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By Salvatore Maiorca

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The landing gear serves the dual purpose of absorbing the shock of impact on landing and of dissipating the energy so absorbed. For this reason the wheels are generally equipped with pneumatic tires and attached to the aircraft by means of an undercarriage and some suitable elastic system called shock absorbers.

The airplane is equipped with a landing gear and two or more wheels having the same geometrical axis of rotation.

The third point of support is the tail skid at the rear end of the fuselage.

From the viewpoint of load distribution over the fuselage the position of the landing gear with respect to the C.G. of the aircraft assumes a special significance. While the different installations have a tendency to raise the position of the C.G., on one hand, it is imperative to have the fuselage as low as possible on the other, so as to bring the C.G. of the airplane close to the ground. But the minimum clearance is contingent upon the propeller in such a way that its size and mounting govern the proportions and the arrangement of the whole.

An airplane equipped with a large propeller in the front of the fuselage presents, in this respect, the most unfavorable conditions. Mounting the propellers on both sides of the fuselage makes it possible to use a smaller landing gear, favors landing itself, and reduces the taxiing run.

At first sight it would seem as if a maximum clearance between the C.G. and the axis of the wheels (one to the rear and the other as far ahead as possible) would result in greater protection against bouncing or dangerous one-wheel landing, but experience has proved it to be otherwise.

Placing the landing gear unduly far forward with respect to the C.G. tends to induce dangerous rebound which imperils the aircraft structure. If the C.G. is too far back and very high the airplane is very unstable during the take-off run.

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*"Sui Carrelli Per Aeroplani," L'Aerotecnica, Vol. 10, Nos. 9 and 10, Sept.-Oct., 1930, pp. 689-745.

With respect to the height of the C.G. the landing gear should move toward this center as much as possible as consistent with the moment of the propeller thrust against the point of contact of the wheels with the ground. To better resist the transverse stresses the axle should be rather large. In single-engine aircraft it averages around 0.18 of the wing span; in the twin-engine types the wheels are always placed directly under the engines (fig. 1); in three-engine and other very heavy aircraft one or more landing gears are used either independently (fig. 2) or conjointly (fig. 3).

Chassis or undercarriage.- The wheels may be independent or mounted on an axle, thus forming one of two types of landing gears, i.e., with or without axle. The axle, usually of steel, may be continuous (fig. 4) or hinged at its center (fig. 5); when enclosed in a fairing it is called false axle and serves to reinforce the chassis.

Ordinarily the axle is guided in a casing which serves to join the landing gear struts. This housing has an elongated opening provided with bronze guides in which the axle slides; it limits the travel in case the shock absorber fails. In case this arrangement is not used, some other suitable means should be provided to limit the travel of the shock absorber.

In the case of the axleless landing gear, the chassis is formed by one or more struts which may be interconnected and fixed to the aircraft by rigid braces or hinged joints. (Figs. 6, 7 and 8.)

The struts should be streamlined. They may be of one solid piece of wood or plywood. In certain cases the two struts may be combined into one and made of plywood.

It is advisable to cover the whole with fabric for reasons of strength. Hard wood, such as beech or oak, is preferable although spruce is in general use today due to the scarcity of the former. Quite often the struts are of metal (steel, duralumin) tubing, either round or oval shaped. The half chassis formed by one strut constitutes an internally braced metal box. These latter type (fig. 9) landing gears have unquestionably better aerodynamic characteristics than the older types.

Wheels.- The diameter of the wheels ranges from 0.60 to 1.50 m (1.97 to 4.92 ft.) as for example in the Linke-Hofmann type. But there are others with 2 m (6.56 ft.) diameter, as the Spiga with 2000 x 400 mm (78.74 x 15.75 in.). The wheels are usually faired with fabric (fig. 10); in some cases with duralumin sheet.

In several countries the disk wheel (fig. 11) has come into favor, and seems to be destined to widespread use because of its good characteristics. This type of wheel is cleaner in appearance, insures better streamline shape than those having spokes, is lighter in weight and cheaper to manufacture. Another feature is the space available for installing the brake and parts of shock absorbers.

Normally the wheels are fitted with tires. Siemens and Linke-Hofmann substituted wood for rubber during the exigencies of the world war, even marketing one certain type made of iron throughout. (Fig. 12.) But the wheel really should be elastic and this is insured only with pneumatic tires. The advantages of these wheels over the others include a lower moment of inertia of the mass about their proper axis and smaller friction of rolling. The pressure of the wheels on the ground should not exceed 4 kg/cm² (57 lb./sq.in.), although one manufacturer advertises tires for 6 kg/cm² (85.3 lb./sq.in.) inflation pressure, which does not permit an airplane to land or take off unless the ground is dry and hard.

To raise the loadibility of the landing gear without any proportional increase in wheel diameter the double wheel has been developed. (Fig. 13.) Such a wheel, normally constructed with 3000 mm (118.1 in.) diameter and 175 mm (6.89 in.) pneumatic tires, weighs 106 kg (233.69 lb.) with fairing cover. A single wheel of the same dimensions weighs 55 kg (116.84 lb.).

As a matter of record there are wheels which can support a load of four tons.

Tires.- The old clincher type (fig. 14) is practically obsolete. The most widely used tire in America and which also finds favor here in Europe is the so-called straight-side tire. (Fig. 15.)

In Italy the airplane wheel has been standardized. (Fig. 16.)

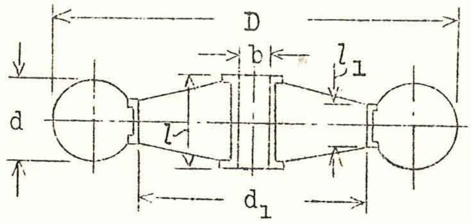

Fig.16

TABLE I

Airplane Wheels

(Government standard)

Type			I	II	III	IV	V	VI	VII	VIII
Outside diameter	mm	D	660	700	750	800	960	1040	1100	1250
Diameter, tire section	"	d	80	100	125	150	180	220	250	250
Diameter, groove of rim	"	d_1	500	500	500	500	600	600	600	750
Length, groove of rim	"	l_1	58.7	58.7	68.3	68.3	110	110	127	127
Length of hub	"	l	170	180	190	200	220	250	300	300
Diameter of hub	"	b	45	55	60	65	80	90	100	100
Airplane weight	kg	Q	500 850	850 1250	1250 1750	1750 2400	2400 3400	3400 4400	4400 5200	5200 6000
Average weight of inner tube	"		0.590	0.950	1.150	1.400	2.890	3.900	--	--
Average weight of outer tire cover	"		1.850	4	5	5.700	10	12.900	--	--
Inflation pressure	kg/cm^2		3	3	4	5	6	6	6	6

mm × .03937 = in.
kg × 2.20462 = lb.
kg/cm^2 × 14.2235 = lb./sq.in.
kgm × 7.2333 = ft.lb.

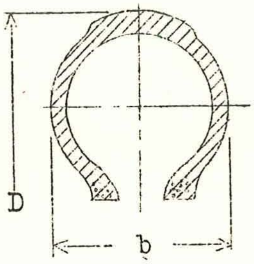

Fig.17

TABLE II

Tires

(Tentative standard)

sizes in mm - tires with wire insert

Name Nominal diam. Nominal width	Measurement	
	Diameter D	Width b
510 X 65	510 ± 10	65 ± 5
610 X 75	610 ± 10	75 ± 5
710 X 85	710 ± 10	85 ± 5
760 X 100	760 ± 10	100 ± 5
810 X 125	810 ± 10	125 ± 5
975 X 150	975 ± 10	150 ± 5
(1,020 X 175)	1,020 ± 10	175 ± 5
1,100 X 220	1,100 ± 10	220 ± 5
1,250 X 250	1,250 ± 10	250 ± 5
(1,300 X 300)	1,300 ± 10	300 ± 5

The sizes within parenthesis may be eliminated.

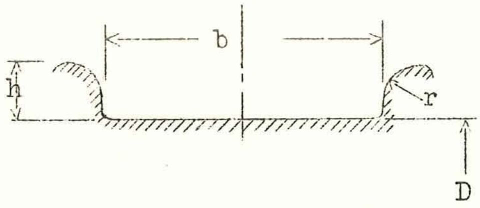

Fig.18

Rims

(Tentative standard)

sizes in mm - rims with straight sides

Name	Diameter of rim D	Circum-ference π D	Width b	Height h	Fitting r	For "Dinel 19" Regular	For "Dinel 19" Oversize
710 X 85	532	1670	45	11	7.5	710 X 85	
760 X 100	551	1730	50	12	8	760 X 100	810 X 125
810 X 125		1730	60	13	8.5	810 X 125	-
965 X 150	657	2065	75	15	10	965 X 150	-
1100 X 220	660	2075	120	20	13.5	1100 X 220	(1200 X 250)
1200 X 250		2075	150	25	17	(1200 X 250)	1300 X 300

TABLE IV

Wheels (mm)

(Tentative standard)

A: wheels with spokes B: disk wheels

Wheel							For "Dinel 19" tires	
No.	Hub		Static load on 1 wheel		"Dinel 20" rim		Regular size	Oversize
	Bore X length	Arrangement of semi-rim		Radial	Transversal	Size		
		A	AB	kg	kg			
1	42 X 160	30	–			710 X 85	710 X 85	–
(2)		–	(0)					
3		"	–					
(4)		–	(")			760 X 100	760 X 100	810 X 125
5		"	–					
(6)	55 X 160	–	(0)			810 X 125	810 X 125	–
(7)		–	(")					
8		"	–					
(9)		–	(")					
10		–	"			965 X 150	965 X 150	–
(11)	65 X 225	40	–					
(12)		–	"					
(13)	80 X 220	"	–			1100 X 220	1100 X 220	(1200 X 250)
14		–	"					
(15)	80 X 220	"	–			1200 X 250	1200 X 250	1300 X 300
16	100 X 250	–	"					

Sizes in parenthesis may be eliminated.

France has also standardized this type of wheel. The present-day tendency is toward large tires and low inflation pressure. The characteristics of the wheel recently proposed are as follows:

TABLE V

	Dimensions of wheel:					
	650/100	700/125	750/150	800/175	900/200	1000/225
Hub:						
length	160 ± 0.5	185 ± 0.5	185 ± 0.5	185 ± 0.5	220 ± 0.5	250 ± 0.5
bore	40 - 0 + 0.1	55.3 - 0 + 0.1	55.3 - 0 + 0.1	55.3 - 0 + 0.1	65.3 - 0 + 0.1	80.5 - 0 + 0.1
Wheel bare:						
min. length of outer ring	30	30	40	40	45	50
radial stress kg	4,000	7,000	8,500	9,500	12,000	-
static stress laterally applied at a distance from edge of hub kgm	500	700	850	850	1,200	-
Wheel mounted:						
max. pressure of static test P kg	4	4	4	4	4	4
height of tire inflated at pressure P	650/10	700/12	750/12	800/13	900/15	1000/20
max. width of flange (inflation pressure P of tire)	105	131	156	187	208	235
total weight kg	1,100	2,600	3,700	5,000	6,500	-
min. static energy to flatten tire kgm	70	120	220	370	550	-
max. pressure on tire kg	10	10	10	10	10	10

These specifications also include a lateral stress expressed in form of a moment, which is not found in the Italian standard.

Shock absorbers.- In order to eliminate the shocks between the wheels and the fuselage it is customary to interpose elastic units which absorb at the moment of landing the vertical component of the energy of the airplane which the tires have not dissipated.

These elastic units commonly known as shock absorbers may be mounted between landing gear axle and chassis, between chassis and fuselage, or between the wheel and the axle. In the latter case we have the internally sprung or elastic wheel.

The shock absorbers may consist of rubber cords acting in tension, rubber disks acting in compression or steel springs acting in tension or in compression.

Lastly there is the oleopneumatic type in which the oil is forced through a series of holes.

In the first three types enumerated the absorption of the kinetic energy results in a number of lesser shocks which make the airplane bounce. The additional stresses set up by these repeated rebounds endanger the strength of the airplane and the safety in landing to such an extent that the airplane commences to bounce from the first impact if the initial tension of the springs is abnormal.

The importance of shock absorbers was soon recognized during the late war. England decided on rubber cord in conjunction with oil shock absorbers, while France equipped the Goliath bombers with Béchereau oleopneumatic shock absorbers along with rubber cord.

Ordinarily the rubber cord is said to function satisfactorily. A steel spring serves the same purpose as was proved by Germany during the war when the lack of raw materials became a vital factor. Rubber cords, even though subject to rapid wear and tear, are preferable to steel springs because they dissipate by friction a large part of the energy absorbed. In normal landings the direction of the shock is toward the rear. Formerly this inclination was disregarded; the return was vertical in such a way that only this component of the shock was absorbed. The axle of the wheels should be mounted so as to be able to travel normally as well as parallel toward the fuselage. Moreover, heavy and rather long airplanes are materially affected by the wind as their speed increases, and it is very important to have the landing gear elastic in the transverse direction also.

Rubber disk shock absorbers.- In order to deform an elastic body, say to compress a flat disk by means of stresses evenly distributed over its bases and acting along its axis, a certain amount of energy is expended which is transformed into potential elastic energy:

$$L = \frac{1}{2} N \Delta l = \frac{1}{2} \frac{N^2 l}{E F} = \frac{1}{2 E} \sigma^2 V.$$

The energy which an elastic body can absorb provided the elastic limit N is not exceeded, is proportional to its volume and to the square of the specific pressure.

But $\sigma = \frac{N}{F}$, or, with parity of volume, the work which this body may absorb increases as the section diminishes, or in other words an elastic body is in best condition to dissipate energy when it is narrow and long.

On the other hand, a body of the desired proportions and loaded at the end bends laterally with the result that in some sections the stresses exceed the elastic limit and may even result in a rapid decrease in tension in the greater portion of the sections and in consequence of the energy absorbed.

Then again, the increase in length Δl may result in figures unsuitable to airplane shock absorbers whose travel should be defined within stated limits.

The first may be remedied by the use of rubber disks interspaced with plates in such a manner as to avoid all flexure of the column which otherwise might force the landing gear strut to give way under any accidental asymmetrical stress.

In the most elementary kind of shock absorbers of this type the spacers and the centering plate are stamped in one piece from aluminum sheet. (Fig. 19.) In the Parnall type (fig. 20) the stamped plates glide in contact with the inside cylindrical surface of the strut. In the Gloster type (fig. 21), disks and plates are both well streamlined and even distribution of load is insured by the contact of the rubber on two guide tubes. These spacing and centering plates should be longer than the rubber disks so as to take care of the expansion when under compression.

In order to decrease the travel of the shock absorber at the moment of impact the shock absorber itself is subjected to an initial tension. In fact, conformably to $L = \frac{1}{2} N \Delta l$ the work is defined in the triangle (fig. 22) with the travel as base and the height as the loads.

Let $B C$ represent the permissible minimum static load, which for rubber disks is around 17 kg/cm² (241.8 lb./sq.in.).

When it exceeds this figure the rubber becomes hard and soon loses its elasticity. Figure 22 shows that for a stated travel a b, naturally less than the complete path A B, a maximum amount of energy is dissipated when b and B coincide.

Likewise, for the dissipation of a stated amount of energy (the exact amount to be given later) the minimum travel may be obtained if one commences with the calculation of the area C B. The work diagram is thus transformed from a triangle into a trapezoid, the smallest base of which yields the value of the initial tension. (The rubber shock absorbers are also put under initial tension.)

Figure 23 illustrates a Potez landing gear equipped with rubber disks working under initial compression by means of a spring, while Figure 24 shows a shock absorbing strut of the Blackburn-Bluebird airplane. The elastic system consists of a steel spring, the disadvantages of which were pointed out above.

For this type of spring as for the rubber disks and for any other type of shock absorber which becomes deformed when compressed along its own axis, the struts as well as the axles must be hinge jointed. The hinges represent nearly always dangerous points of rupture and materially contribute to diminish the aerodynamic characteristics of a landing gear.

Rubber cord shock absorbers.- They are formed by a stated number of 1 × 1 mm (.04 × .04 in.) square rubber strands wrapped in a double webbing of cotton. The threads are continuous over their entire length and should stretch 600% under a 500 g (1.1 lb.) stress. The threads break under 1000 g (2.2 lb.) and stretch about 700%.

The texture of the cotton webbing should permit the threads to stretch evenly, be of woven fabric and of first grade cotton so as not to deteriorate too quickly.

These shock absorbers are in rings or twisted strands. In the latter case the ends terminate in special rings and attachment hooks shown in Figures 25, 26 and 27. Their installation should be such that all rubber rings work evenly and be as parallel as possible to the direction of motion of the axle. It is very important to cover the parts on which the shock absorbers rest with heavy leather and to avoid all sharp angles which inevitably cut them in two.

The whole should be protected against mud and oil by a leather covering or casing.

There are various ways in which rubber cord shock absorbers may be used. One type, shown in Figure 28, is part of the Morane-Saulnier split-axle landing gear in which the strands are not tied; the one in Figure 29 is similar but has a shorter travel. Figure 30 shows the Junkers type, which features three shock-absorbing struts. The struts and the axle are interconnected and hinged to the fuselage. Two original arrangements are seen in Figures 31 and 32, viz: the Fokker trimotor and the Bernard type. In the Fokker the wheel supports the fuselage by means of an elastic system which joins a fixed hollow body to a strut which glides along this body and which is hinged to the fuselage. The body at the same time serves as travel stop. In the Bernard type the strut is connected to the wheel. Another well known type, particularly on heavy aircraft, is shown in Figure 33. Here the wheels can also shift horizontally. Note the leather covering.

In Figures 34 and 35 is shown a type with steel springs where many small springs are preferred to few large ones. It will be noted that one end is fastened to an upper box which rests on the wheel hub and the other to a lower box. The springs are not all parallel; they are in two sets and form a sharp angle. This arrangement makes it possible to absorb shocks inclined to the vertical.

Oleopneumatic shock absorbers.- For ordinary landing the shock absorber should, as a rule, be flexible in order that the shocks be as light as possible and the rebound which is always dangerous moderate.

On the other hand, in violent landings the shock absorber should be capable of absorbing a maximum amount of energy without exceeding the permissible static load.

With the present day rubber-cord and compression-disk gears the static load curve plotted against the travel shows an upward convexity and this applies to gears capable of absorbing a great many kilograms. If the gears are very flexible the convexity of the curve is downward.

The oleopneumatic gear solves the difficulty (fig. 38). It consists of a steel cylinder with two chambers and a valve. The upper chamber contains a piston which bottoms against the valve under normal load. The space above the piston is filled with compressed air (50 kg) (110.23 lb.). The lower chamber is closed at the bottom by a second piston equipped with a rod which forms the connection with the axle of the wheel. The space between the two pistons is filled with antifreezing oil or glycerine. When, under the effect of the shocks transmitted by the axle, the lower piston expels the oil, which passing across the space provided by the valve lift acts in its turn on the piston and compresses the air in the other chamber. When the stress has disappeared the compressed air relaxes and recoils the top piston, the valve closes and limits the return flow of oil to a bleeder hole in the valve.

In this type of absorber the typical static load elongation curve embodies the curve of the compressibility of the air and another the resistance due to hydraulic restraint which grows with the piston speed. But such a gear shows an almost constant deformation curve no matter what the impulsion of the airplane on the ground. The rate of oil outflow during the compression or during the expansion of the air can be suitably graphed from the normal load supported by the wheels. To make the landing gear of a heavy airplane more elastic the oil flow may be adjusted to the load variations by varying the air pressure in the cylinder.

The attempts to improve this type of shock absorbers have been many.

In the Messier gear the passage of the oil is across a rectangular orifice which houses a slide valve of variable section; the curve corresponding to hydraulic retardation varies with the size of this valve. The appended diagram (fig. 39) shows the curve for the Messier-type E 3 gear during the compression stroke. Curve C represents the compressibility of the air; a the deceleration of the oil for a 3 m/s (9.84 ft./sec.) vertical velocity on contact; b for 1 m/s (3.28 ft./sec.) and A B the resultant curve.

Thus, the adjustment or other similar device of the outlet orifice enables us to apply the load gradually until a maximum is reached which remains constant throughout the stroke. As a result the stresses on the airplane structure are kept at a minimum. This minimum is, in certain cases, lower by half than that obtainable by a fixed orifice according to G. H. Dowty who attempted to find some means capable of absorbing the kinetic energy of an airplane conformably to the same law of variation of this energy, i.e., proportional to the square of the speed. He is said to have found the solution of the problem by using a needle valve, and in particular by the selection of a needle so that the square root of the weight ratios of airplane and oil to be displaced was equal in ratio of piston area to flow orifice

$$\sqrt{\frac{\text{airplane weight}}{\text{weight of oil}}} = \frac{\text{area of piston}}{\text{outflow orifice}} .$$

Landing gears (examples). We list here various orthodox types of landing gears:

There is the continuous axle type of Dewoitine (fig. 40) featuring an elastic ligament which joins the regular axle with a second on which the wheels turn. Other details may be seen on the figure.

In the V-type landing gear of Bleriot (fig. 41) the streamlined false axle is jointed to the V struts.

The two semiaxles of Potez (fig. 42) are hinged in a central V instead of to a false axle.

The Wibault gear is of the so-called no-axle type, each wheel (fig. 43) being attached to the fuselage by means of a steel trihedral and universal joints. This structure is very susceptible to failure. One of the struts is equipped with an oleopneumatic gear.

The Avimeta has independent wheels. (Fig. 44.) Note the return gear of the rubber stacks.

Special landing gears.- The "shock" landing gears is simply a smaller auxiliary landing gear under the nose of an airplane and which is to prevent the wings from touching the ground when the airplane tends to turn over on its nose. Admittedly, this gear means more weight but its usefulness cannot be disregarded. Some large commercial airplanes in Germany (fig. 45) and the Caproni in Italy use it on training airplanes. In this particular case (fig. 46) it consists of a skid mounted on wheels, and turning on an axle which also plays the role of the stem for the engine nacelle. It carries a spring at the top and about 5 meters (16.40 ft.) of 12 mm (.47 in.) rubber cord. This cord passes in two ends to a ring; it encloses the support which it maintains against the nacelle. At the lower end the shock gear carries the two ordinary wheels; the axle is wound with 12 meters (39.37 ft.) of 12 mm (.47 in.) rubber cord.

Two 50 X 1.5 vertical tubes connect the support fitting in a universal joint D which enable the wheels to orientate on rough ground. This orientation is partially retarded by two 12 mm (.47 in.) elastic stays. Two struts lead from the upright tube to the support attachment. They are of steel tubing with wood fairing and are intended to absorb the shock of the landing gear.

The forward skid also consists of 13 ply pine and oak, faired and covered with fabric.

Chassis for 4 wheels. (Fig. 47.)- Here the use of brakes becomes necessary because the airplane deprived of tail skid has a too long taxiing run. Braking itself is difficult to regulate and sets us rebounds very easily as shown in the Caproni airplanes which, however, seems to have been temporarily abandoned.

<u>Amphibian gear</u>.- The fuselage is built as a hull to provide alighting on water. In addition it is equipped with two retractable wheels as in the Ireland "Neptune" (fig. 48) or as in the American Towle W. C.

The landing gears with lateral shock absorbers merit special mention. (Figs. 49 and 50.) Others are the De Havilland 54 and the Levasseur gear. The disappearing type is relatively well represented by the Bellanca, Burnelli, etc.

Lastly, there are the various caterpillar systems of which the French L. Vinay type is a representative. This was intended to be substituted for the orthodox types of landing gear, but the inherent drawbacks seem to outweigh its alleged advantages.

<u>Brakes</u>.- The use of wheel brakes presents numerous advantages. The high value attached to quickness of pull-up, or time to stick is apparent. Aircraft for deck landing benefits by braking owing to the very limited length of run available. Independently operated wheel brakes give the single-engine aircraft maneuverability on the ground, thus augmenting in a great measure its safety in rough terrain, unfavorable winds or night operation. Lastly, they permit landing at higher speeds and the elimination of wheel chocks for the preliminary starting and running up of the engine.

Because of all these advantages, wheel brakes are becoming normal equipment in America on military as well as on commercial aircraft. The brakes do not differ very much from automobile brakes and the pilots have found them satisfactory.

In Europe, on the other hand, the use of brakes has found no widespread favor.

Admittedly their use has always been associated with additional weight and complications consequent to their adoption, and in the search for a suitable method many schemes have been suggested and tried. The following present some of the most popular types:

The <u>Bendix</u> wheel and brake which is of the expanding two-sector type, the operating cam and lever being visible in Figure 51. The brake drum is entirely contained within the wheel. The primary shoe <u>A</u> is articulated to the secondary shoe <u>B</u> at the point <u>C</u> and is not anchored to the brake drum. The location of pin <u>C</u> and anchor pin <u>D</u> have been carefully selected to provide effective braking. Cast aluminum is used almost exclusively. Figure 52 shows the installation and operation.

Following are the weights and the deflections of various size wheels

TABLE VI

Tire size mm	Tire deflection mm	Capacity of wheel kg	Airplane weight kg	Torque reaction kgm
760 X 127	25.4	5,000	1,400	142
810 X 152	31.7	8,170	2,270	234
915 X 203	44.4	2,170	4,085	464
1120 X 254	50.8	13,625	6,360	888
1370 X 305	63.5	22,700	9,080	1,557

The torque reaction based upon the braking effort and the axial stresses is computed from the formula

$$M_t = \mu \frac{G}{2} (R - \lambda), \quad \text{where}$$

μ = coefficient of friction = 0.55,
G = airplane weight,
R = radius of wheel,
λ = tire deflection.

A 760 X 127 mm (29.92 X 5 in.) size wheel withstands a radial load of 5900 kg (13,000 lb.) and a side load of 1820 kg (4012 lb.); a 915 X 203 mm (36.02 X 8 in.) wheel a radial load of 9080 kg (20,018 lb.) and a side load of 2800 kg (6173 lb.).

It will be seen that each wheel is operated independently. Although this system does not present any special features, it seems to have found widespread favor.

The Sauzedde wheel and brake has a spoke arrangement; the brake is the same as in automobiles; the brake mechanism is inside the wheel and has fins along the circumference of the drum to dissipate the heat generated as a result of friction. The brake of each wheel is operated by a separate foot pedal. Compared to the Bendix wheel, the Sauzedde wheel is much more complicated, less reliable and heavier.

TABLE VII

Size of wheel	Weight of wheel with		Weight of brake	
	Bendix brake	Sauzedde brake	Bendix	Sauzedde
760 X 127	10.0	10.6	4.1	4.3
810 X 152	13.6	15.8	5.5	5.5
915 X 203	14.1	18.9	5.6	5.7
1120 X 254	27.3	44.3	10.9	9.8

The Vickers wheel and brake (fig. 53) is of the expansion type hydraulically operated. The three brake shoes are operated by a simple hydraulic cylinder and plunger. The brake drum is inside the wheel; the brakes are completely enclosed and well protected against sand, mud and water. The wheel is readily removed without in any way disturbing the brakes. The braking system is exceedingly simple. The pilot has a brake lever which operates a small hydraulic pump. Two backward and forward movements of this lever raise the pressure to 14 kg/cm^2 (199 lb./sq.in.) and take up all the brake clearances. The third stroke raises the pressure to 55 - 70 kg/cm^2 (782.3 - 995.6 lb./sq.in.) and the brakes are applied in direct proportion to the movement of the lever. The oil circulation pipes are of steel. To insure independent brake operation of each wheel a special valve (pilot's control) is provided. When the control stick is in neutral position the brakes automatically balance one another. A pressure gauge mounted on the dashboard indicates the pressure existing in the system.

This braking system has been fitted on the Vickers Vanguard which is in the service of the Imperial Airways; and the system has been found very effective. It permits of pulling up the airplane, which weighs 8125 kg (18,000 lb.) loaded, in some 70 - 90 m (230 - 328 ft.) without that scarifying effect on the landing field surface produced by the usual tail skid.

But in spite of the indisputable advantages of hydraulic operation the following disadvantages must not be lost sight of: great weight, and danger of leakage at the inevitable soldered joints.

The Engineering Division brakes.- The first experimental brake (fig. 54) was of the double-disk type and separately controlled. The braking unit consisted of two superimposed disks attached to each wheel, the larger being riveted to the wheel parallel with the outer row of spokes. The braking disk is actuated by means of three cams mounted concentric with the axle, the brake being applied by depressing a pedal in the cockpit connected to the cams by cables running inside the axle.

The next brake (fig. 55), an independently controlled unit of the internal expanding hydraulic type was incorporated in a disk wheel with built-in brake drum.

In both types the brake is enclosed in the wheels within the fairing.

The Palmer wheel brake.- (Figs. 56 and 57.)- The wheel has wire spokes and the latter carry a drum. A disk attached to the axle carries a castellated channel to which a complete ring of small friction blocks are recessed. Below these blocks is an annular expansion chamber; when air is forced into this chamber, this expands and brings the blocks into frictional contact with the revolving drum. The castellated channel prevents the blocks from revolving with the drum. This arrangement is novel and exceedingly simple.

On airplanes not equipped with a compression starter the air supply for working the brake is obtained from a flexible air cylinder (rubber), reinforced with Palmer cord, and although but a fraction of the weight of the usual steel cylinder, it has an ample margin of strength.

Automatic release devices.- These may be grouped into three categories:

1) Those controlled by the reaction of the ground on the tail skid;

2) Those in which braking is regulated as a function of the angle of the vertical passing through the C.G. and the straight line which connects this center in the point of contact of the wheels with the ground;

3) Those controlled by the reaction of the ground on the landing gear.

The second and third systems have, moreover, the advantage of braking the airplane even when it travels on the ground in line of flight.

The Messier device belongs to the first category, because it is operated by the tail skid. It is applicable to a brake operated by an hydraulic servo brake. The oil pressure is subject to various factors: action of pilot, reaction of ground, and the time element.

The regulating device, which quickly opposes a too sudden deceleration and insures instantaneous release of the brakes as soon as the tail skid no longer touches the ground, consists of:

A pump barrel which sends oil under pressure into a pipe emptying into two regulators, one to each wheel (fig. 58).

The regulator which is the organ of the brake control (fig. 59) consists of two pump barrels, one for the incoming compressed oil and the other for sending the oil under pressure to the brake shoe. The lever which operates the plunger of the latter pump barrel and which is likewise connected with the other, is manipulated by the pilot. When the piston, due to lack of oil, is completely extended (fig. 62), it cannot brake even if the pilot steps on the pedal because the lever is inoperative. A device inserted in the oil inlet pipes of the brake and in front of the regulator forces the oil through a small metering orifice while permitting the oil to flow through a large opening in the opposite direction.

The Dhainaut-Fauvelière system (fig. 60) belongs in the second category. It releases the brake when the airplane strikes any obstruction, rough ground, or any other object which might set up frontal or lateral rebound. Spring m acts on lever L which operates the cam of the shoes and keeps the wheel braked under normal conditions. When the pilot, for taking-off or any other maneuver, wants to release the brakes he pulls cable c which turns on A so that lever S contacts with lug B, which compresses spring m and releases the brakes. M is the wheel hub.

During an ordinary maneuver of the airplane on the ground, the wheel being braked, the spring moves backward and stops in an equilibrium position so that if F is the braking effort and C the load on the wheel $F = C \tan \alpha$ or α is the angle formed by straight line M A with the vertical.

The relative position of A and M is independent of the inclination of the airplane, but the distance from B to L is not. Thus, when the wheel moves excessively backward, whether due to abnormal braking effort in soft ground or any other cause, or when the fuselage slopes beyond a stated limit, B contacts with L, compresses the spring and releases the brake shoes. The system is truly simple and original.

Hydraulic servo brakes. (Fig. 61.)- A rim with four cams is housed on the bottom of the brake drum. Two small oil pumps are connected to a roller arm with pivots at the ends and driven by cams. The oil is put under pressure and fed into a small cylinder having two pistons which act directly on the brake shoes. The brake action is controlled by a valve from the pilot's seat.

Other types of servo brakes utilize a hand lever connected to the cylinder of an oil piston. The oil is forced through pipes to the brake cylinder, the cylinder of which is fastened to a set of special levers and transmits the pressure of the compressed oil to the brake shoe.

Reversing the lever forces the compressed oil through the orifice of a valve into a small tank. When the pressure is lowered in the brake cylinder a return spring returns the piston and thus releases the shoes. The multiplied force of this servo brake is contingent on the ratio of brake cylinder diameter to control cylinder diameter.

Brake-control devices. (Fig. 62.)- Brake control is carried out by two buttons on the pedals of the rudder bar. Pushed down these buttons tighten the cable of the brake cam. The travel depends on the airplane weight, brake diameter and reduction gear ratio.

TABLE VIII

Total weight	1,350	2,750	4,100	6,400	9,100
Brake diameter	300	300	300	500	500
Pedal movement	60	88	110	88	140

Internally sprung or elastic wheels.- At the beginning of this study we put in evidence the characteristics and the advantages attendant to this type.

Admittedly the present day methods are far from being perfect, but the studies of this problem are not without benefit and modern technique inevitably will arrive at a satisfactory solution.

The Bleriot elastic hub wheel. (Fig. 63.)- The wheel proper turns on a drum which plays the role of the axle. The landing gear axle is connected to this drum by elastic rings. It has only rotating parts, no sliding movement.

The Avimeta wheel.- Figure 64 shows the frame at the bottom of the drum which, as in the Bleriot wheel, is stationary with respect to the wheel. Rubber cords from this frame extend to a second frame on which the axle may be supported.

Dowty wheel. (Figs. 65, 66 and 67.)- In this disk wheel the shock absorbing parts embrace two sets of solid rubber disks with fluid dashpot in the center. There are three distinct motions:

1) The units which turn about the hubs and move vertically relative to the landing gear,- tire, rim, side disk and brake drum;

2) The parts which move up and down,- the side flanges of hub, the brake shoes, the compression rubber columns, lower beams and dashpot piston;

3) The units rigidly attached to the airplane,- dashpot cylinder, top beam, central guide member and hub fitting.

The dashpot is enclosed in a second cylinder built integral with it. When, under the action of a shock, the cylinder of the shock absorber comes to the end of the down stroke, the outer cylinder, by acting on a plate, determines the compression of the two rubber columns. The inflation valve of the oleopneumatic shock absorber is of the needle type so the absorption of the shock can be regulated. This wheel may be braked once its inventor has overcome the following difficulty: any internally installed braking system is continually raised and lowered with respect to the structure. It is impossible to see how this arrangement can absorb the horizontal component of the shock and the idea certainly does not stand forth as an exponent of excessive simplicity.

Wheel with inside tube - brakable (fig. 68), according to my invention.- A tube is placed near the hub between two rims, one integral with the hub and the other with the wheel proper. This wheel is essentially like the ordinary wheel except for its larger hub diameter. The resistance to axial stresses is insured by two side disks, which are mounted loose on the axle, cover the whole wheel and bring the length of the two round rims in contact with it. There is some clearance between the wheel and the disks to enable the wheel to slide when, under the effect of a shock, it is pushed against the axle.

For braking the wheel one of the disks is blocked and applied to the wheel which in this manner is gripped between the two rims lined with Ferodo. This movement is produced by a multiple friction disk assembly. (Fig. 69.) The outer parts or female disks mesh in the grooves of a drum integral with the disk; they turn with it. The inside or male disks recess into the grooves of the axle and do not rotate. This part has a smaller inside diameter so as to support the disk; it also carries a small drum on which the disk rests and turns.

At the moment of braking a disk-locking sleeve normally kept in place by a spring (not shown in the figure) moves toward the disk assembly and actuates by the first movement the block of the brake disks, and by a second the axial motion of the latter male friction disk, and through it the brake disk. Thus the wheel is braked.

The salient features of this wheel are: inside tube, shoulder disks and brake. Its advantages are notable simplicity, and in consequence light weight with respect to wheels with internal springs; the actual absorption of shocks, the side disks and the wheel flanges function like the Hartford friction shock absorber.

Figure 68 represents this wheel deflected under axial load; Figure 70, the wheel without the usual outside tire.

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National Advisory Committee
for Aeronautics.

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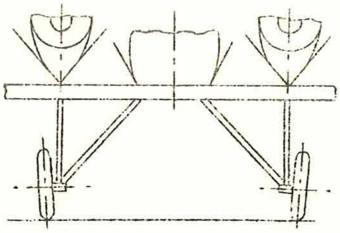


Fig.1

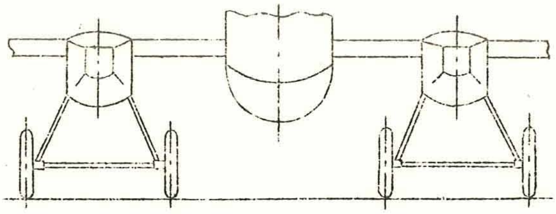
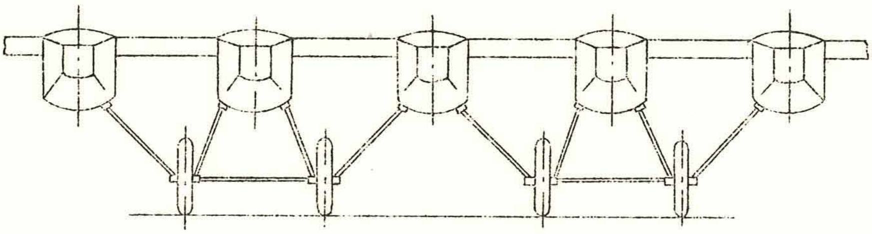


Fig.2



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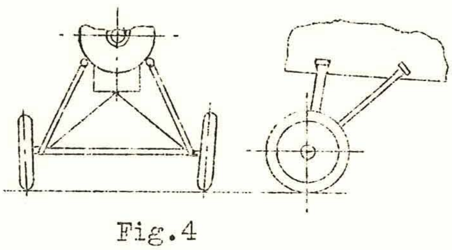

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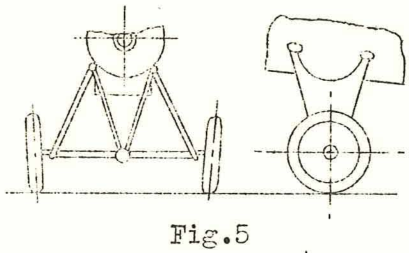


Fig.5

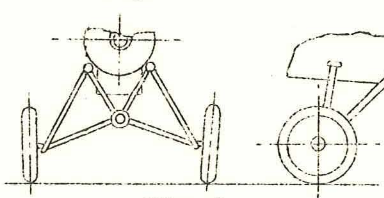
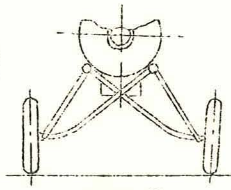


Fig.6



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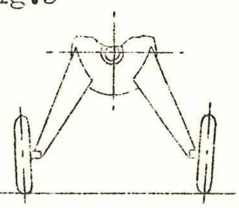


Fig.9

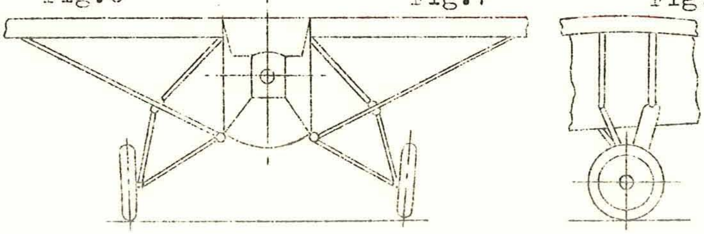


Fig.8

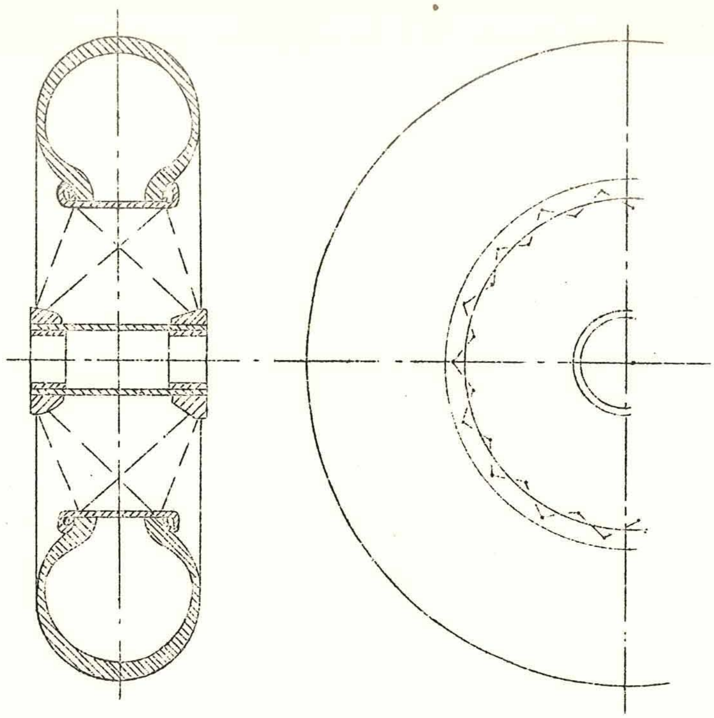


Fig.10

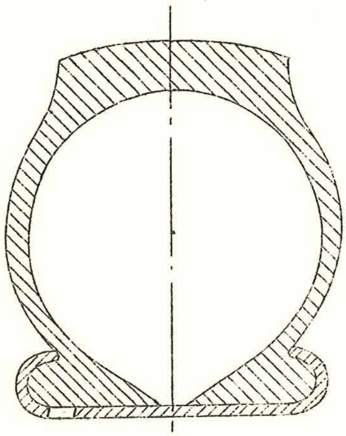
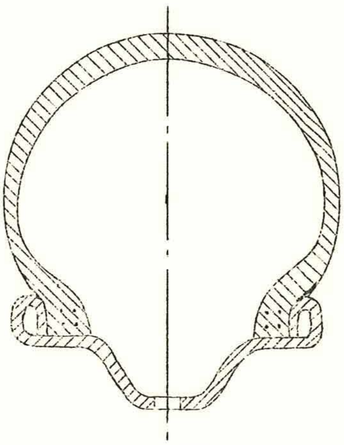


Fig.14



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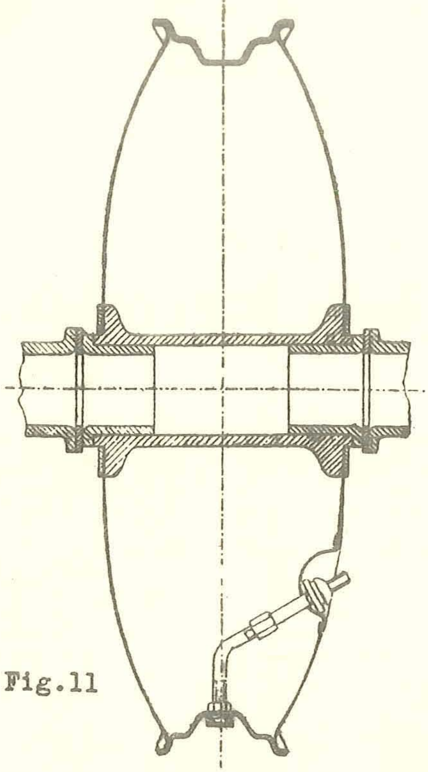
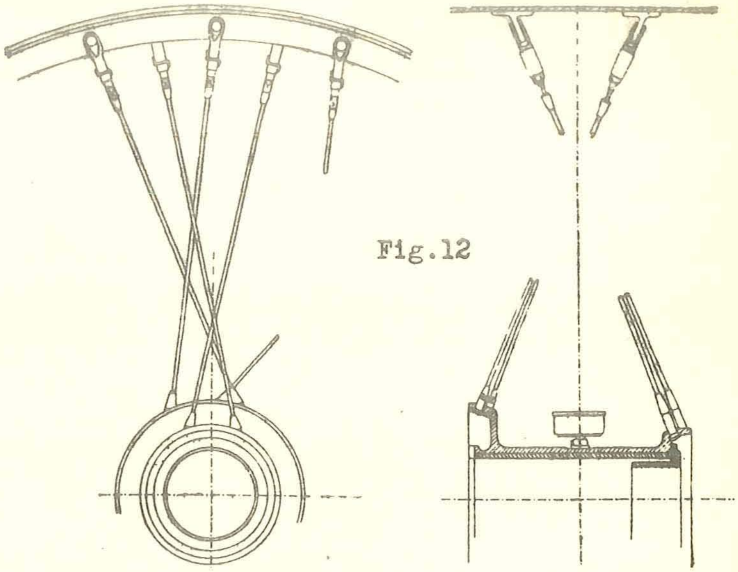


Fig.11



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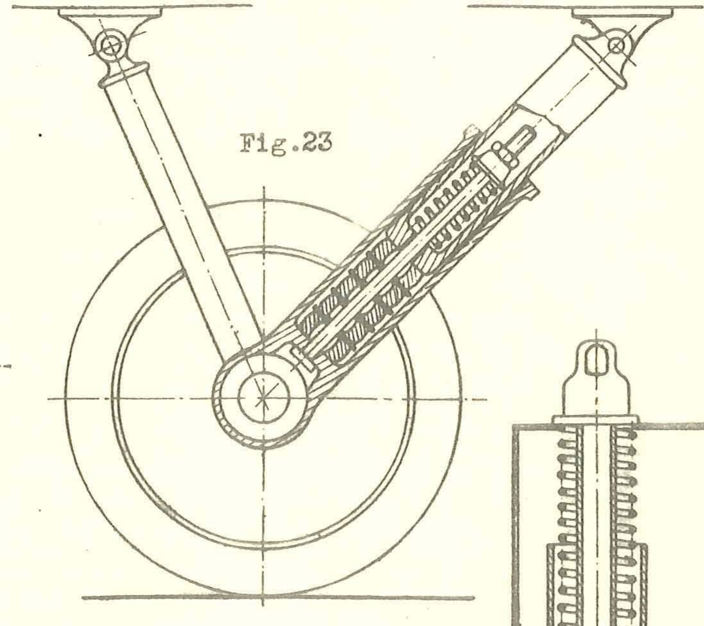

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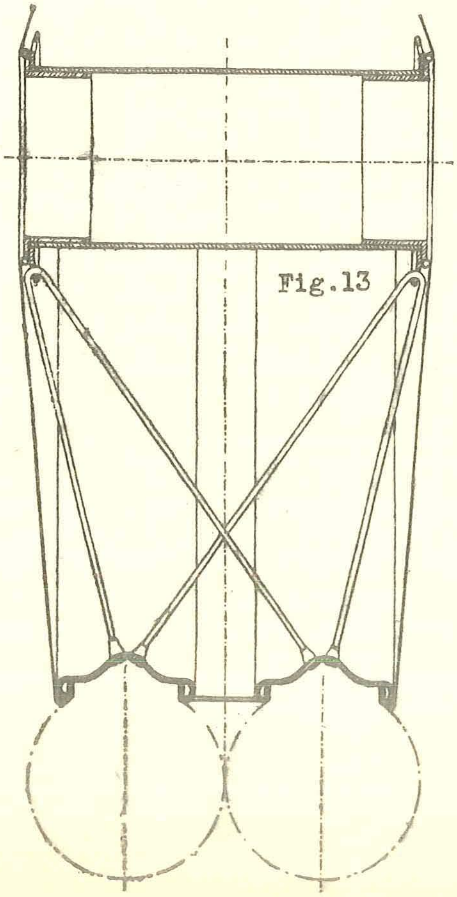


Fig.13

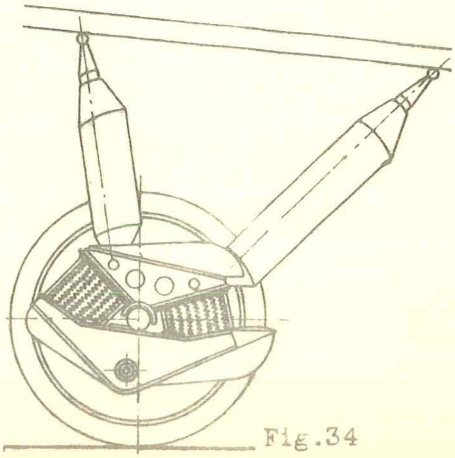


Fig.34

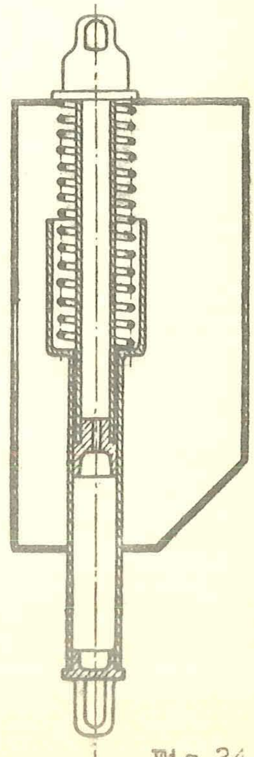


Fig.24

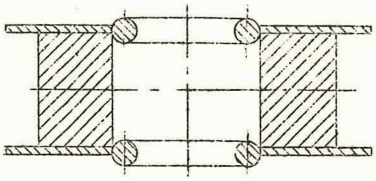


Fig.19

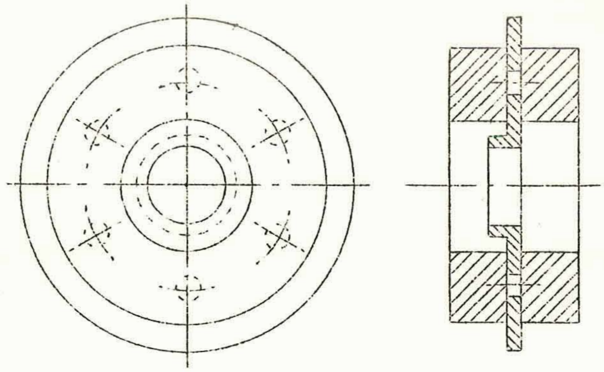
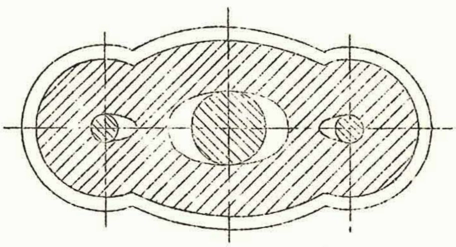


Fig.20



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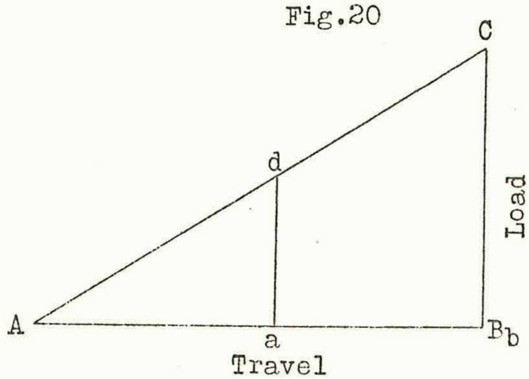

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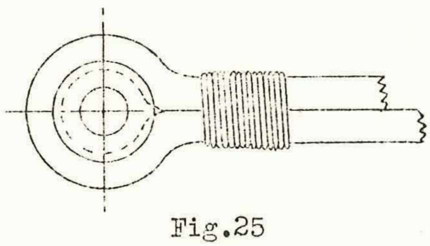

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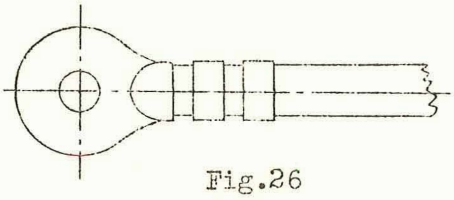

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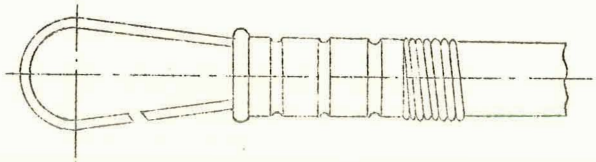

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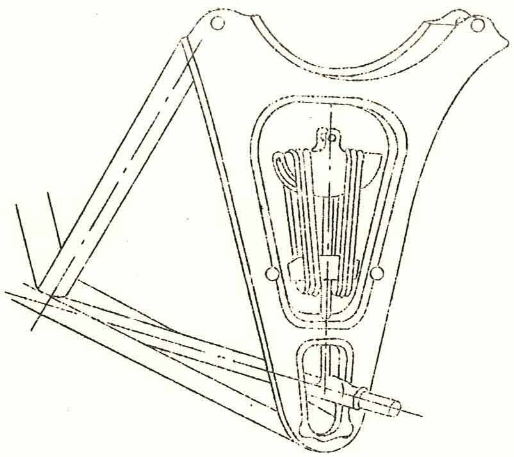

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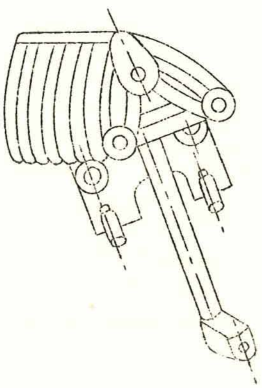

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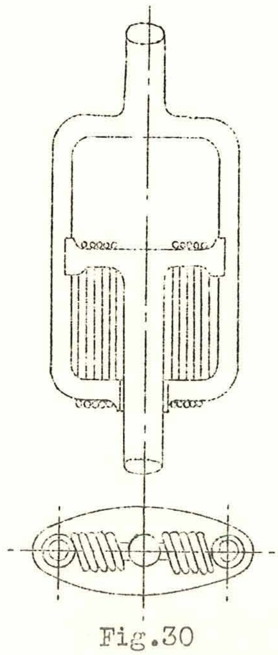

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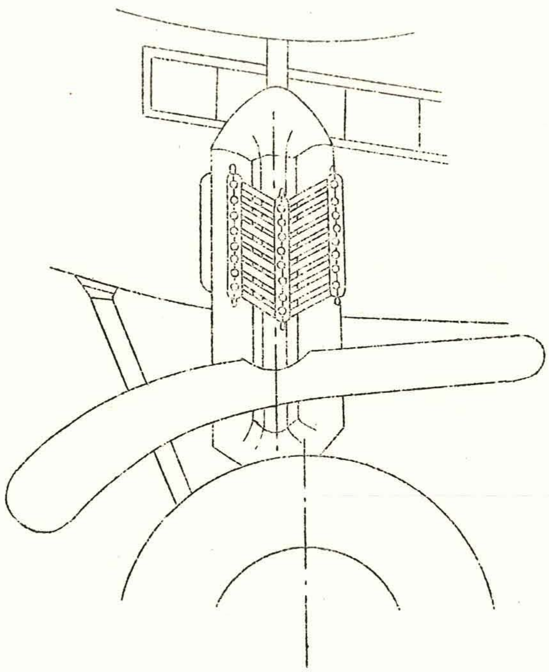

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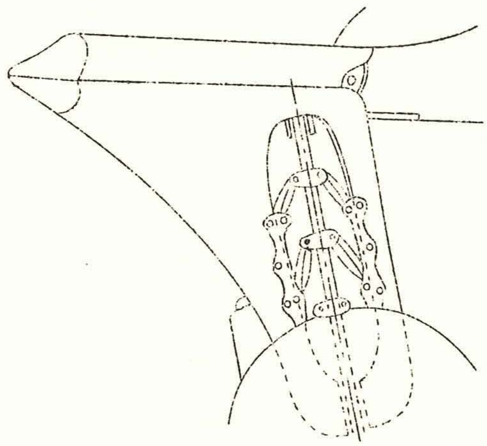

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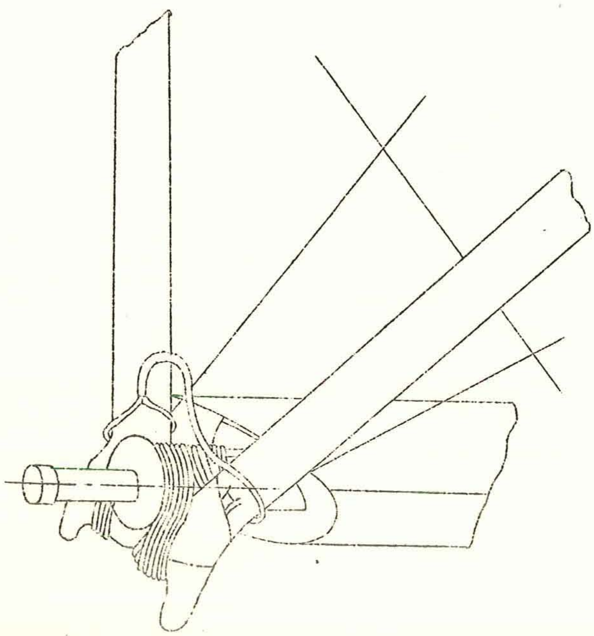

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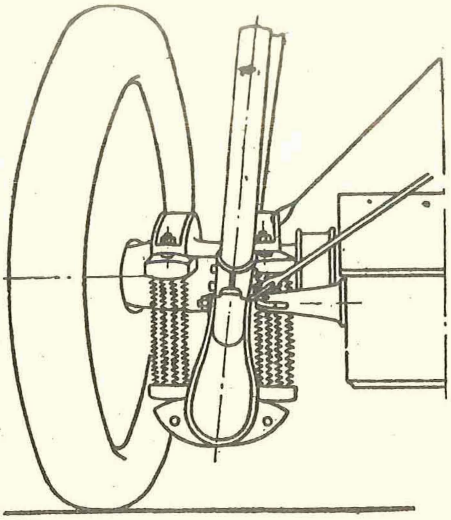

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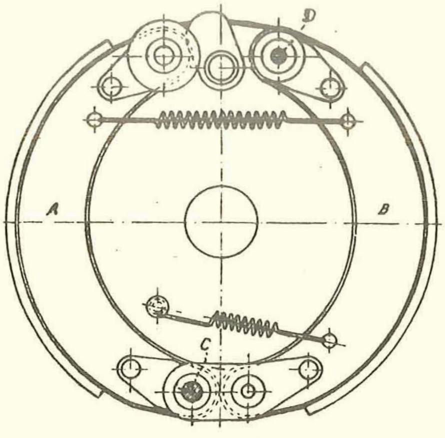

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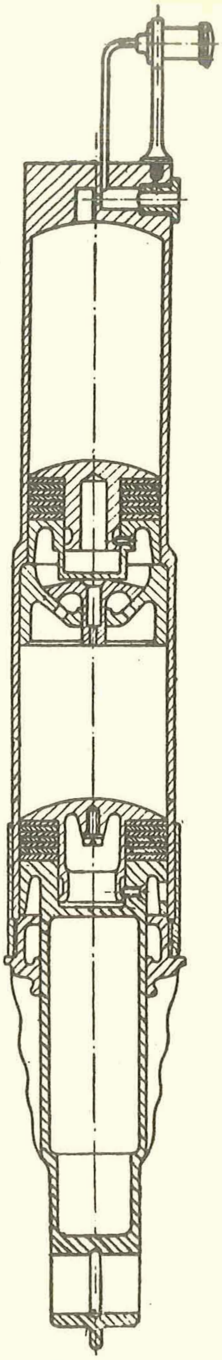

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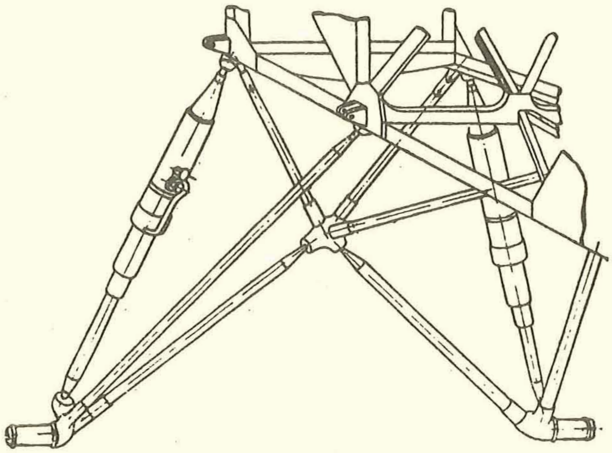

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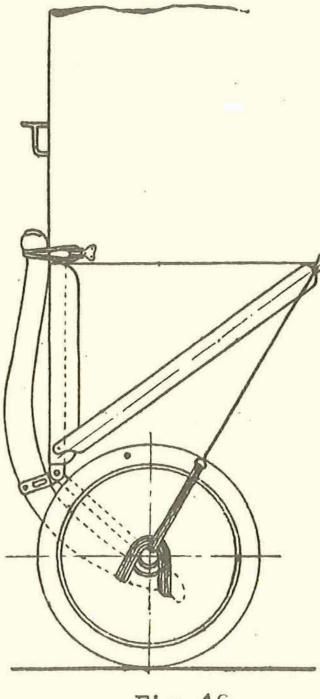

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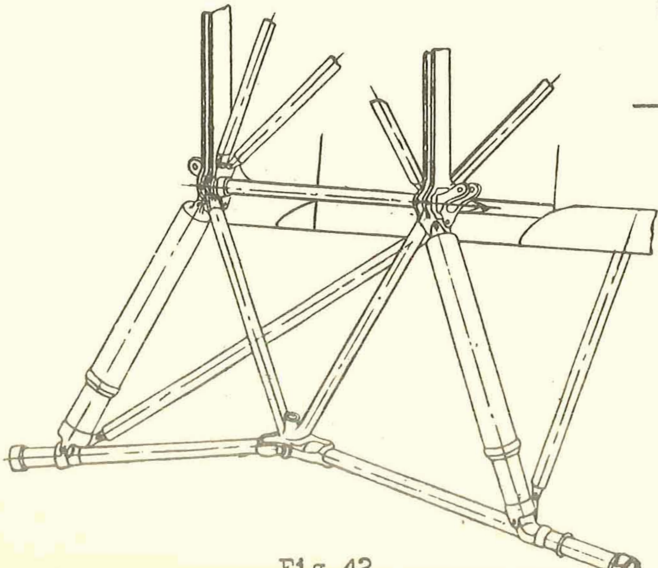

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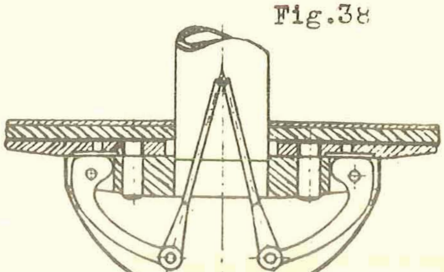

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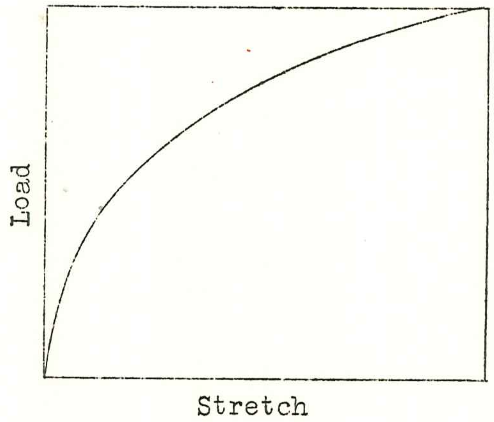

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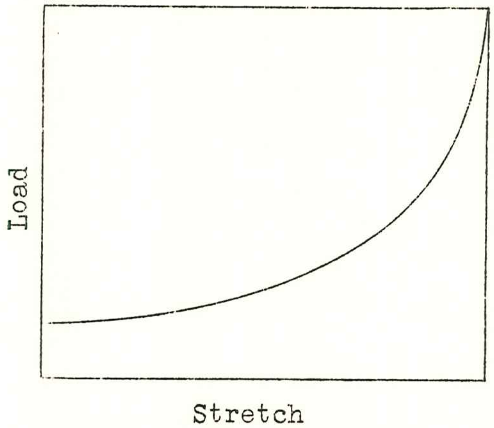

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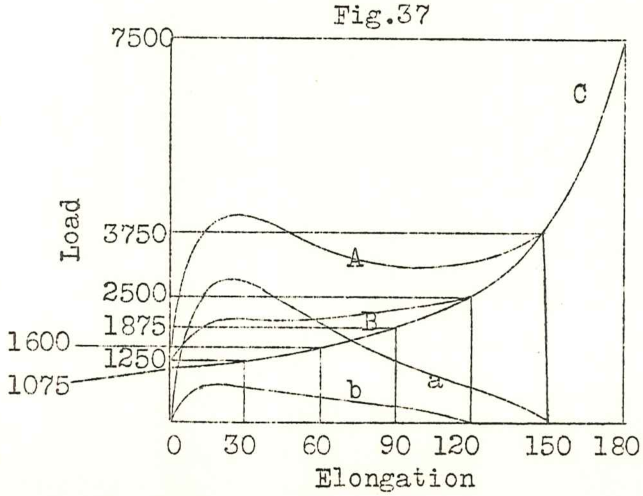

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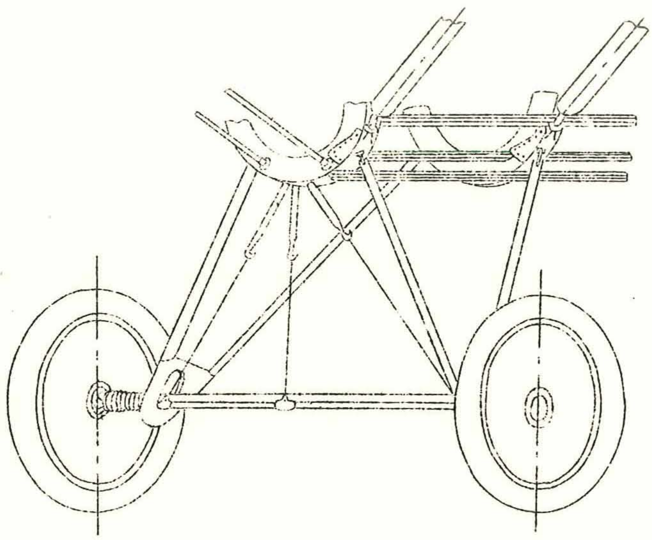

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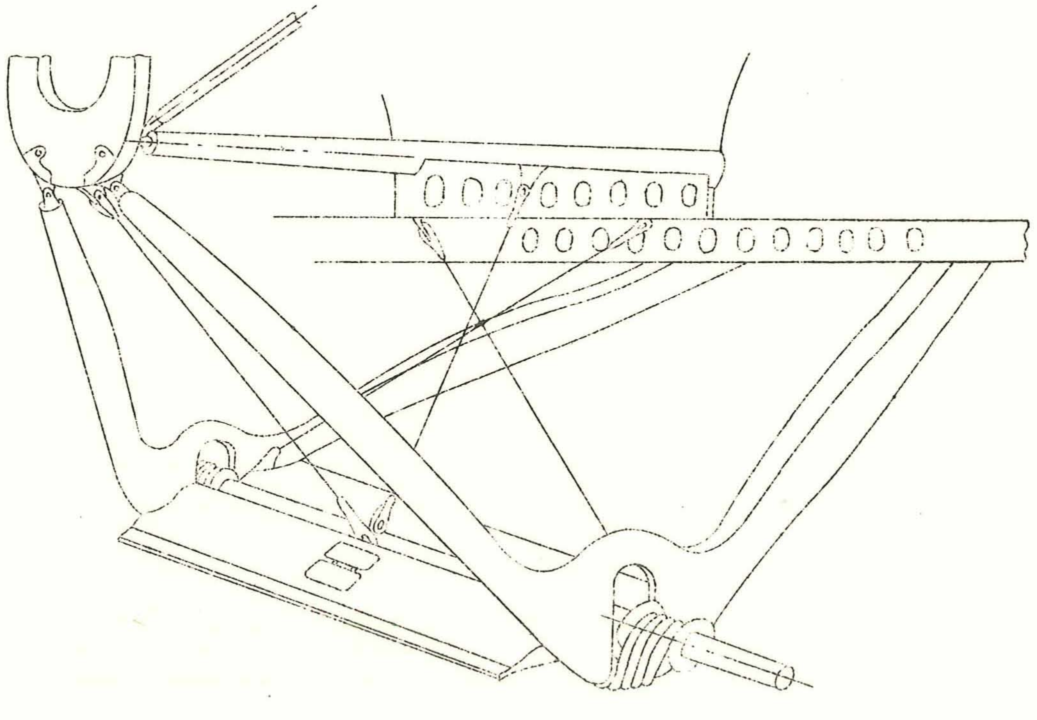

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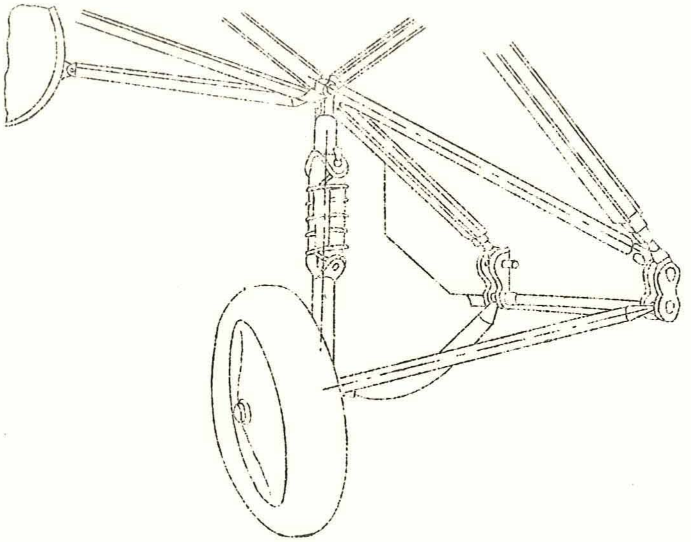

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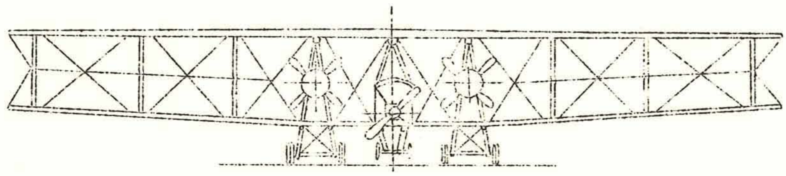

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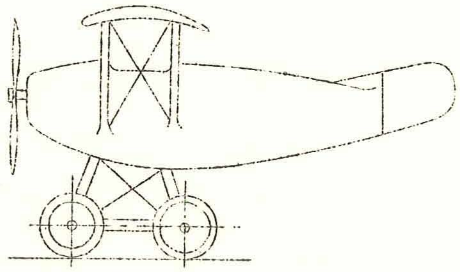

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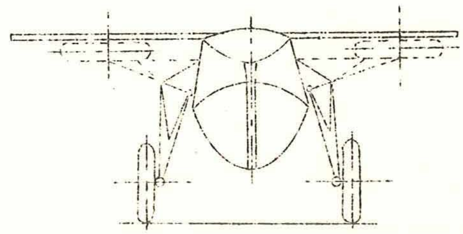

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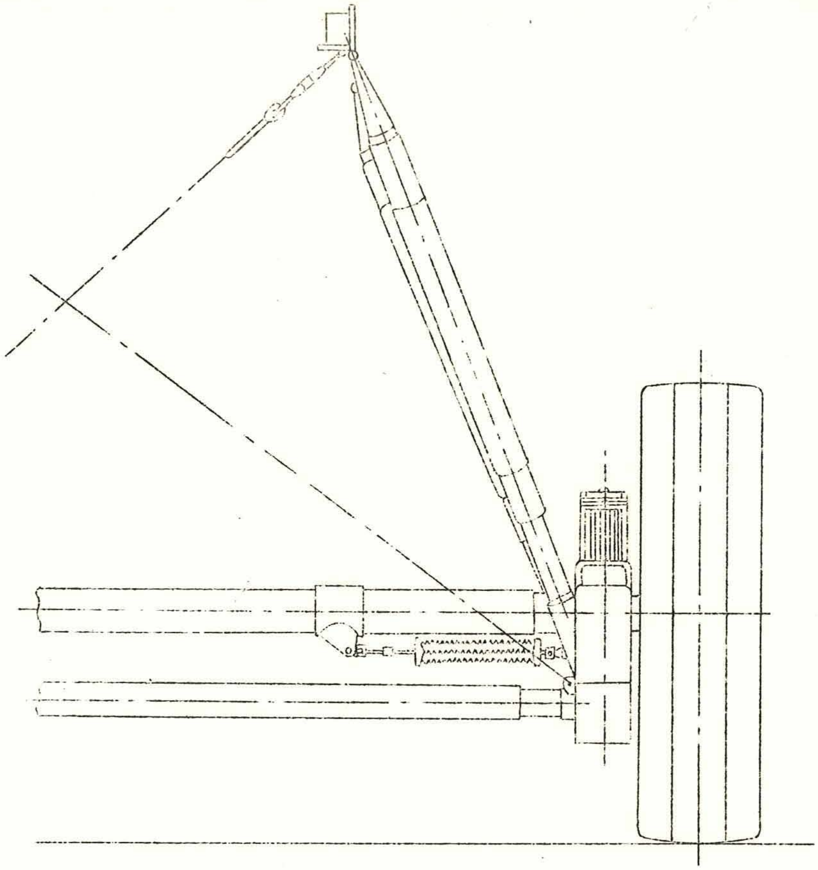


Fig.49

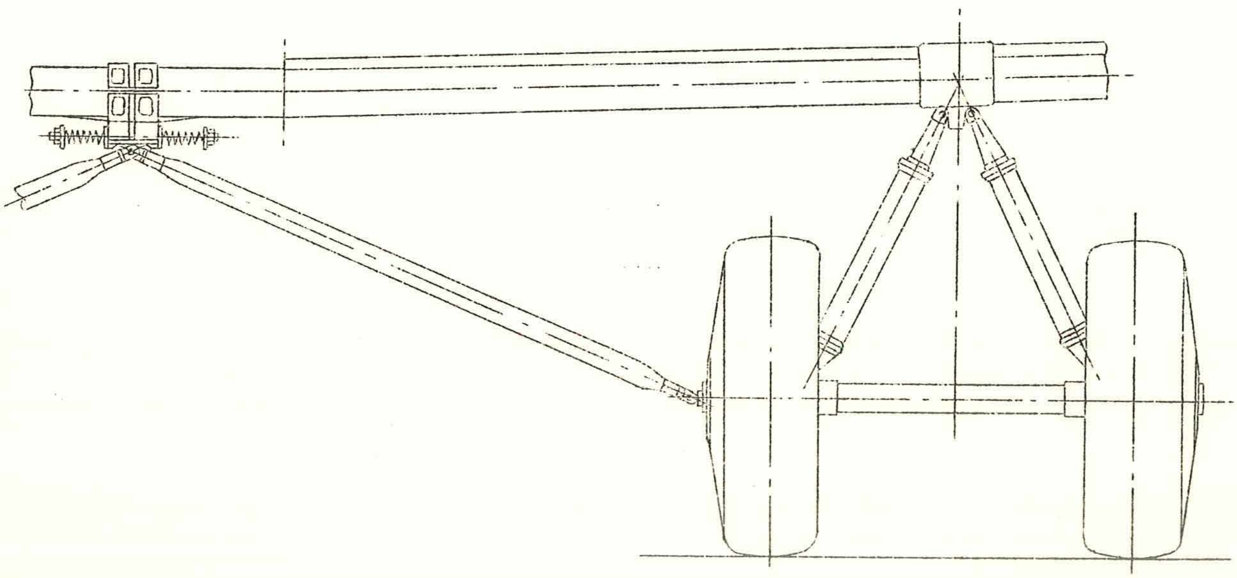


Fig.50

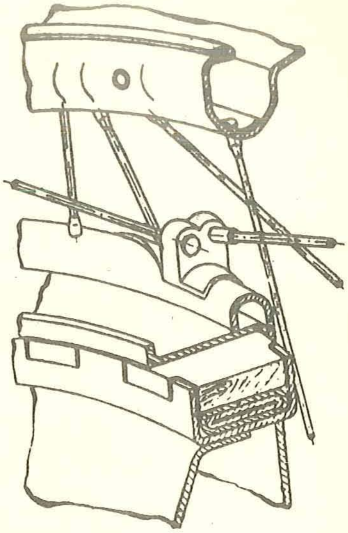


Fig.56

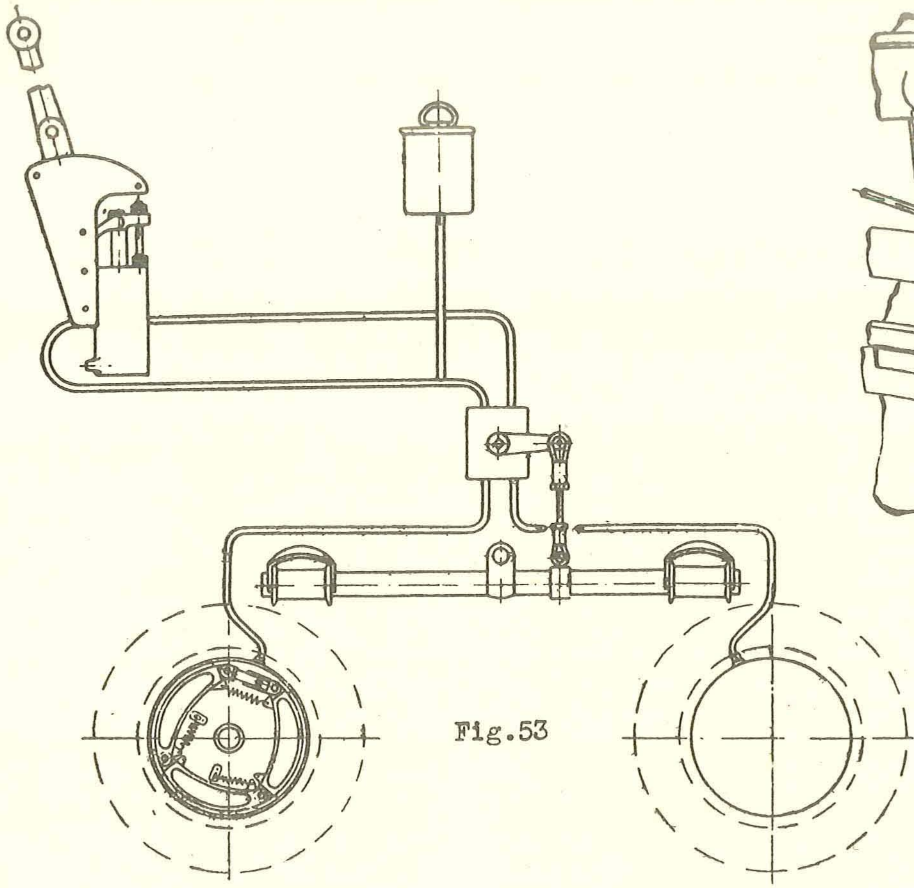


Fig.53

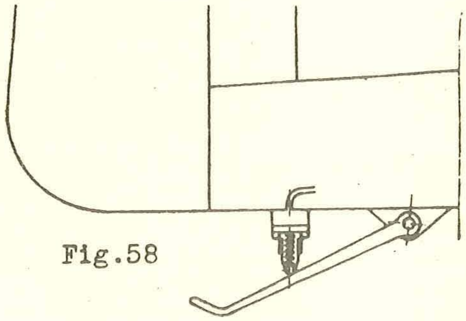


Fig.58

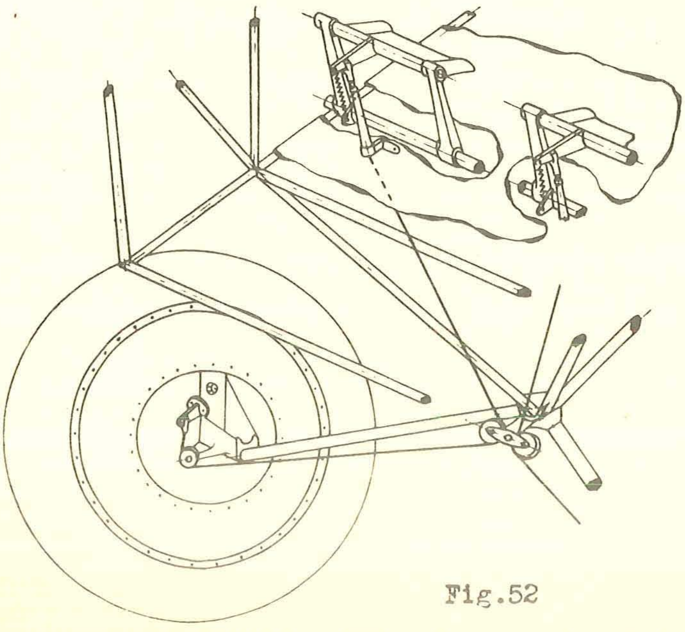


Fig.52

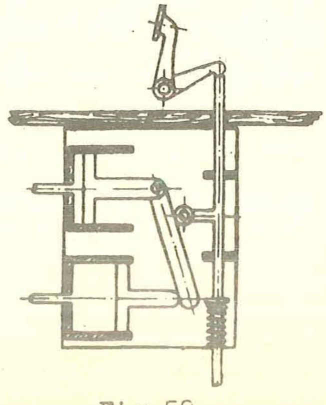


Fig.59

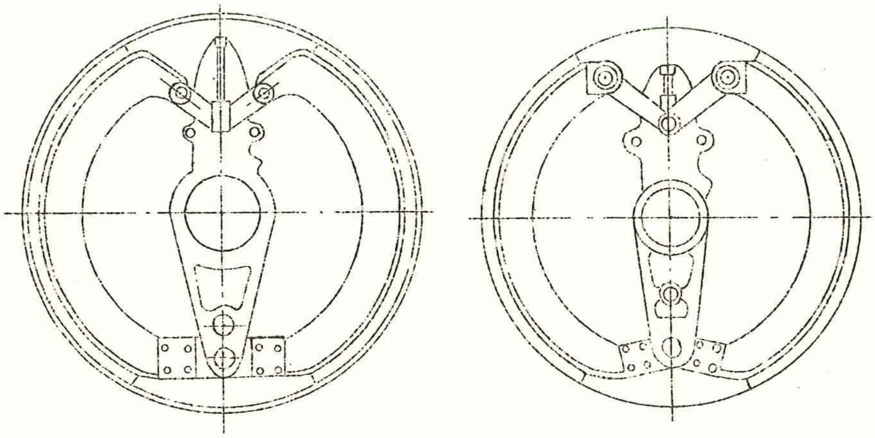


Fig.55

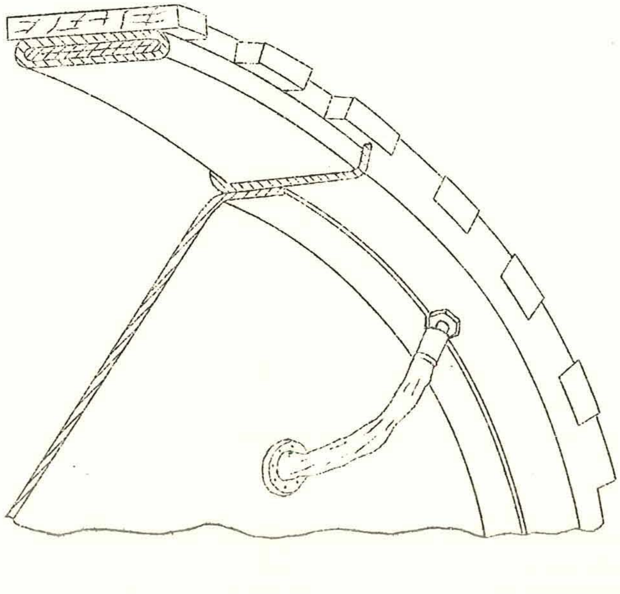


Fig.57

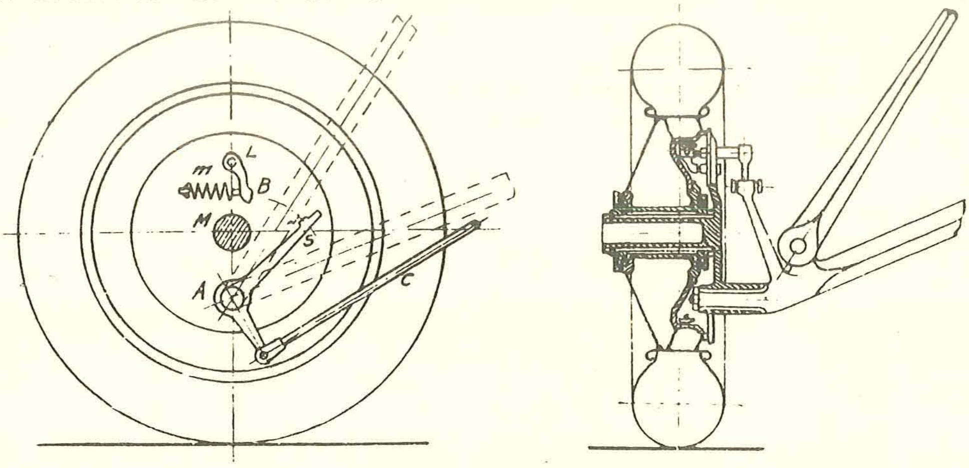


Fig.60

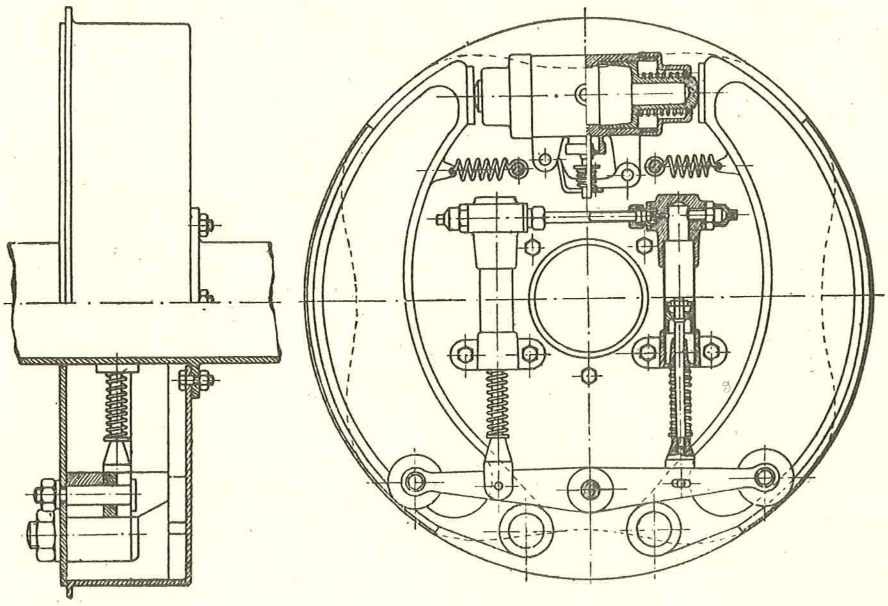


Fig.61

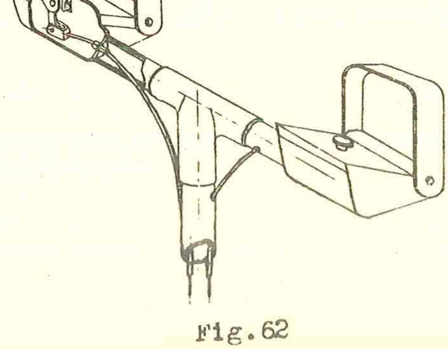


Fig.62

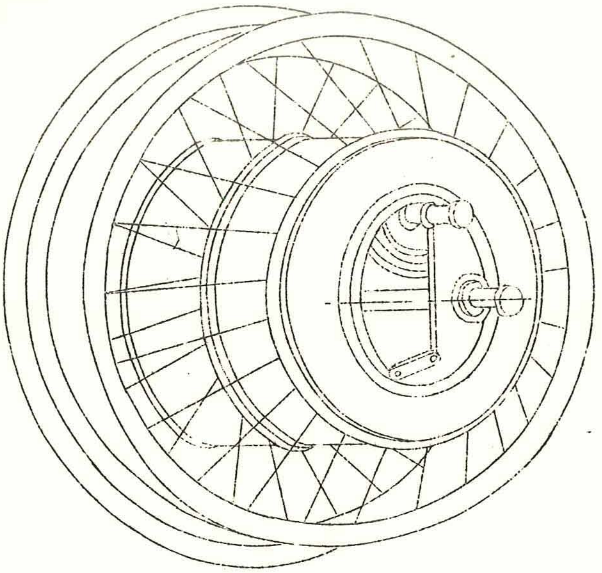


Fig.63

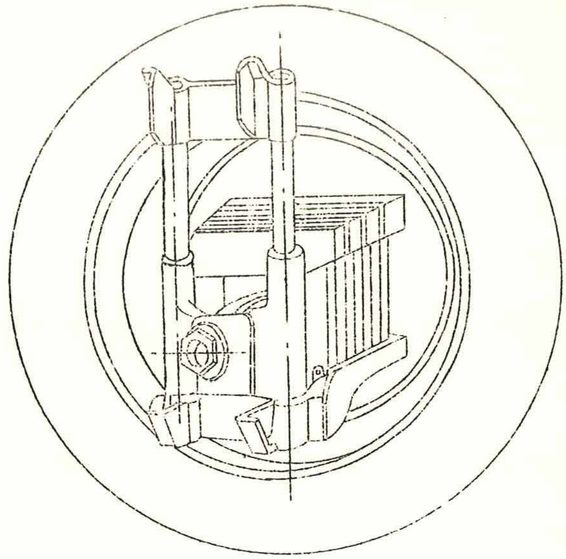


Fig.64

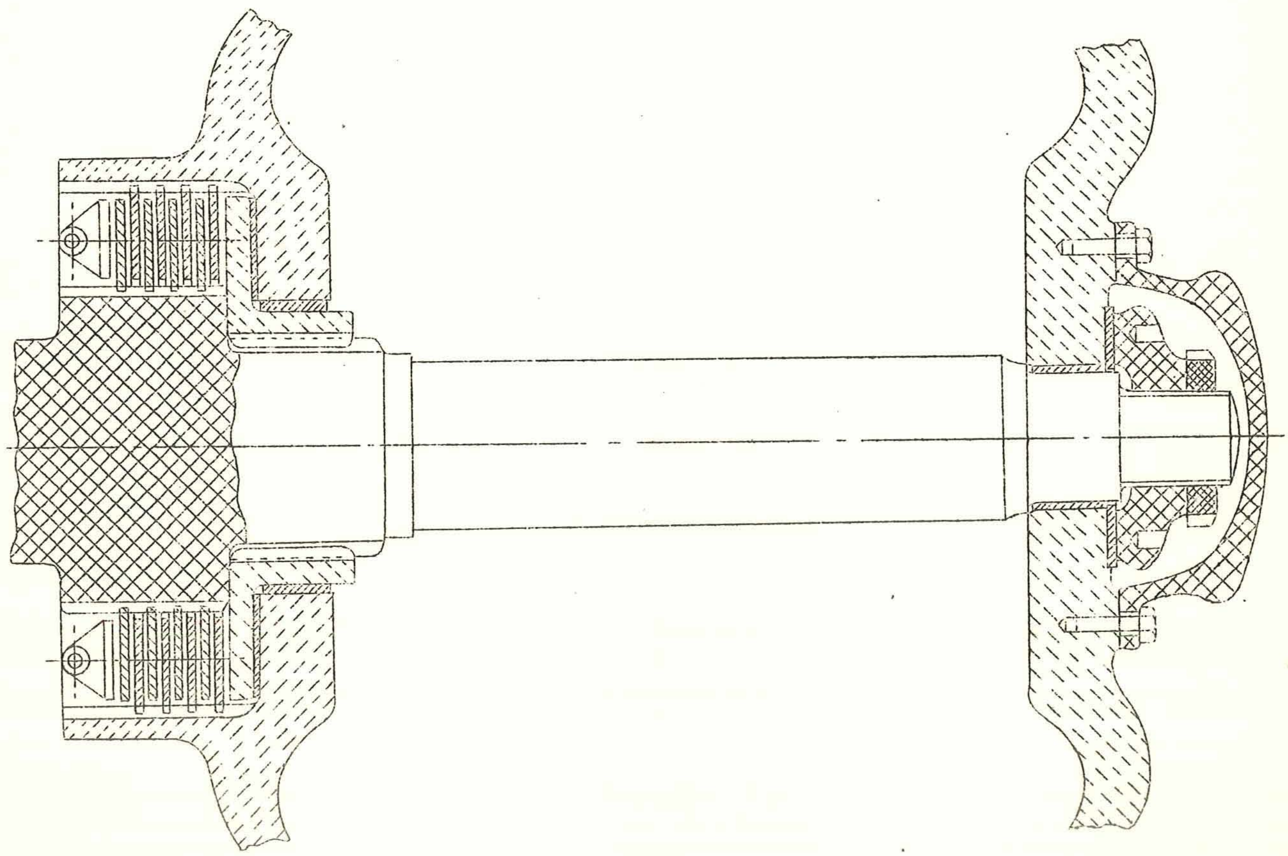


Fig.69

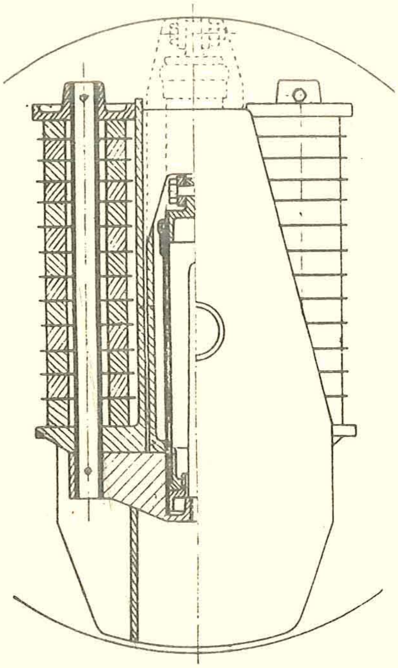


Fig.65

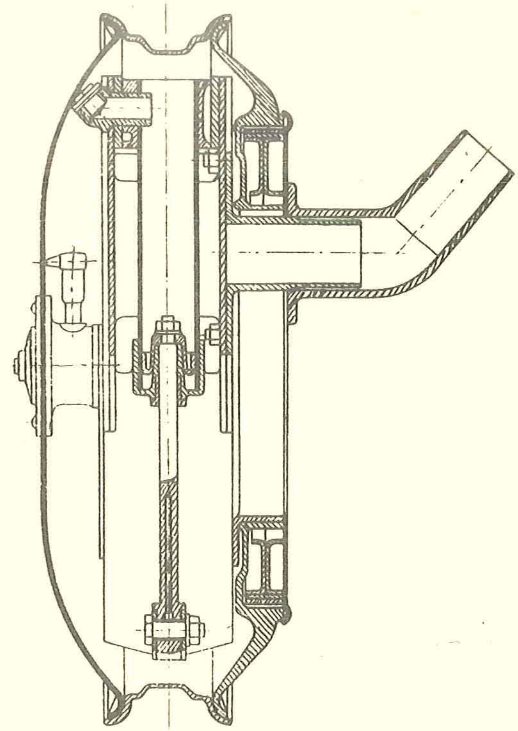
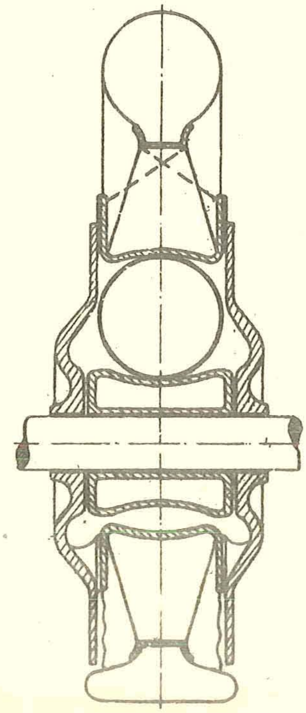


Fig.66



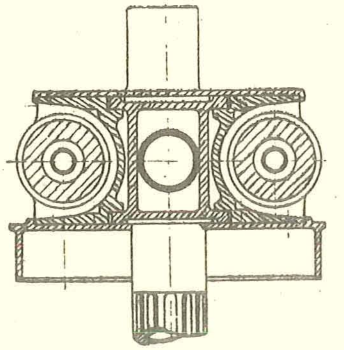


Fig.67

Fig.68

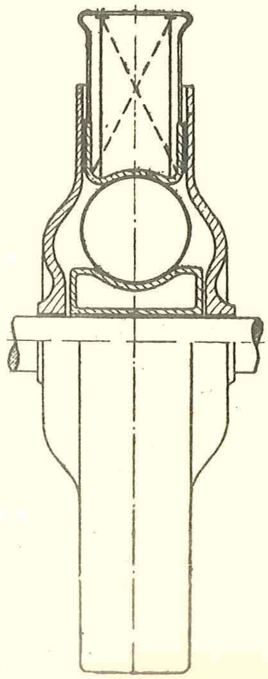


Fig.70