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DEVICES FOR PREVENTION OF STALLED FLIGHT

By Paul Mazer

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TECHNICAL MEMORANDUM NO. 389.

DEVICES FOR PREVENTION OF STALLED FLIGHT.*

By Paul Mazer.

In a communication to the Société Francaise de Navigation Aérienne," Mr. Brunat showed that the larger number of fatal accidents in aviation is due to stalling and that the use of devices capable of indicating, or still better of preventing, stalled flight would add greatly to the general safety.

Many constructors have made warning or correcting devices based on the registering of two distinct factors, the air speed and the angle of attack.

In order to justify the use of these devices, we will first define the conditions for the flight of an airplane and then study the causes of stalled flight in the different cases where it can occur.

Flight Conditions

In studying the horizontal flight of an airplane, it is said to be "tangent" when the curves of available power and of power required for horizontal flight are tangent. At the angle of attack and the speed corresponding to this point, the airplane descends for any maneuver whatsoever of the pilot. Since the speed of descent, which is practically proportional to the vertical distance on the two curves, is minimal, the speed can not

* "Les appareils avertisseurs ou correcteurs de parte de vitesse," from "L'Aéronautique," October, 1926, pp. 333-337.

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be instantaneously increased, even by diminishing the angle of attack. These curves are tangent for a remarkably large value of the angle of attack. It is the angle of attack at the ceiling.

On the other hand, for a given airplane and propeller, the angle of attack at the ceiling will always be the same, whatever the weight and the engine couple, and the ceiling can be very near the ground in both cases. In the case of ascending flight, we may have theoretically an angle of attack greater than at the ceiling, though the latter angle is approached as the ceiling is approached. In the method of climbing generally adopted at $V^2\delta$ constant $= V_o^2$, we have, at each instant, $R_z V_o^2 = P \cos \omega$ (ω being the angle of climb) and, at the ceiling, $R_{zm} V_o^2 = P$. Therefore the best angle of attack in climbing is always smaller than the angle in horizontal flight at the ceiling. In practice, if the airplane is carrying a heavier load than usual, or if the engine power decreases, one may suddenly find himself very near the new ceiling, in which case it is important not to exceed the angle of attack of the ceiling.

Stalling

The causes of stalling or "loss of speed" may be classified in two groups.

1. Exterior causes independent of the action of the pilot, whether occurring in ascending, horizontal or descending flight.

2. Causes resulting from wrong maneuvers by the pilot in any kind of flight.

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1. Exterior causes independent of the action of the pilot.-

a. Stopping or weakening of the engine;

b. Sudden horizontal gust from the rear;

c. Ascending gust of wind.

A. We will first consider the effect of the couple due to the tractive force of the propeller. The disturbances b and c are independent of the existence of this couple and the cause a can be studied by disregarding the influence of this couple.

We know that, under the given conditions of load and altitude, a single angle of attack and, consequently, a single relative speed of equilibrium correspond to each position of the elevator. If the airplane is stable, the disturbances, resulting from the above-mentioned causes, will produce couples tending to re-establish the original conditions of equilibrium. The airplane will tend to resume its original speed and angle of attack without intervention by the pilot.

Of course this re-establishment of the original speed and angle of attack is not instantaneous. Since it is accomplished by rotation about the axis of pitching, it is retarded in proportion to the moment of inertia about the axis, which is greater in large airplanes. In a stable airplane, therefore, these causes of stalled flight contain their own remedy, without in-

terference on the part of the pilot.

Let us now consider the phenomena which accompany the re-establishment of the original flight conditions. The immediate effect of the causes a and b is a diminution of the relative speed (air speed) and, consequently, of the lift. The airplane sinks with respect to its original flight path. This causes an increase in the angle of attack. A righting moment is created, which causes the airplane to pivot in the direction of diving, due to the shifting of the center of thrust. The airplane thus resumes its original speed and angle of attack.

In case a, the reflexes of the pilot are such that, as soon as he notes the weakness of the engine, he throws the airplane into a dive, thus increasing the righting moment.

In case b, the airplane sinks and tends to dive for the same reasons as given above. In this case, the reflex of the pilot is to act against the effect, the cause of which he can not distinguish. He noses the airplane up, thus aggravating the stalled flight.

In case c, the increase in the angle of attack produces, on the one hand, a righting moment which causes the airplane to pivot in the direction of diving; on the other hand, an increase in the lift, which produces an upward acceleration.

The reaction of the pilot to this acceleration, of which he can not discern the cause, is to cause the airplane to dive, thus increasing the righting moment which tends to re-establish

the original equilibrium of the airplane.

Conclusion.- In normal flight, the causes of stalled flight a, b and c, are not dangerous, if the pilot does not interfere. The need of a preventive device is nevertheless apparent in cases b and c, especially in case b, where the reaction of the pilot aggravates the stalling. An air-speed indicator or a wind vane would show the pilot that the airplane, which appears to be diving, is really stalling.

B. We will now consider, for the first case a, the couple due to the tractive force of the propeller:

1. This couple tends to make the airplane nose up (the case of land airplanes with correctly installed engines). Any weakening of the engine tends to make the airplane dive, which increases the righting moment for regaining the original equilibrium.

2. The couple due to the tractive force of the propeller tends to make the airplane dive (land airplanes with poorly installed engines and seaplanes). The consequence of a stopping or weakening of the engine is then, by eliminating or reducing the value of the couple, due to the tractive force of the propeller, to introduce a couple tending to nose the airplane up. The result is exactly the same as that produced in the case where, after an arrest or weakening of the engine, the pilot tries to nose his airplane up, in order to avoid an obstacle.

In summarizing, it may be said that, with the exception of seaplanes which are victims of the arrest or weakening of the engines, the causes of stalled flight are not dangerous when the pilot does not interfere.

The study of the dangerous cases of stalled flight concerns therefore only the second group of causes, the case of seaplanes being comparable to such wrong maneuvers

2. Causes resulting from a wrong maneuver by the pilot.- Whatever the contemplated conditions of flight, a wrong maneuver is always an excessive deflection of the elevator unconsciously made by the pilot. In the case when, for example, after a weakening of the engine at low altitude, the pilot in diving finds himself confronted by an obstacle, he seeks to avoid it by nosing up, thus adding a new cause for stalling to the one resulting from the weakness of the engine. This deflection of the elevator causes a rotation of the airplane about the axis of pitching in such a way as to increase the angle of attack and consequently reduce the speed. The angle of attack becomes dangerous when it reaches the value of the angle of flight at the ceiling. Beyond this value, as we have already seen, equilibrium is no longer possible between the power necessary for flight and the available engine power for holding the airplane to its path. In the latter case, the wind vane will instantaneously indicate the increase in the angle of attack before the air-speed indicator shows the consequent change in speed.

From these considerations, it follows that some indicator of stalled flight or loss of speed is useful and necessary.

In the first cases of stalled flight, a, b, c, the air-speed indicator and the wind vane may be considered of equal rank. In the latter cases, due to an excessive elevator deflection, the wind vane gives a quicker indication than the air-speed indicator. In all these cases, the wind vane, after it has been calibrated to indicate the exact angle of flight at the ceiling, will give a valuable indication under any given conditions of load and altitude. The air-speed indicator gives indications independent of the altitude, but differing according to the load of the airplane and hence variable during the same flight, due to the reduction of the load through the consumption of fuel.

Indicating Devices

The first one used in France was the "Étévé." It is a well-known instrument, which we will not stop to describe. The Badin and Dugit anemometric indicators with Venturi and Pitot tubes are now in use.

The "Constantin" angle-of-attack indicator is a wind vane with two horizontal directive surfaces mounted on a jointed trapezoid (Fig. 1). The deformations of the trapezoid control the brush of a segment commutator. The jointed trapezoid enables a great sensitivity for a small bulk. A dial located in the pilot's cockpit has the same number of lamps as there are

segments in the commutator. They light up therefore, one at a time, as the commutator brush passes from one segment to the next. Each position of the brush corresponds to a direction of the relative wind and the lamp dial is graduated in degrees (Fig. 2).

We have seen that for dangerous cases of stalled flight, the indications of the wind vane precede those of the air-speed indicator. Furthermore, its indications are valid for a given airplane, whatever its load. It is necessary to calibrate an air-speed indicator for each flight, in order to obtain correct readings. A prudent pilot will note the reading of his speed indicator at the moment of taking off. Since the airplane is under full load at this moment, this speed constitutes a lower limit, above which there is no risk. Under these conditions, it may be asked why indicators of the angle of attack are not preferred to air-speed indicators. The answer is simple. Air-speed indicators with Venturi or Pitot tubes give continuous indications which are easily read. The pointer follows the deformations of a manometric diaphragm subjected to suction or pressure due to the relative wind, the deformations being such that the position of equilibrium is established without oscillations which impair the readings.

The angle-of-attack indicators consist of wind vanes of small inertia. The indications of the wind vane are valuable in proportion to the smallness of its inertia in comparison with

that of the airplane. Consequently, these instruments indicate the slightest gusts and the slightest changes in the angle of attack, thus rendering the reading of the dial very difficult in gusty weather. The pilot who must continually vary the angle of attack indicated by the wind vane, soon becomes tired of following the variations and abandons the attempt.

Moreover these wind vanes must be subjected to an undisturbed air current, which often renders it necessary to place them at the end of horizontal rods well in front of the airplane cell. These mounts lack in rigidity and introduce appreciable structural resistances. We will find, however, that some of these criticisms do not count, if only the limiting angle is required of the wind vane.

Warning and Preventive Devices

The indicators of stalled flight are addressed to the sense of flight. Now, stalled flight is especially dangerous at a low altitude when the pilot is watching the ground for the purpose of selecting a landing place or avoiding obstacles. Under these conditions, an indicator on the instrument board rarely serves its purpose.

Many constructors have thought to warn the pilot by a sonorous signal. Mr. Costa de Beauregard invented an "Étévé" in which the red mark was replaced by a contact which closed an electric circuit. In this circuit there was a siren which sounded

when the red mark was crossed.

Mr. De Guiche invented an acoustic anemometer which indicates the variations in the air speed by variations in sound. The instrument consists of an inductor alternator of special form located in a streamlined body and operated by a windmill. The inertia of the instrument being very small, the rotational speed of the whole windmill alternator is practically proportional to the speed of the airplane. The frequency of the alternating current is also proportional to this speed. The musical sound of the same frequency, which is emitted in a telephone receiver, thus characterizes this speed. This instrument obliges the pilot to wear a telephone receiver on his head continuously, which is often inconvenient and may be inoperative when the noise of the engines drowns that of the instrument.

Lastly, Mr. Constantin and Messrs. Savage and Bramson attempted to make a wind vane act directly on the elevator controls. When the pilot makes a dangerous maneuver, he applies a certain force to the control stick, which must be offset by the wind vane. One can calibrate the force necessary to cause diving after excessive stalling.

The Constantin wind vane has the remarkable property of being able to develop a very large force for a very small surface. It can also be joined directly to the control stick by a suitable system of levers (Fig. 3). The stress exerted on the surfaces by the relative wind is transmitted to the control stick

by two king posts and a bent lever. For a wind vane whose surfaces are 300 × 60 mm (11.81 × 2.36 in.) with a camber equal to 1/7 of the radius and in which the non-parallel arms of the hinged trapezoid are 400 mm (15.75 in.) long, the force transmitted to the control stick can amount to 7.9 kg (17.4 lb.) for an air speed of 90 km (55.9 mi.) per hour and 3.5 kg (7.7 lb.) for 60 km (37.3 mi.) per hour. A check block stops the vane in a position near the limiting angle, but does not intervene till this angle is exceeded. The tractive cable of the wind vane remains slack for all stallings below the limiting angle. As soon as the pilot perceives the warning and yields his hand, the cable of the vane is no longer in tension. This device necessitates an extremely accurate adjustment of the control cables and has not yet been perfected.

Savage and Bramson had the same idea but, since their wind vane could not develop an appreciable force with a small surface, they introduced a servomotor device. The vane (Fig. 4) is placed in unstable equilibrium between two stops. In normal flight the incidence of the vane is negative. The thrust is then directed downward and the vane rests on the lower stop. When the angle of attack of the airplane approaches the angle of flight at the ceiling, the incidence of the vane, which is regulated with respect to that of the wings, becomes zero. As soon as the pilot exceeds this incidence, the thrust on the vane becomes positive and it comes in contact with the upper stop, thereby

opening a valve which operates a pneumatic relay. The preventive device consists of a cylinder in which moves a piston connected with the control stick. This piston is put in motion by compressed air stored in a container supplied by a windmill pump. The pneumatic relay opens the valve admitting the compressed air into the cylinder (Fig. 5). When the wind vane, after the diving, returns to the lower stop, the cylinder is again put into communication with the atmosphere and the force applied to the control stick disappears.

These wind vanes necessitate an extremely careful adjustment to each airplane but, after this adjustment has been made, one is sure of having a constant indication independent of load variations. The two solutions thus obtained are very interesting.

The utilization of the force of the wind vane itself for warning the pilot, has the disadvantage of causing the force exerted on the pilot's hand to depend on the speed of the airplane. Since the indicator is especially useful at low speeds, it must have quite large vane surfaces. The force, moreover, can be regulated only by shifting the point of application to the control stick.

With a servomotor, on the contrary, the instrument is heavier, but since the force required of the wind vane is small, the instrument can be made less cumbersome. The force exerted on the control stick is independent of the speed of the airplane

and can be regulated either by shifting the point of application to the control stick or by varying the power of the servomotor.

We believe, therefore, that these instruments, which materialize the limiting angle of stalling without being affected by the angle utilized in normal flight, are destined to render very great service.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.

N.A.C.A.Tech.Memo.389 Figs,1,2,4

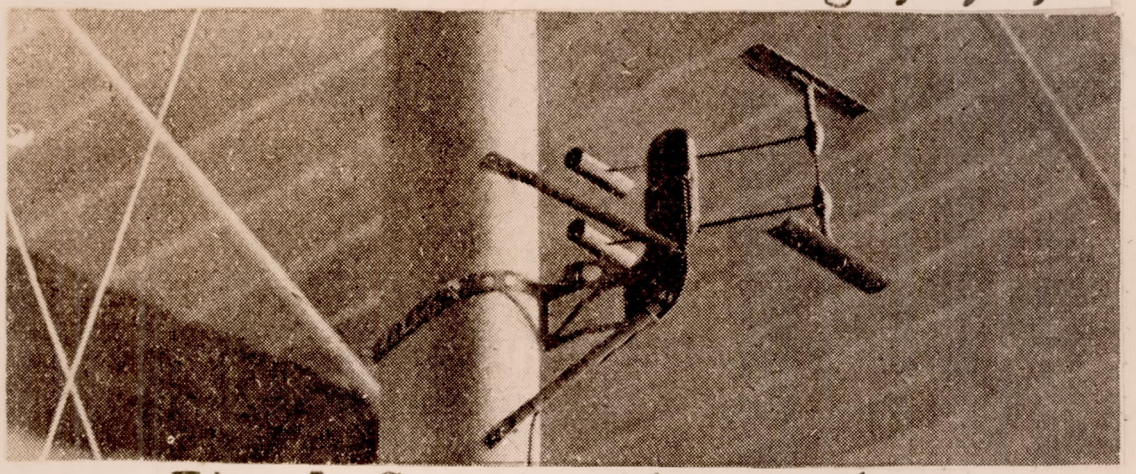


Fig.1 Constantin device

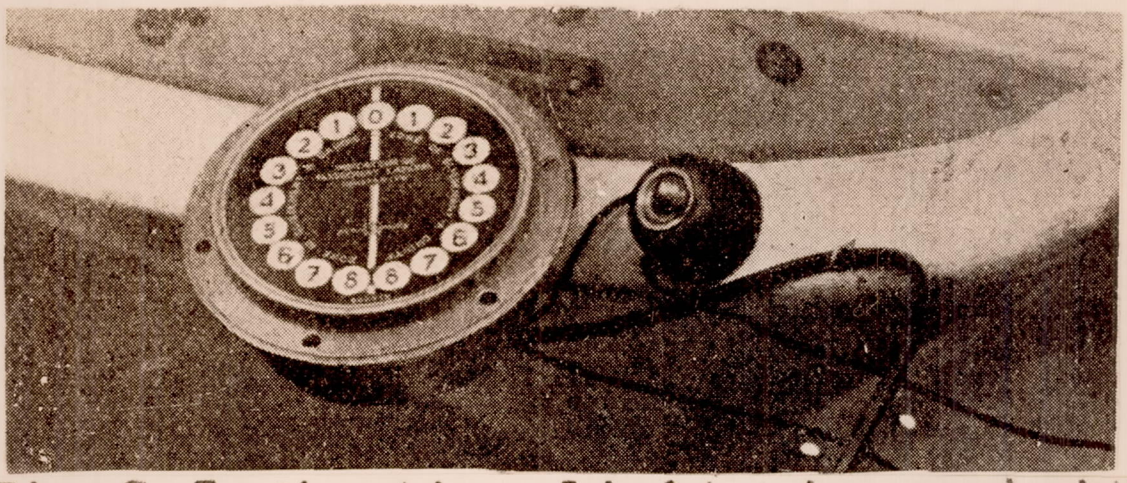


Fig.2 Indicating-lights in cockpit

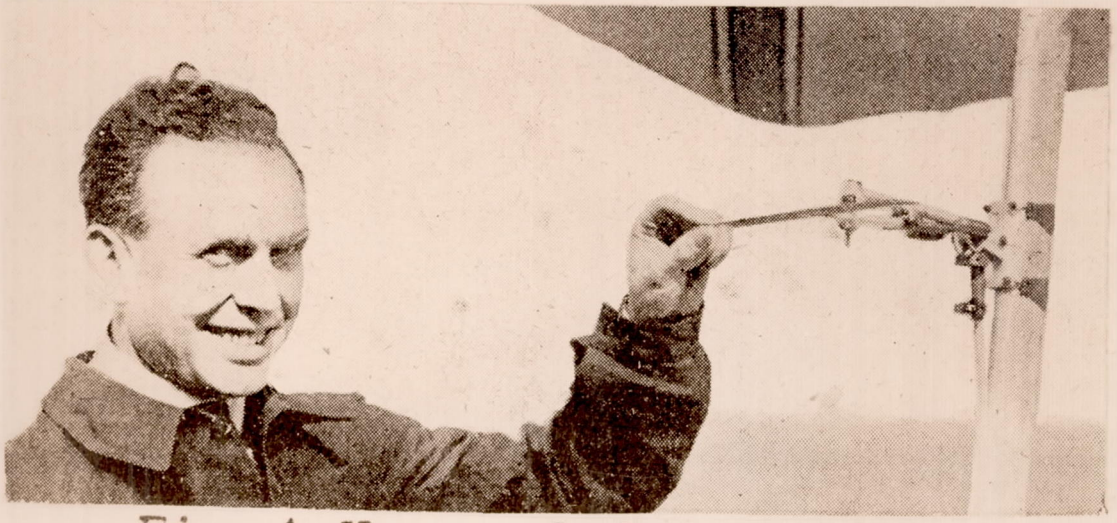
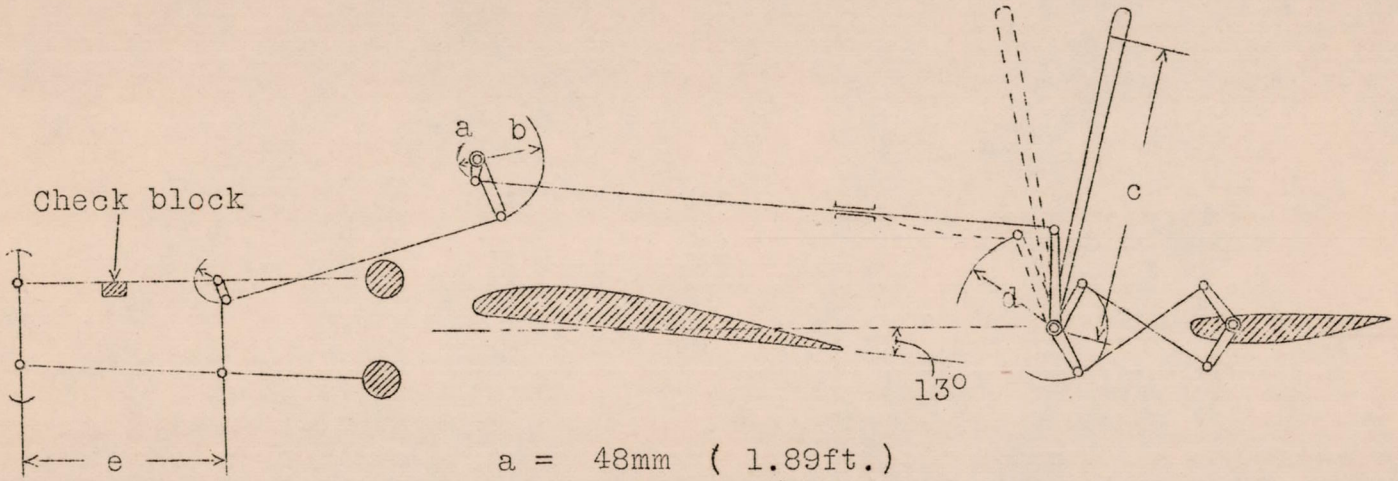


Fig.4 Vane of S-B device



a = 48mm (1.89ft.)

b = 120mm (4.72ft.)

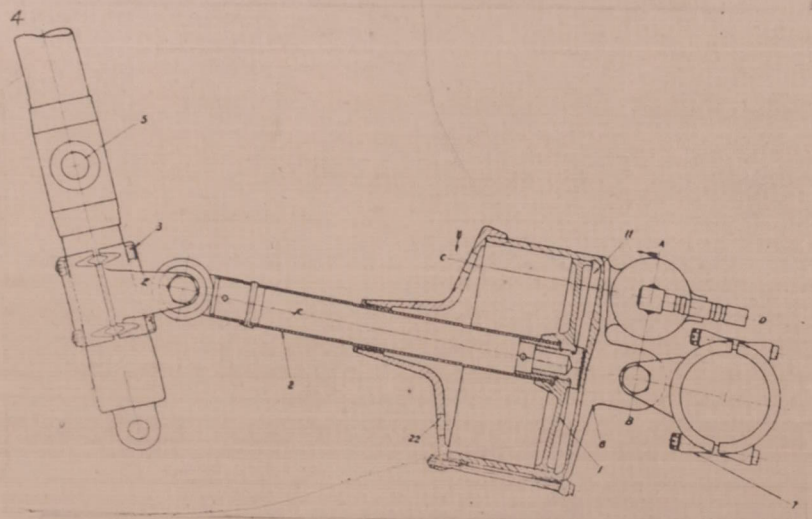
c = 600mm (23.62ft.)

d = 200mm (7.87ft.)

e = 400mm (15.75ft.)

Fig.3 Diagram showing direct action of a Constantin vane on the control stick.

1,piston; 2,piston rod; 4,control stick; 11,expansion chamber; 25, vane pivot; 26,tube support of vane; 22,cylinder; 23,vane; 24,vane stem; 27,fixed stop of vane; 29,valve; 30,air-exit tube; 32,attachment clamps



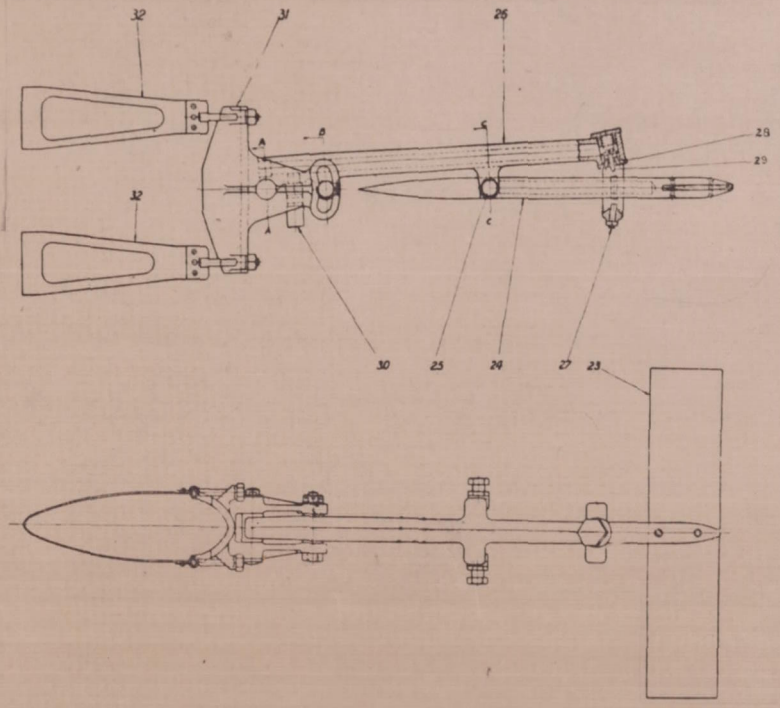


Fig.5 Savage-Bramson device. Lateral and plan views on the right. On the left, the connection of the preventive device with the pneumatic relays and the control stick