as almost negligible).

2. The weight of the portion of the main parachute already released from the pack.

Owing to this slowing up of its descent, the main parachute does not inflate until the suspension lines are completely extended. The shock of opening is produced twice: as soon as the cords are completely extended, the entire weight is supported by the main pilot. But when the main parachute expands, the weight of the rider pulls on the sail. The shock to the main parachute is therefore slight and the shock-absorbing pilot is of no further use.

XIV. Mail Parachutes.- In addition to its chief function of saving life, the parachute may be put to an important use in the mail service, or in delivering supplies by airplane, by making it unnecessary for the latter to land.

For this purpose some device must be used which will make it possible for the airplane to drop a bag or a package from a comparatively high altitude in such a way that it will fall to the ground within a small radius. The parachute should at first fall almost freely and not open entirely until near the end of its descent. On leaving the airplane, it generally falls at the rate of from 10 to 11 meters per second and slows up at 40 meters from the ground, to land at from 3 to 4 meters per second.

A parachute with two speeds has been invented by Messrs. Perrin and Bourgeois (Figs. 32-33), its principle of operating being as follows: The sail of the parachute is divided into two main parts, the lower part forming the crown, and the upper part or cap connected with this by cords of such length that a downward pull on the apex of the cap detaches the latter from the crown, leaving a gap between them and, if the tension is sufficient, reducing the supporting surface of the parachute. The package is suspended from the crown by means of a cord, all danger of tangling being thus eliminated. A long central cord, at the end of which a suitable weight is attached, is attached to the apex of the cap.

When the parachute descends, this cord, actuated by the weight which it carries, pulls on the cap which prevents the crown from spreading out entirely and forms a valve. The parachute then falls very swiftly (more than 18 meters per second). On reaching the ground, the central cord is relieved of its weight and the valve closes. The parachute is retarded by opening completely and the package strikes the ground at a speed of about 4 meters per second.

Chapter III.

The various experiments with parachutes show that the best types are very similar in performance, but that they are all capable of improvement, either as to bulk, weight, folding (avoidance of complications necessitating the services of a specialist), or fabric (elimination of silk, which is difficult to store, deteriorates from dampness and is difficult to fireproof).

In order to obtain the improvements recognized as necessary, a contest of airplane parachutes was held at the end of the year 1922, at the suggestion of the "Maison Nieuport-Astra" with the cooperation of the Assistant Secretary of Aeronautics and Aerial Transportation. This contest was governed by the following regulations:

Regulations.- The essential qualities of a military parachute were considered to be, in order of their importance:

1. Safety;

2. Small bulk and weight; suitable devices for its installation on an airplane;

3. Rapidity of opening attended by only a slight shock;

4. Slow descent.

Moreover, consideration was to be given to the following elements which, although they cannot be measured accurately, largely determine the practical value of a parachute.

5. Kind of fabric and the country from which it comes;

6. Possibility of the aviator's increasing his rate of descent.

In drawing up the regulations, it was attempted to take these different elements into account, particularly in reckoning the points necessary for winning.

Since safety is an essential condition, no parachute concerning which there were any doubts on this score could be considered. Additional prizes were provided for parachutes having special safety guaranties.

A maximum rate of descent of 5.5 meters was prescribed by the regulations. This was admissible, since it corresponds to a free fall, after jumping, of only 1.5 meters. However, in order to avoid a rough landing, parachutes having less velocity of descent were given the preference.

A bonus was accordingly given for any diminution of this velocity. In awarding these bonuses, the constructors were not encouraged to try to decrease the surface area, and consequently the bulk and weight, of their parachutes, unless, by doing so, the most advantageous rate of descent could be obtained, not exceeding approximately 4.50 meters per second for cotton and 4 meters for silk.

A premium was awarded for linen or cotton parachutes, which have the advantage of being easy to store, can be made fireproof and are cheap. Nevertheless, this premium could only be awarded to parachutes having an already reduced volume and weight (less than 6 kg).

Lastly, a prize was provided for French products, in order to encourage French industries and to be able, in case of war, to dispense with foreign supplies.

The other premiums need no explanation, especially those awarded to parachutes with which the rate of descent may be varied. This characteristic will enable a military pilot forced to descend during a flight, either to escape more rapidly from the enemy or to choose, to a certain degree, his landing place. Moreover, variable-speed parachutes are important for the mail service.

Translated in Office of Naval Intelligence,
Navy Department.

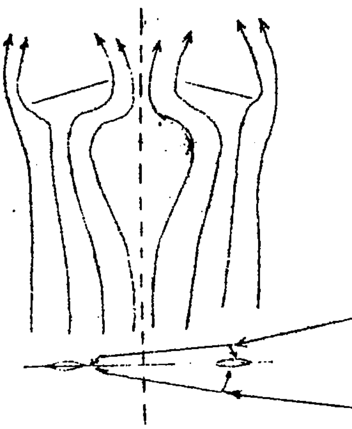

Fig.1 Spherical dome.

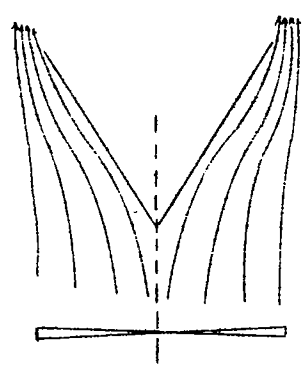

Fig.2 Inverted cone.

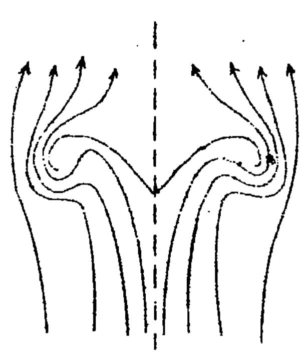

Fig.3 Trumpet-shape.

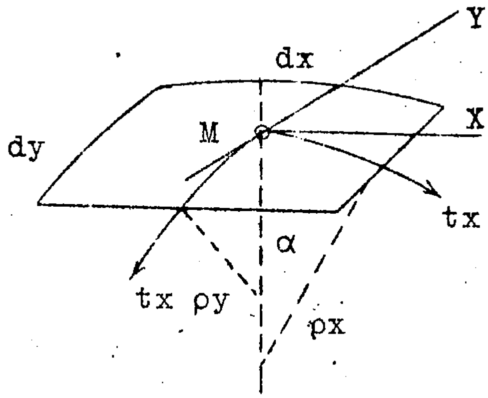

Fig. 4

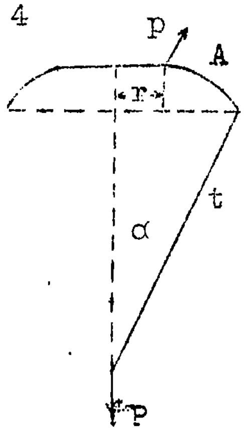

Fig. 5

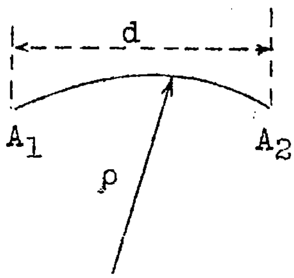

Fig. 6

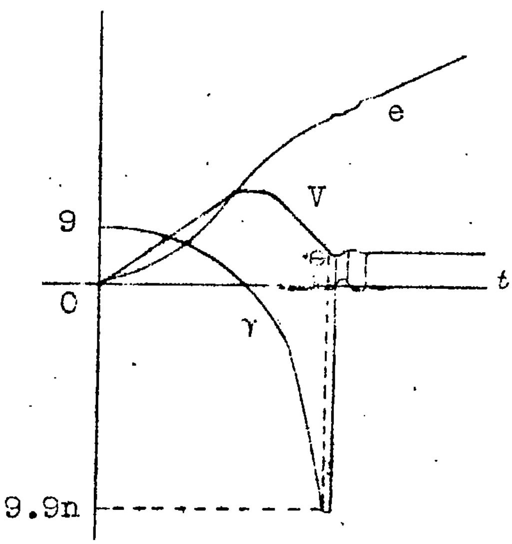

Fig. 8

Fig.7 Equipment on a Potez limousine IX.

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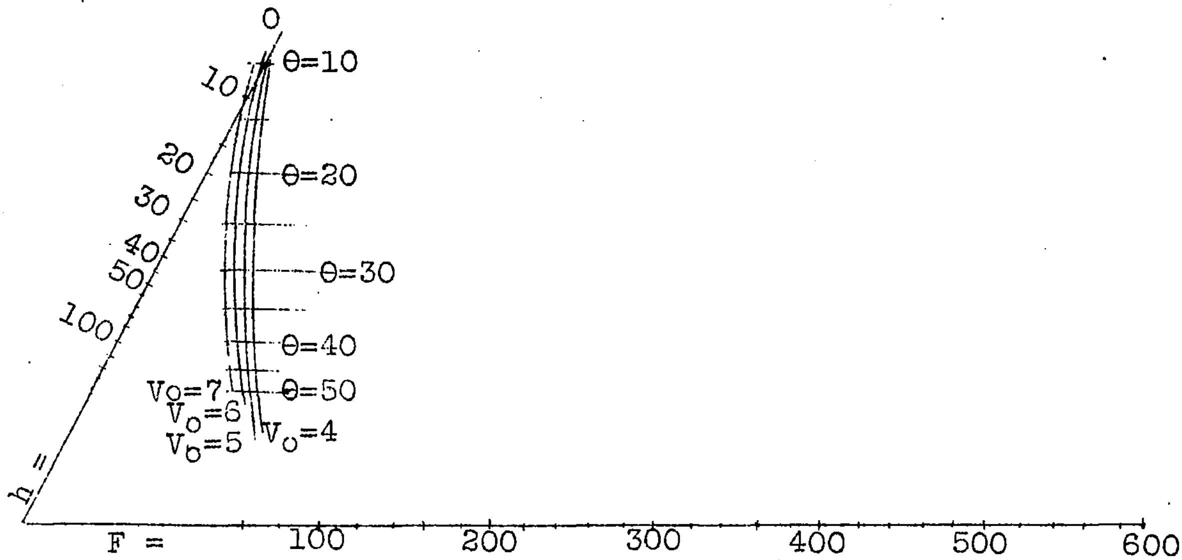


Fig.9 Calculation of the altitude at which the parachute opens.

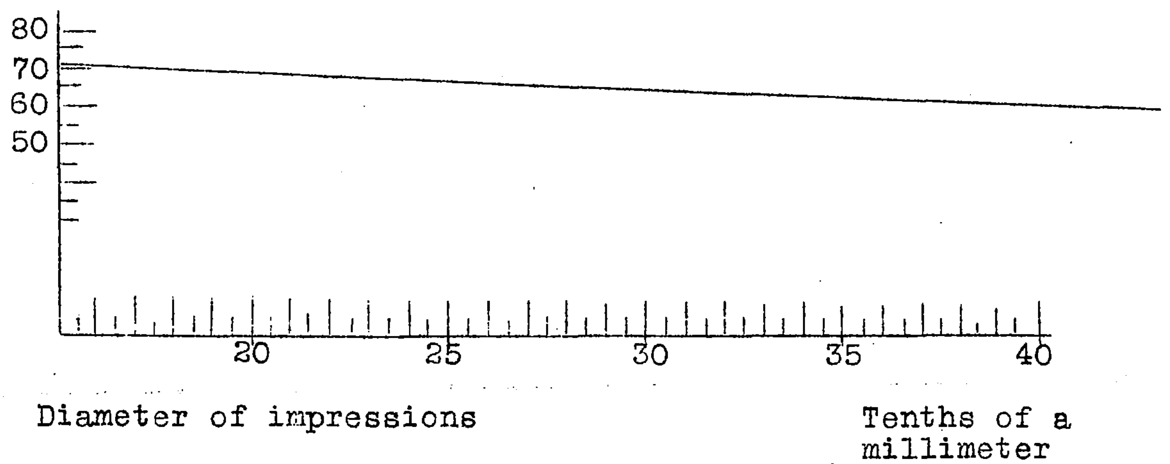
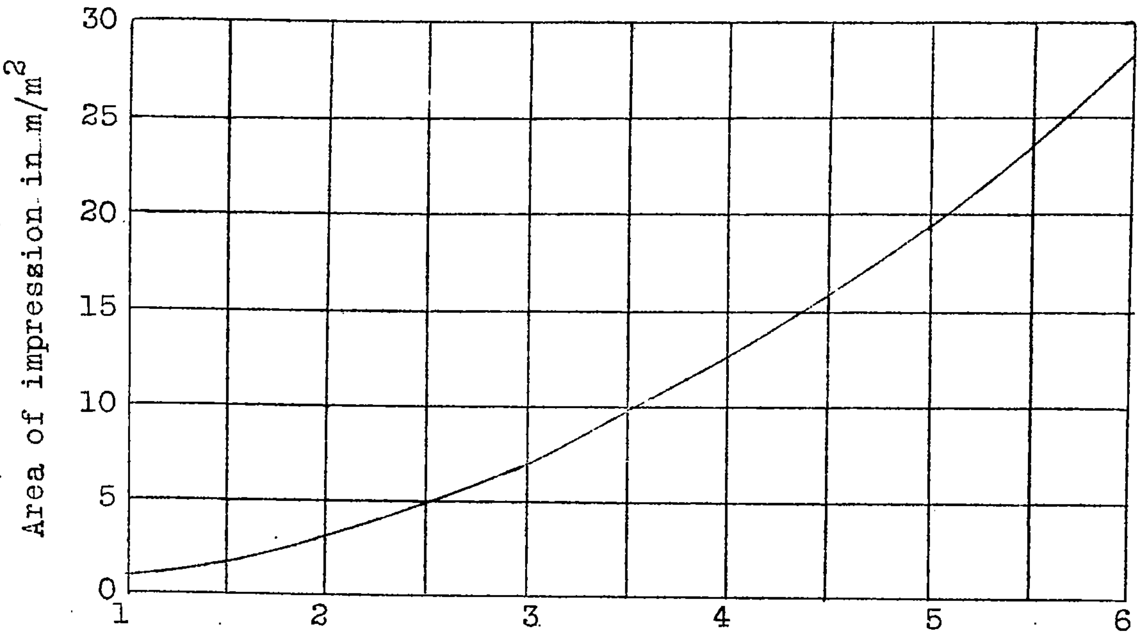


Fig.11 Ball-dynamometer curve.

A. Measure the diameter of the impressions of the ball with a gage.

B. The stress sought is the product of the area of the impression by the index stamped on the end of the test-piece.



Remark.- For stresses between 50 and 200 kg, use test-pieces whose index is approximately 10 (tin).

For stresses between 200 and 1000 kg, use test-pieces whose index is approximately 50 (copper).

For stresses between 500 and 3000 kg, use test-pieces whose index is approximately 150 (mild steel).

Fig.10 Lenoir ball dynamometer, 50 to 3,000 kg.

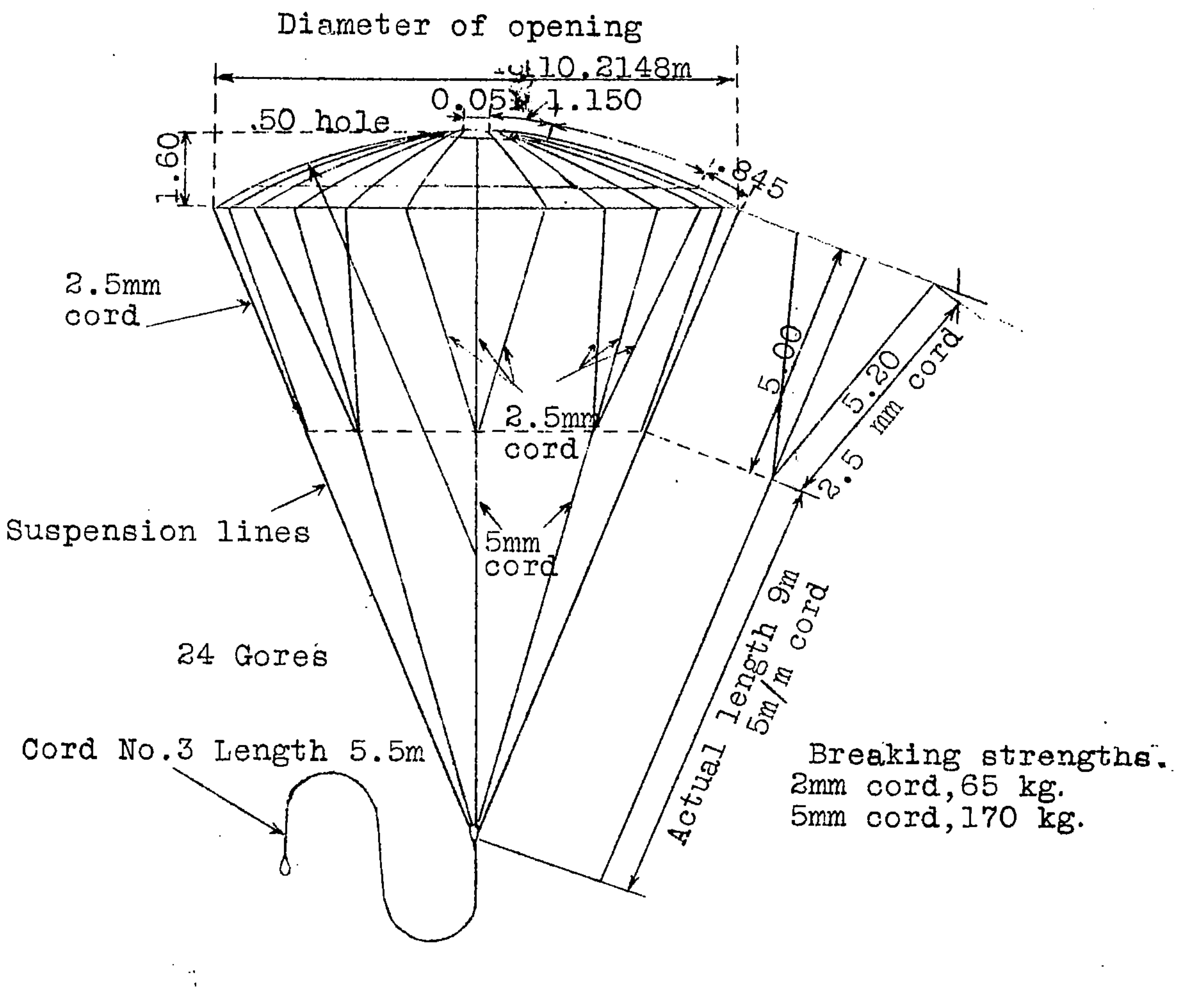
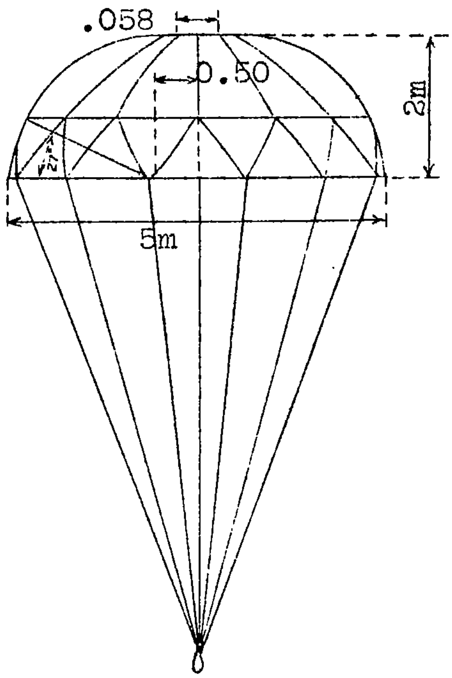
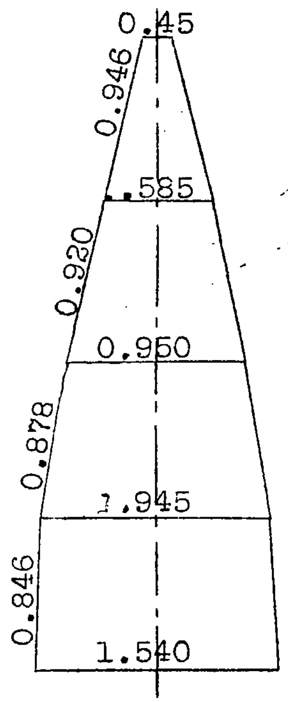


Fig.12 Regulation parachute for use on ballons.



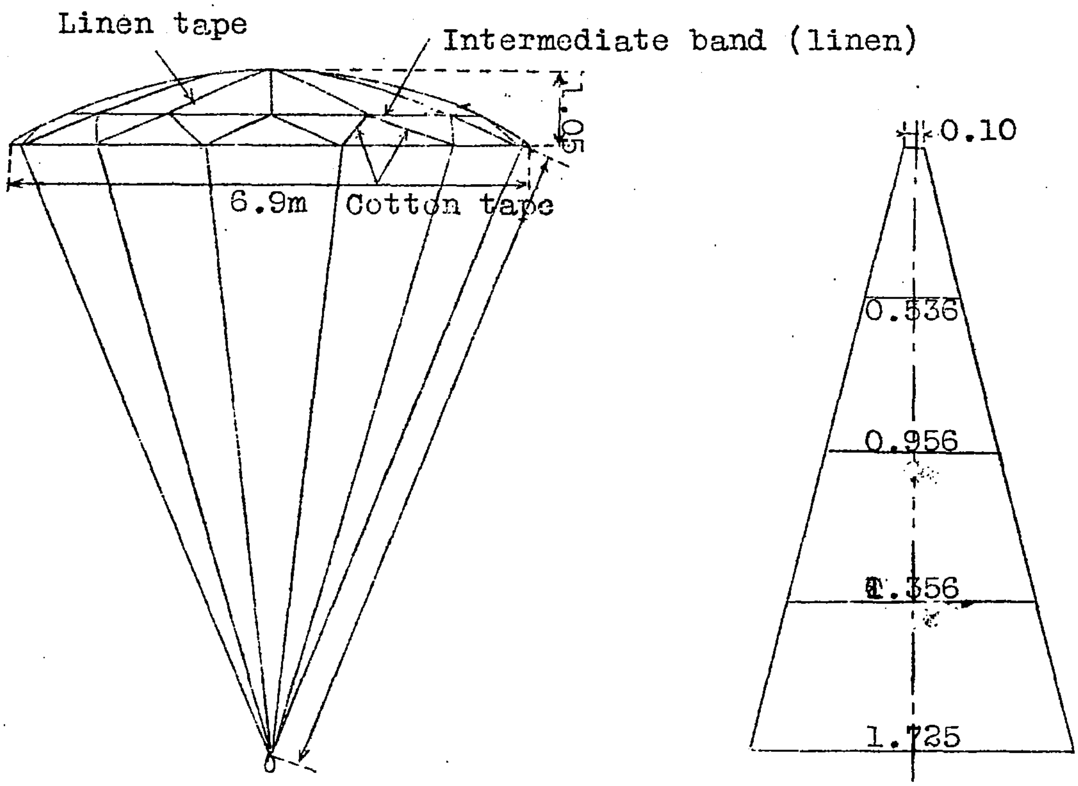
Assembly

12 lines 7m in length.
Breaking strength of each line, 250kg.
Diameter of vent, 0.58m.



Details of gore

Fig.13 Galbè parachute.



Assembly

Details of a gore

Spherical,
12 gores of 4 panels each,
12 suspension lines 9.2m long,
Length of arc, 7.12m,
Vent, 0,4m in diameter,
Width of panels from center to center of the seams, 0.84m.

Fig.14 Parachute with spherical dome.

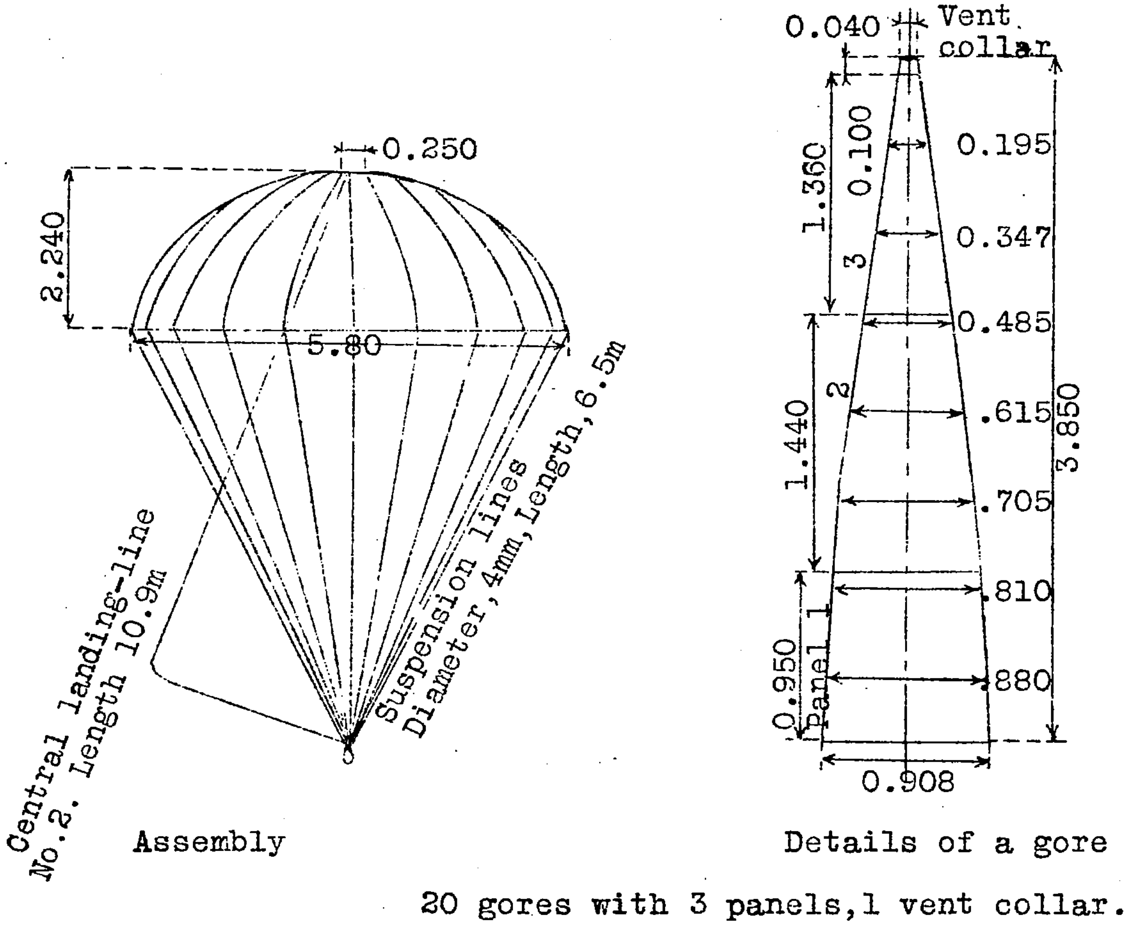
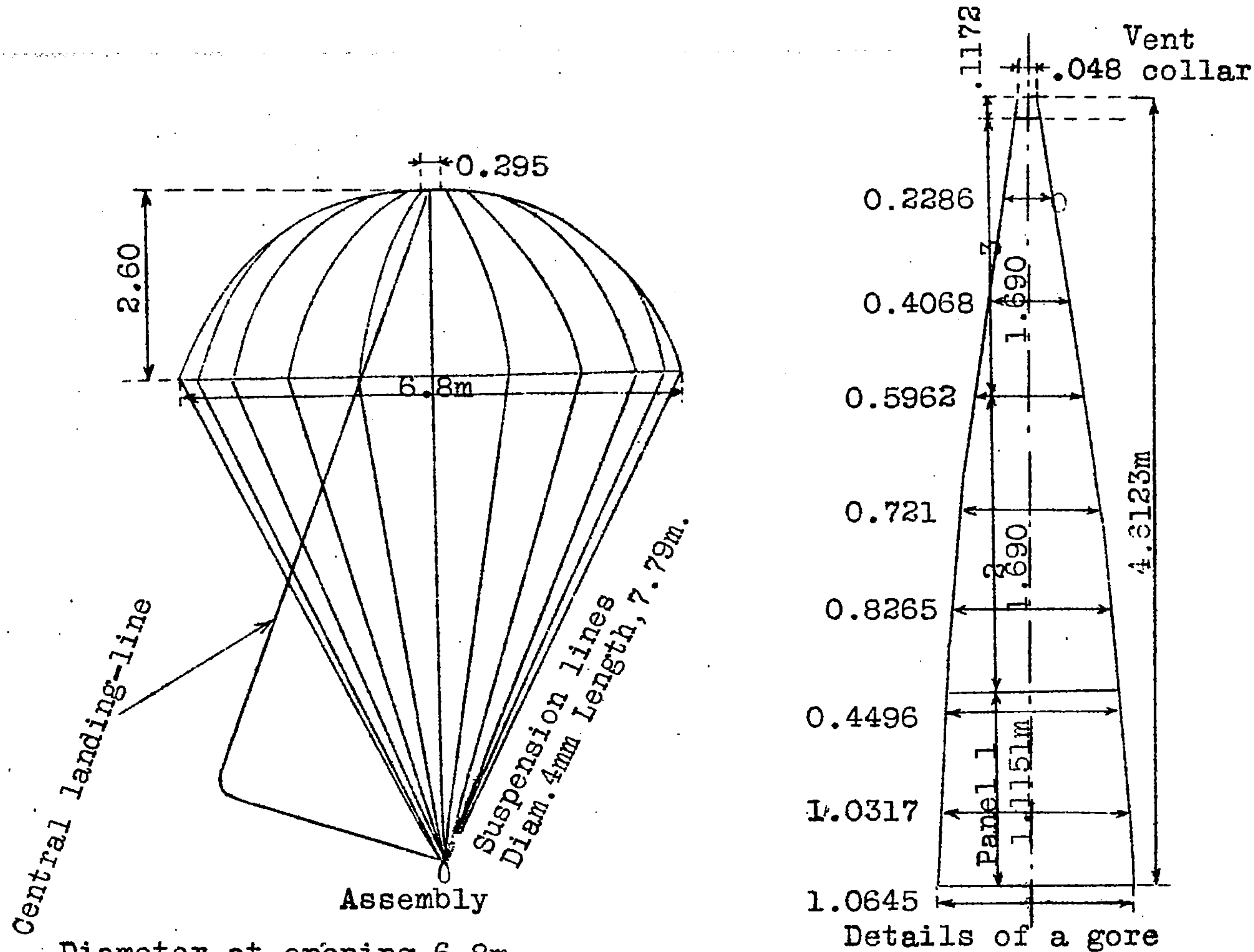


Fig.15 German parachute.



Diameter at opening,6.8m.
Depth,2.6m.
20 gores with 3 panels each.
1 vent collar.

Fig. 16 Pilot parachute (S.T.Aé).

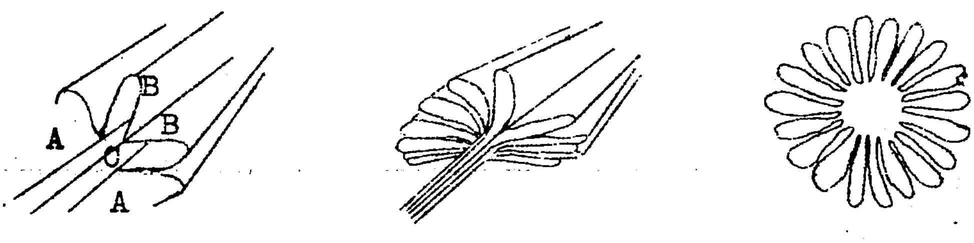


Fig. 17 Folding umbrella-fashion.

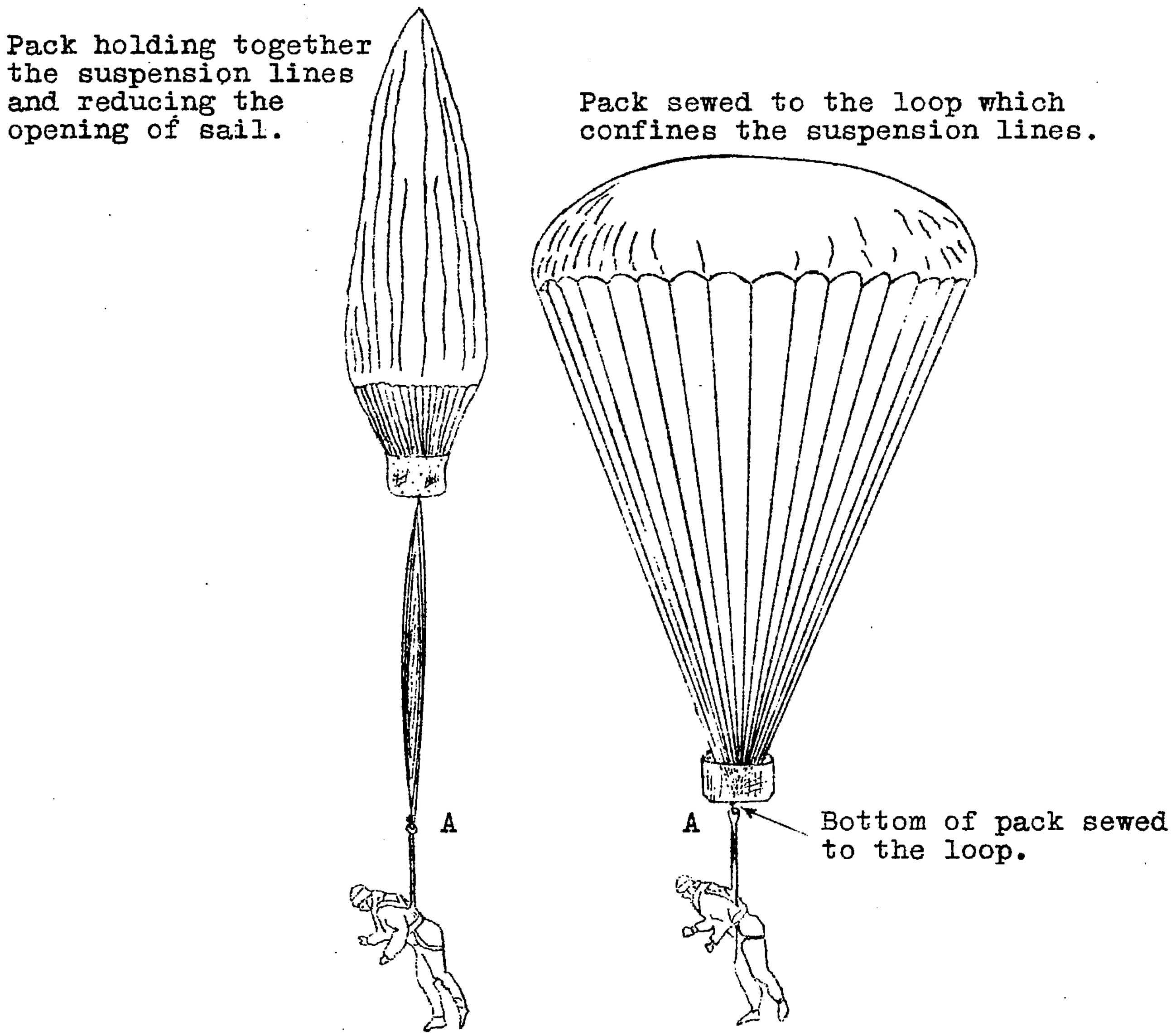


Fig. 18 Attachment of pack to the loop.

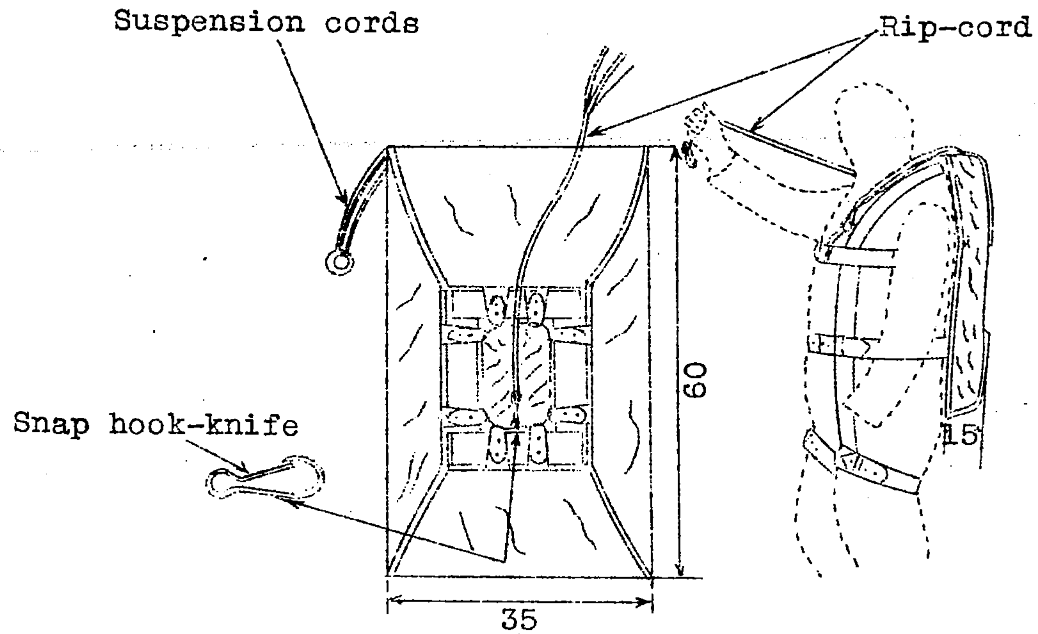


Fig.19 Pack of 1923 "Providence" type.

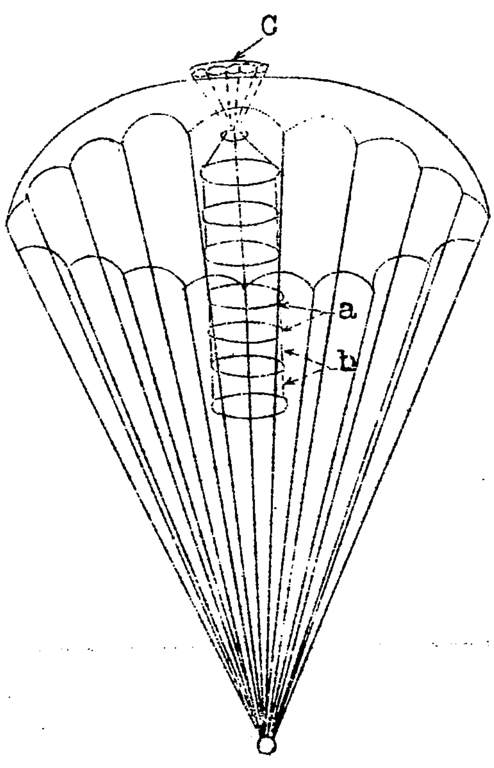


Fig.20 Ors parachute.

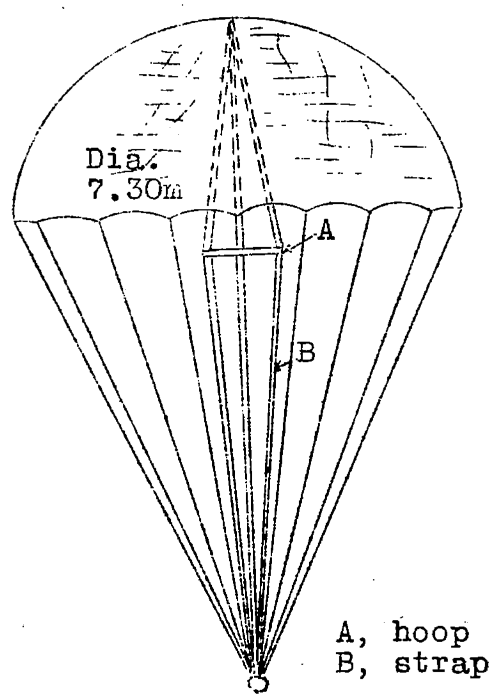


Fig.22 Blanquier parachute.

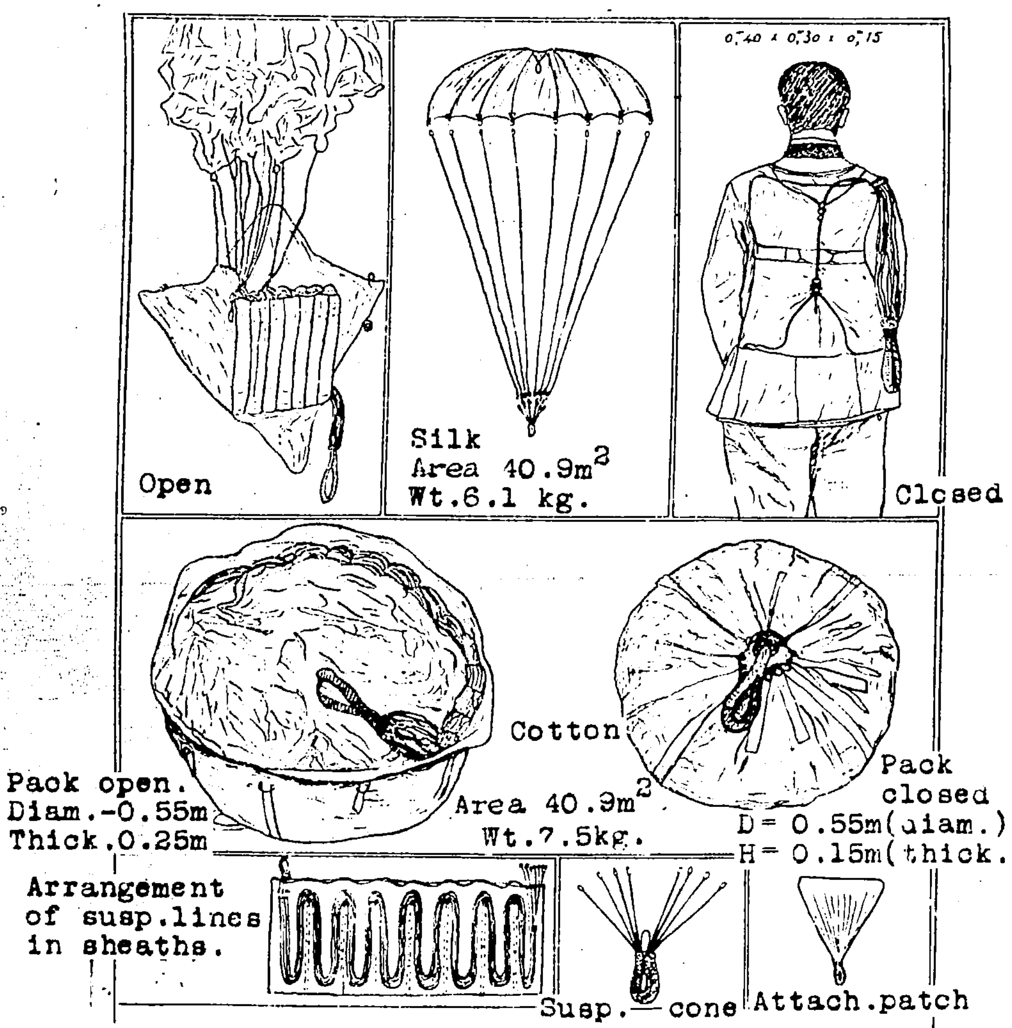


Fig.21 Cormier parachute.

Folding the parachute accordion-fashion from the edge to the center, with cordage inside.

Ground plan.
Parachute inverted and spread out flat.

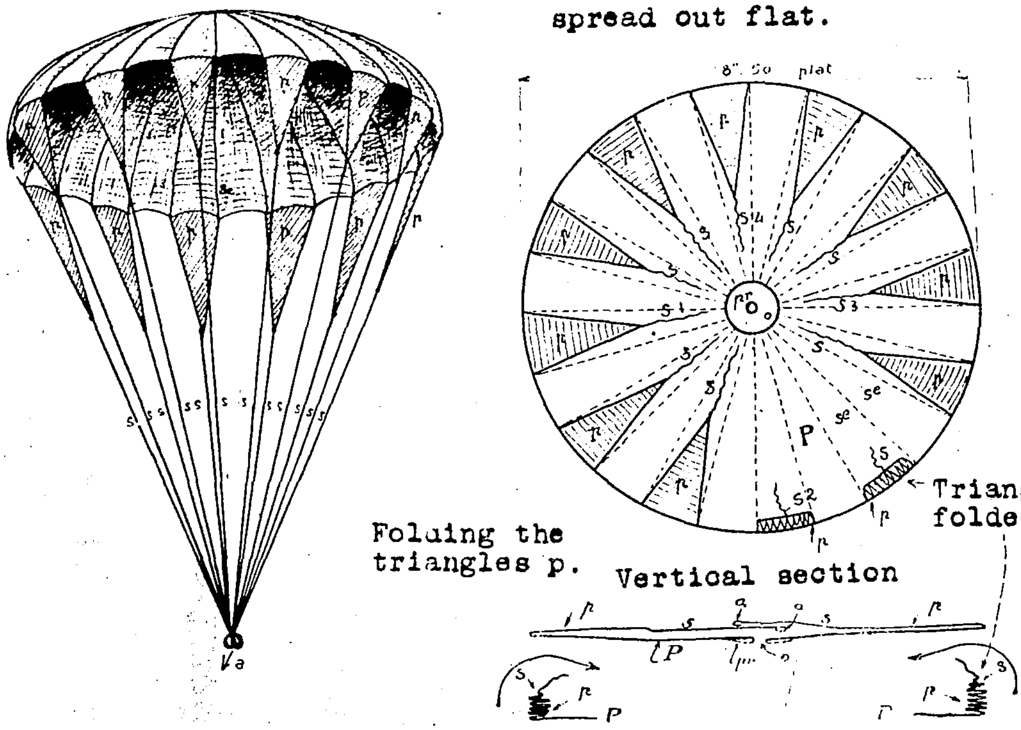


Fig.23 Robert parachute.

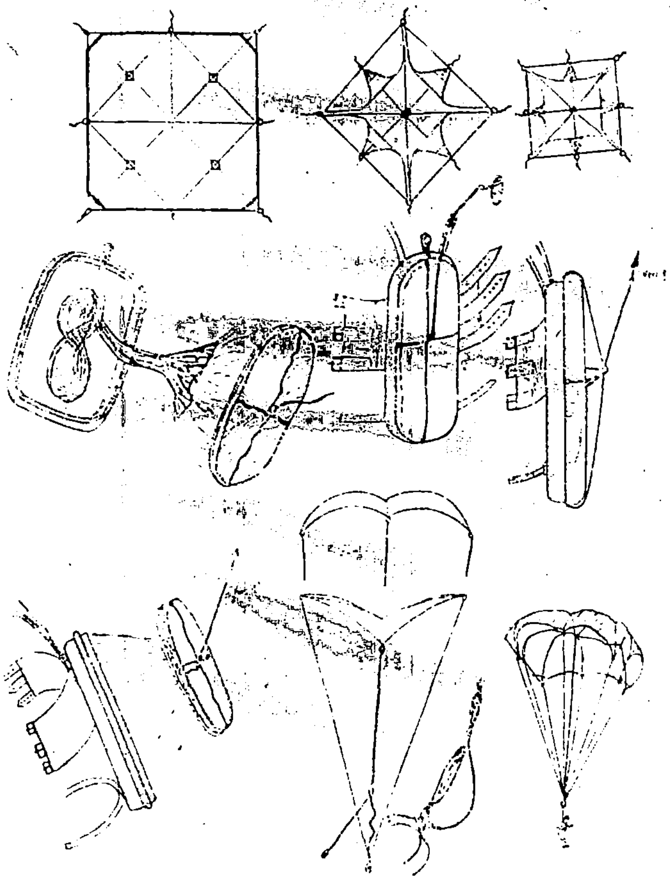


Fig.24 Froidure parachute.

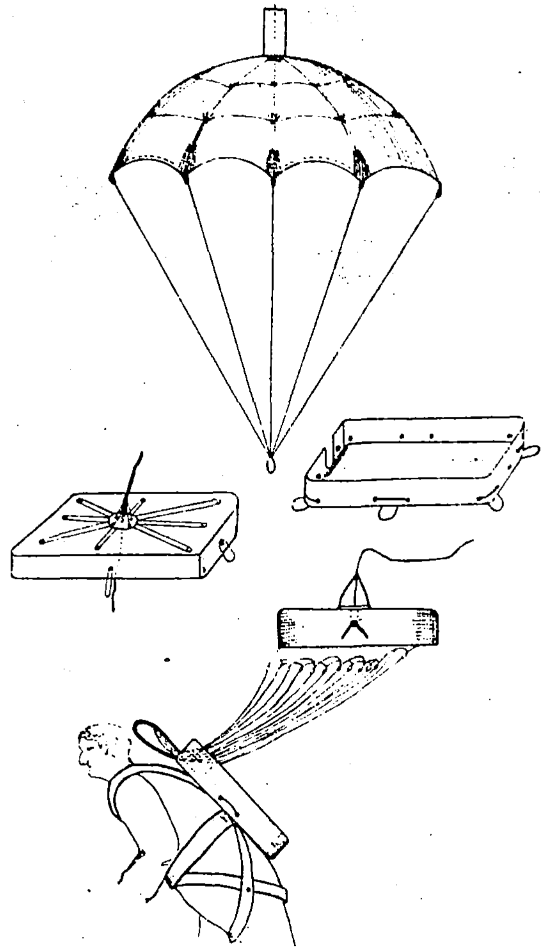


Fig.25 Tinsonnier parachute.

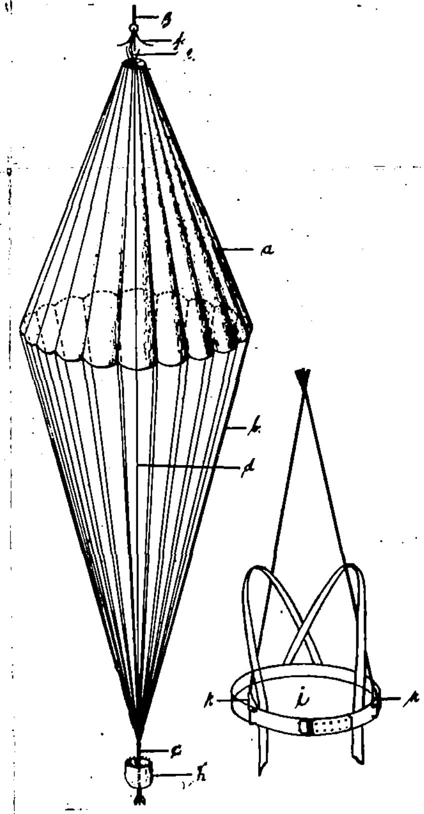


Fig.26

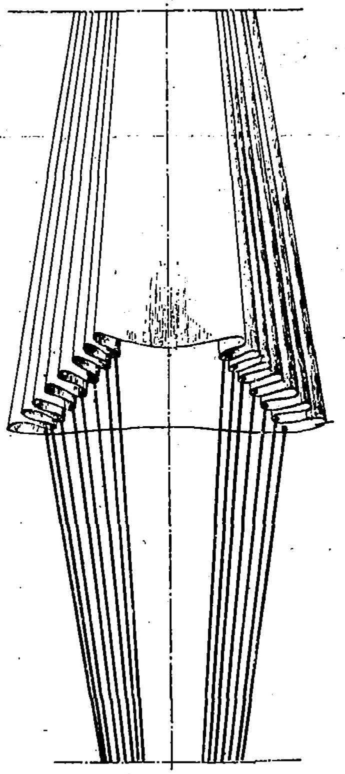


Fig.27

Fig.28

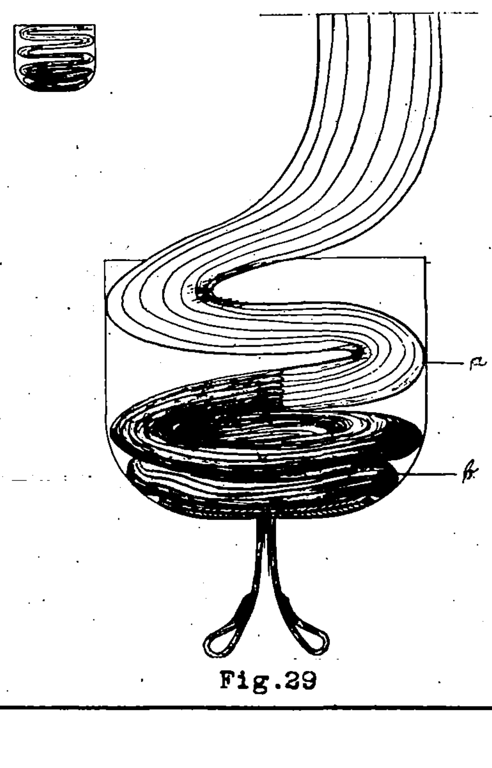


Fig.29

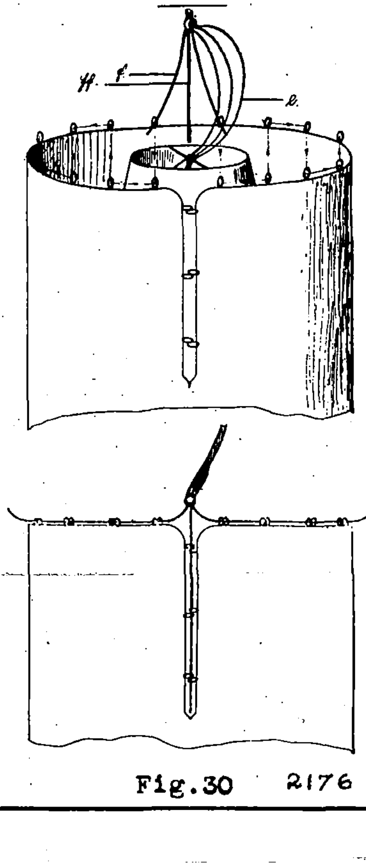


Fig.30

2176 A.S.

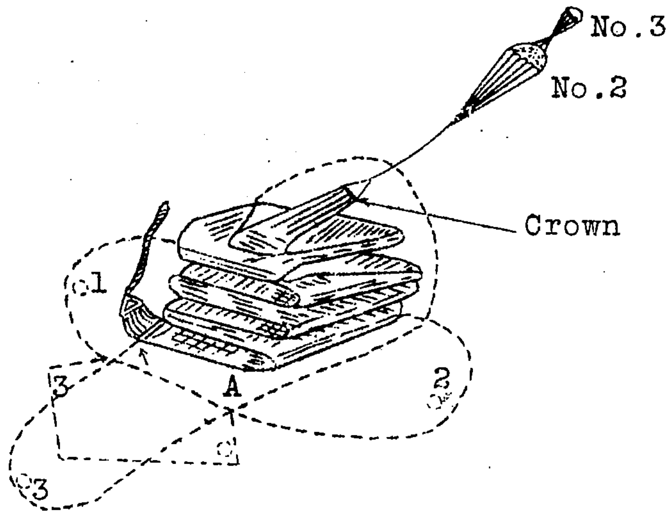


Fig.31 Folding and packing of the main parachute.

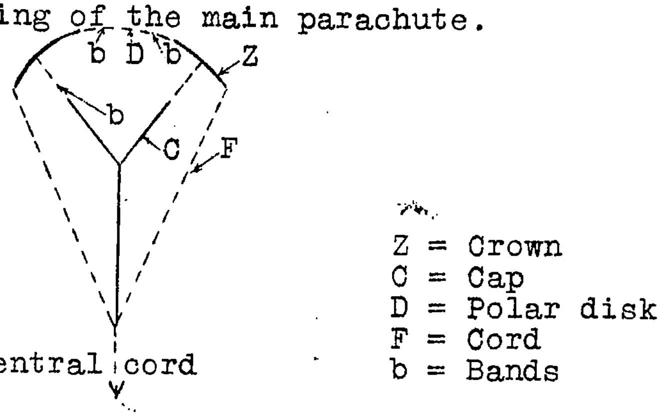


Fig.32 Perrin-Bourgeois parachute.

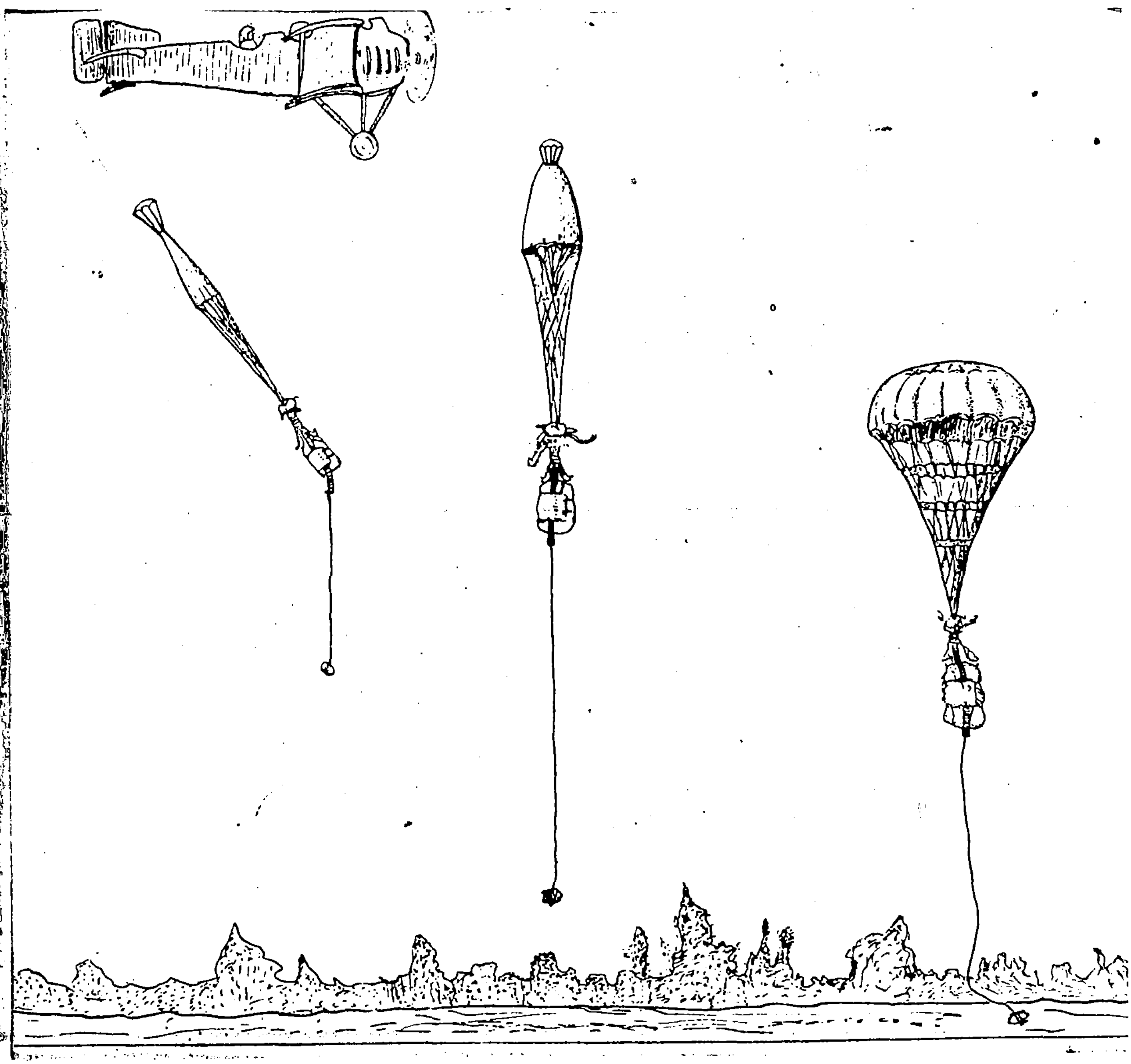


Fig.33 Perrin-Bourgeois parachute.