TECHNICAL NOTES.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 80.

THE DEAD WEIGHT OF THE AIRSHIP

and

THE NUMBER OF PASSENGERS THAT CAN BE CARRIED.

By

Colonel Crocco.

Extract from
the Transactions of the Aeronautical Experimental Institute
Rome, Italy, September, 1920.

January, 1922.

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Formula for Obtaining Weight of Dead Load.

In order to determine an approximate formula giving the weight of the dead load in function of the volume V of the envelope and of the maximum velocity v, we will take the relative weight of the various parts of the airships P^V, M, V, A, T^{34}, adopting a mean value of the coefficients determined.

This formula may be adopted both for semi-rigid airships with suspended nacelle and non-rigid envelope, with or without internal suspensions, and to airships with rigid longitudinal

* In 1913, comparing the effect of increase of dimensions in airplanes and airships, I demonstrated in a lecture given at the Congress of Civil Engineers, Rome ("The Catastrophe of the L.2 and the Future of Airships," Annals of the Society of Italian Engineers and Architects, No.5, March 1, 1914) that there was a fairly approximate limit of gain for the airplane, and that though such a limit was a little more extended for the airship it nevertheless existed.

Some years later, after the War, in a publication of the British Air Ministry, there appeared similar calculations showing the advisability of increasing the cubature of airships, without setting any limit to such increase. Wishing therefore to find a complete and practical solution of the problem by means of strict numerical calculations, we confided such calculations to Signor Primo Cellini, who from the very first, has made the computations for our airships. The result shows that there is an OPTIMUM value of the ratio between the useful load and the total load at about 270,000 cubic meters, and that practically the increase of cubature beyond this limit and even up to it, hardly compensates for the greater commercial risk incurred by the concentration of tonnage.

Extract from the Transactions of the Aeronautical Experimental Institute, Rome, Italy, (September, 1920).

beam, with power units on external supports or in nacelles, and with non-rigid envelopes, with or without internal bracing cables.

Weight of the envelope.- The envelope consists of various parts:

1st. Rubber on the outer reinforced part (about 0.200 kg. per square meter); its weight is proportional to the surface, ($V^{2/3}$).

2nd. Fabric of the outer reinforced part; its weight is proportional to the surface ($V^{2/3}$) and to the tension, which increases according to the pressure ($V^{1/3}$) and the diameter ($V^{1/3}$). Therefore the weight of the fabric increases as

$$V^{2/3} \quad V^{1/3} \quad V^{1/3} = V^{4/3}$$

3rd. The inside portion of the reinforced part (internal bracing cables) proportional to the Volume V.

4th. The diaphragms and butts proportional to their number n, and to the surface ($V^{2/3}$).

5th. Interior ballonet on beam, tubes, etc., proportional to the surface area ($V^{2/3}$).

N.B. For all the envelopes enumerated below, the volume of the ballonet = 0.5 of the envelope.

Airships	Volume	Rubber outer reinforced part		Fabric outer reinforced part	
	cu. m.	Weight kg.	Coefficients	Weight kg.	Coefficients
M^A	12100	705	$1.34\ V^{2/3}$	303	$0.00290\ V^{4/3}$
A	18000	975	$1.41\ V^{2/3}$	1060	$0.00226\ V^{4/3}$
T^{34}	36000	1550	$1.42\ V^{2/3}$	2700	$0.00227\ V^{4/3}$
Mean Coefficient			$1.39\ V^{2/3}$		$0.00227\ V^{4/3}$

Airships	Internal bracing cables.		Diaphragms and Butts		Inner Ballonet on beam, tubes etc.	
	Weight kg.	Coefficients	Weight kg.	Coefficients	Weight kg.	
M^A	160	$0.0132\ V$	300	$0.114\ n\ V^{2/3}$	600	$1.14\ V^{2/3}$
A	290	$0.0161\ V$	830	$0.112\ n\ V^{2/3}$	770	$1.12\ V^{2/3}$
T^{34}	585	$0.0162\ V$	1300	$0.120\ n\ V^{2/3}$	890	$0.90\ V^{2/3}$
Mean Coefficient		$0.0152\ V$		$0.115\ n\ V^{2/3}$		$1.09\ V^{2/3}$

When the volume of the ballonet = 0.5 that of the envelope, the mean weight of the envelope is given by:

$$1.39\ V^{2/3} + 0.00227\ V^{4/3} + 0.0152\ V + 0.115\ n\ V^{2/3} + 1.09\ V^{2/3} =$$

$$= 0.0152\ V + (0.115\ n + 2.48)V^{2/3} + 0.00227\ V^{4/3}$$

<u>Weight of Gas and Air Valves and their Controls</u>.- This weight is proportional to the volume V of the envelope, and from the mean value taken for the various airships it comes out at:

$$0.01\, V$$

<u>Weight of the reinforced armature</u>.- By reinforced armature we mean the whole of the parts which help in bearing the load given by

Volume - Weight of envelope and valves

or, the longitudinal beam, the nacelle suspensions with their brackets, the longitudinal girder, the reinforced sides of the nacelle and their suspension cables. The stresses in the beams of the armature are due partly to the bending moment and partly to shear, caused by the load carried : Volume-Weight of envelope and valves = $V - I$. The bending moment produces in the beam stresses proportional to the load $(V - I)$ and to the length of the bays $(V^{1/3})$ and inversely proportional to the height of the armature $(V^{1/3})$: that is, in all, proportional to

$$(V - I)\, \frac{V^{1/3}}{V^{1/3}} = V - I.$$

Shearing stresses are produced:

1st. In the beams and their diagonals proportional to the load, the bay, and the height, as for bending moments, therefore proportional to $V - I$.

2nd. In the struts proportional to the load $V - I$.

Therefore the stresses, and with them the weight of the reinforced armature (longitudinal beam, suspensions, the reinforced part of the bow and nacelle suspensions, the reinforced part of the longitudinal girder, the reinforced sides of the nacelle and their suspension tubes) are proportional to the remainder of the load:

Volume-Weight of envelope and valves = V - I.

	Airships		
	M(heavy)	T^{34}	V
Volume .... cu.m.	12000	36000	14650
Envelope and valves ..kg.	2690	7350	3575
V - I .... "	9310	28650	11075
Reinforced Armature .. "	1210	3750	1460
Coefficient	0.130 (V-I)	0.131(V-I)	0.132(V-I)

Mean Coefficient = 0.131 x (V - I)

which may also be written:

$$0.131 \left\{V - [0.01\ V + 0.0152\ V\ (0.115\ n + 2.48)V^{2/3} + 0.00237\ V^{4/3}]\right\}$$

$$= 0.131\ [0.9743\ V - (0.115\ n + 2.48)V^{2/3} - 0.00227\ V^{4/3}] =$$

$$= 0.1277\ V - (0.01506\ n + 0.325)\ V^{2/3} - 0.0002975\ V^{4/3}$$

<u>Weight of the Stiffened Part of the Bow.</u> - The weight of this is proportional to the bending moments which it has to support. These moments depend on the length of the stiffened part proportional to $V^{1/3}$, to the pressure of the wind on the surface, and

to the square of the velocity, that is, to $v^2V^{2/3}$.

From this it follows that the bending moments, and therefore the weight of the stiffened part, are proportional to

$$V^{1/3}\ v^2\ V^{2/3} = v^2\ V$$

N.B. - While in the airships P, M, A, and V, the stiffened part is separate from the beam and therefore resists alone the external pressure, leaning on the envelope, in the airship T the stiff ened part is incorporated with the beam on which it leans for resisting external pressure. In the T^{34} the weight indicated, 600 kg., is that of the cupola alone, as we cannot determine the weight of the beam which bears the resistance together with the stiffened part: the coefficient determined will therefore be less than the true one, and is not reckoned in determining the mean coefficient.

	Airships.		
	P^V	M^A	V
Volume cu.m.	5000	12100	15000
Speed km/h	86	76	82
Weight of stiffened part of bow kg.	66	120	180
Coefficient	$0.0000232\ v^2\ V$	$0.0000225\ v^2\ V$	$0.0000230\ v^2V$

	Airships	
	A	T^{34}
Volume cu.m.	18000	36000
Speed km/h	83	120
Weight of stiffened part of bow	215	600
Coefficient	$0.0000225\ v^2\ V$	$0.0000150\ v^2\ V$

Mean coefficient for P^V, M^A, V, A:

$$0.00002273\ v^2V \quad (v = \text{speed in m/sec.})$$

Weight of empennage.- The rotating couples of the empennage are proportional to the volume V and are equal to the product of the forces and their distance from the baricenter of the envelope. As the distances are proportional to $V^{1/3}$, the forces and consequently the surfaces of the empennage, and also the weight of the empennage, are proportional to:

$$\frac{V}{V^{1/3}} = V^{2/3}$$

N.B.- In order to deduce a coefficient, we must abstract from the lower reinforced keel the weight of the part considered as being incorporated with the reinforced armature. The rest of the weight of the empennage we add to the weight of the upper, lateral keels. In the weight of the rudders is included only the weight of the planes and frames.

	Airships			
	P^V	M^A	A	T^{34}
Volume .... cu.m.	5,000	12,100	18,000	36,000
Weight of keels ..... kg.	85	146	171	400
Coefficient	$0.29\ V^{2/3}$	$0.28\ V^{2/3}$	$0.25\ V^{2/3}$	$0.37\ V^{2/3}$
Weight of rudders kg.	185	340	460	600
Coefficient	$0.63\ V^{2/3}$	$0.65\ V^{2/3}$	$0.67\ V^{2/3}$	$0.55\ V^{2/3}$

Mean coefficient of keels = $0.30\ V^{2/3}$

" " rudders = $0.62\ V^{2/3}$

Weight of Engine Sets.- In the engine sets, or power plant, are included: engines, radiators, tubes, water, oil, controls, propeller and longerons. Since head resistance varies according to the square of the speed and area $(v^2V^{2/3})$ and power according to $v\ v^2V^{2/3} = v^3V^{2/3}$, the weight of the power plant will vary according to:

$$v^3\ V^{2/3}$$

	Airships.	
	P^V	M with wooden nacelle
Volume .... cu.m.	5,000	12,100
Speed .... km/h	86	83
Power .... H.P.	420	630
Weight of plant kg.	780	1170
Coefficient	$0.000189\ v^3V^{2/3}$	$0.000176\ v^3V^{2/3}$

	Airships	
	A	T^{34}
Volume ....cu.m.	18,000	36,000
Speed .... km/h	86	120
Power .... H.P.	1050	3700
Weight of plant kg.	1950	4960
Coefficient	$0.000200\ v^3\ V^{2/3}$	$0.000123\ v^3\ V^{2/3}$

As the airships P^V, M, and A, have suspended nacelles and are similar in type, we may deduce from them the mean coefficient for their type:

$$0.000188\ v^3\ V^{2/3}\ (v = \text{speed per m/sec.})$$

while the T^{34}, a rigid type in which only the engine set juts out, is therefore more penetrating than the preceding and has a smaller coefficient:

$$0.000123\ v^3\ V^{2/3}\ (v = \text{speed per m/sec.})$$

If, instead, we wish to have a coefficient in function of HP only, and given that all the above-named airships have light engines (about 1 kg. per HP) with wooden propellers in direct transmission, the weight of the power plant will be about:

1,900 kg. per HP.

Weight of Supports of Power Plant.- By supports we mean: transversal bridges, external supports, engine nacelles and the part relating to the power plant only in mixed nacelles. The mean for the foregoing airships in function of HP gives

0.350 kg. per HP

Weight of the Pilot's Cabin.- This may be taken as about proportional to the volume:

$$0.013\ V$$

Weight of the Mooring Cables and Holding Devices.- This may also be taken as proportional to the volume:

$$0.01\ V$$

Total Weight of Dead Load. - From the sum of the foregoing coefficients we have the following formula, which gives approximately the total weight of the dead load in kg.:

$$P = (0.1759 + 0.00002275\ v^2)V + (0.09994\ n + 3.075)V^{2/3} +$$

$$+ 0.0019725\ V^{4/3} + (\text{number HP})2.150$$

N.B.- As we said at the beginning, such formulas are meant to be taken as approximations, for we cannot say definitely that, with increase of cubature, the weight of the various parts of the dead load will increase exactly according to the coefficients given. In the development of the details of each project various problems may arise, the solution of which may cause increase or decrease of the weight calculated by the formula. However, the values obtained by the formula are always good for a preliminary study.

Weight of Dead Load for Various Cubatures.

In order to determine the weight of the dead load* for various cubatures, we will suppose that we have a profile of envelope with an aspect ratio of about 1/6, 10 diaphragms, and a maximum speed of 120 km/h. For the whole airship we will assume that the head resistance expressed in kg. is equal to:

$$R = 0.008\ S\ v^2$$

where v = speed per m/sec. and S the cross section in square meters at the point of greatest diameter. This section may be taken as

$$S = 0.318\ V^{2/6}$$

* This determination is much influenced by the characteristics of the airship (maximum speed, coefficient of resistance, etc.). For the present, we shall confine ourselves to the study of a type having average characteristics.

and we therefore have:

$$R = 0.00302\ V^{2/3}\ v^2$$

The useful power in kilogrammeters will be:

$$L = 0.00302\ V^{2/3}\ v^3$$

and the motive power in HP for a propeller efficiency = 0.7 will be:

$$HP = 0.0000576\ V^{2/3}\ v^3$$

With a maximum velocity of 120 km/h., the motive power in HP for the various cubatures will be:

Volume	Power in HP		Volume	Power in HP	
	Total	Per cu.m.		Total	Per cu.m.
50,000	2,900	0.0580	250,000	8,470	0.0338
100,000	4,600	0.0460	300,000	9,570	0.0319
150,000	6,020	0.0401	350,000	10,600	0.0303
200,000	7,300	0.0365	400,000	11,570	0.0289

and the weight of the dead load will be as follows:

Total and Unit Weight (per cubic meter) of the Envelope and Its Parts.

10 Diaphragms. Volume of Ballonet = 0.5 that of the envelope.

Volume	Outer Rubber		Outer Fabric (reinforcing)		Internal Suspension (reinforcing)	
cu. m.	Total kg.	Unit kg.	Total kg.	Unit kg.	Total kg.	Unit kg.
50,000	1,890	0.0378	4,200	0.0840	760	0.0152
100,000	3,000	0.0300	10,600	0.1060	1,520	0.0152
150,000	3,930	0.0262	18,120	0.1208	2,280	0.0152
200,000	4,765	0.0238	26,620	0.1331	3,040	0.0152
250,000	5,520	0.0221	35,780	0.1432	3,800	0.0152
300,000	6,245	0.0208	45,750	0.1525	4,560	0.0152
350,000	6,910	0.0197	56,100	0.1603	5,320	0.0152
400,000	7,565	0.0189	67,200	0.1680	6,080	0.0152

Volume	Diaphragms and Butts		Internal Ballonet on Beam Tubes, etc.		Total Weight	
cu. m.	Total kg.	Unit kg.	Total kg.	Unit kg.	Total kg.	Unit kg.
50,000	1,565	0.0318	1,485	0.0297	9,900	0.1980
100,000	2,485	0.0248	2,355	0.0235	19,960	0.1996
150,000	3,250	0.0217	3,080	0.0205	30,660	0.2042
200,000	3,940	0.0197	3,735	0.0186	42,100	0.2105
250,000	4,565	0.0183	4,330	0.0173	53,995	0.2160
300,000	5,165	0.0172	4,000	0.0163	66,620	0.2220
350,000	5,715	0.0163	5,420	0.0155	79,465	0.2270
400,000	6,260	0.0157	5,930	0.0148	93,035	0.2326

Total and Unit Weight (per cubic meter) of Dead Load

for a maximum velocity of 120 km/h. (33.3 m/sec.).

Volume cu.m.	Envelope with 10 Diaphr. Total kg.	Envelope with 10 Diaphr. Unit kg.	Gas & Air Valves and Controls. Total kg.	Gas & Air Valves and Controls. Unit kg.	Reinforcing Armature Total kg.	Reinforcing Armature Unit kg.
50,000	9,900	0.1980	500	0.010	5,190	0.1038
100,000	19,960	0.1996	1,000	0.010	10,350	0.1035
150,000	30,660	0.2042	1,500	0.010	15,450	0.1030
200,000	42,100	0.2105	2,000	0.010	20,400	0.1020
250,000	53,995	0.2160	2,500	0.010	25,350	0.1014
300,000	66,620	0.2220	3,000	0.010	30,200	0.1006
350,000	79,465	0.2270	3,500	0.010	35,000	0.1000
400,000	93,035	0.2326	4,000	0.010	39,700	0.0992

Volume cu.m.	Stiffened Part of the Bow Total kg.	Stiffened Part of the Bow Unit kg.	Keels Total kg.	Keels Unit kg.	Rudders Total kg.	Rudders Unit kg.
50,000	1,260	0.0252	410	0.00820	845	0.01690
100,000	2,520	0.0252	650	0.00650	1,340	0.01340
150,000	3,780	0.0252	850	0.00567	1,750	0.01167
200,000	5,045	0.0252	1,030	0.00515	2,120	0.01060
250,000	6,305	0.0252	1,190	0.00476	2,460	0.00984
300,000	7,560	0.0252	1,350	0.00450	2,785	0.00928
350,000	8,820	0.0252	1,490	0.00420	3,080	0.00880
400,000	10,090	0.0252	1,630	0.00407	3,370	0.00842

Total and Unit Weight (per cubic meter) of Dead Load

for a Maximum Velocity of 120 km/h. (33.3 m/sec.)

Volume cu.m.	Engine Set Total kg.	Engine Set Unit kg.	Supports of Power Plant Total kg.	Supports of Power Plant Unit kg.	Cabin Control and Passengers. Total kg.	Cabin Control and Passengers. Unit kg.
50,000	5,510	0.1102	725	0.0145	650	0.013
100,000	8,740	0.0874	1,150	0.0115	1,300	0.013
150,000	11,440	0.0763	1,505	0.0100	1,950	0.013
200,000	13,880	0.0694	1,825	0.0091	2,600	0.013
250,000	16,100	0.0644	2,120	0.0084	3,250	0.013
300,000	18,200	0.0606	2,390	0.0079	3,900	0.013
350,000	20,120	0.0575	2,650	0.0076	4,550	0.013
400,000	22,000	0.0550	2,890	0.0072	5,200	0.013

Volume cu.m.	Mooring Cables Total kg.	Mooring Cables Unit kg.	Dead Load Total kg.	Dead Load Unit kg.
50,000	500	0.010	25,490	0.510
100,000	1,000	0.010	48,010	0.480
150,000	1,500	0.010	70,385	0.469
200,000	2,000	0.010	93,000	0.465
250,000	2,500	0.010	115,770	0.463
300,000	3,000	0.010	139,005	0.463
350,000	3,500	0.010	162,175	0.464
400,000	4,000	0.010	185,915	0.465

From Figs. 1 and 2 it follows that the unit weight of the envelope increases with the increase of cubature owing to the fabric of the external reinforcing part, and that, increasing the cubature up to about 200,000 m., there is an appreciable gain in the unit weight of the dead load, although this cubature gives a slightly diminished unit weight and reaches a minimum between 250,000 and 300,000 cubic meters.

Number of Passengers for a Given Flight.

As we have said, by dead load we mean the whole of the essential parts of the structure; then, according to the duration and object of the journey, must be taken on board navigating instruments, the crew, the passengers, cabins, foodstuffs, baggage, tanks for ballast and fuel, etc.; in short, all that constitutes the load to be carried and which, varying from time to time, forms, together with the dead load, the fixed load.

As a first approximation, we may take the weight (in kg.) of the load which can be carried as follows:

Gangway	= $12\ V^{1/3}$
Wireless Set	= 200 kg.
Generating Set and Electric Lighting	= $6.5\ V^{1/3}$
Engine Spare Parts and Tools . . .	= 0.1 (No. of HP)
Tanks for fuel and liquid ballast contained therein if not under pressure; 10% if under pressure.	= 7% of the liquid

Cabins and furniture for crew and passengers = 25 kg. per person.

Minimum Crew:

1 First Commander.

1 Second Commander.

1 Chief Pilot.

2 Pilots (Steersmen).

2 " (for elevator).

1 Head Driver.

$$\frac{\text{Power HP}}{500} = \text{Number of drivers (1 for each 500 HP).}$$

2 Wireless Operators.

4 Mechanics and Riggers.

$14 + \frac{HP}{500}$ average weight of each . . . . 75 kg.

Passengers, average weight of each . . . . 75 kg.

Baggage per person (crew and passengers) each . . 25 kg.

Food and water per person for 24 hours . . . . 3 kg.

We will now suppose that a distance of 5,000 km. is to be covered in calm weather, at a cruising speed of 95 km/h. at half power (53 hours' sailing) and we wish to know how many passengers can be carried for the different cubatures. We will take:

1.100 kg. the lifting force of the gas per cubic meter.

0.250 " hourly consumption of fuel per HP.

0.050 " liquid ballast available per 1 cubic meter of ga

The total weight per passenger carried will be:

Passenger	75 kg.
Cabin	25 "
Baggage	25 "
Food for two days	6 "
Total	131 "

The following Table gives the weight of the various parts of the useful load and fuel, and the number of passengers which can be carried.

Weight of Fuel, of the Various Parts of Possible Load and Number of Passengers.

Volume cu.m.	Lifting Force 1 cu.m.= 1.1 kg.	Dead Load kg.	Ballast kg.	Fuel for 53 h Flight at half power kg.	Gangway kg.	Wireless Set kg.
50,000	55,000	25,490	2,500	19,200	440	200
100,000	110,000	48,010	5,000	30,500	560	200
150,000	165,000	70,380	7,500	39,900	640	200
200,000	220,000	93,000	10,000	48,350	700	200
250,000	275,000	115,770	12,500	56,120	760	200
300,000	330,000	139,000	15,000	63,400	800	200
350,000	385,000	162,170	17,500	70,250	850	200
400,000	440,000	185,910	20,000	76,350	890	200

Volume cu.m.	Generating Set kg.	Engine Spare Parts kg.	Tanks for Ballast & Fuel kg.	Crew Number	Crew Weight kg.
50,000	240	290	1,520	20	1,500
100,000	300	460	2,480	23	1,730
150,000	350	600	3,320	26	1,950
200,000	380	730	4,080	29	2,180
250,000	410	850	4,800	31	2,320
300,000	440	960	5,490	33	2,480
350,000	460	1060	6,140	35	2,630
400,000	480	1160	6,770	37	2,770

Weight of Fuel of the Various Parts of Possible Load

and Number of Passengers.

Volume cu.m.	Cabin kg.	Baggage kg.	Food for Crew for 2 Days. kg.	Total Weight kg.	Remaining Lifting Force kg.
50,000	500	500	120	52,500	3,500
100,000	580	580	140	90,540	19,460
150,000	650	650	160	126,300	38,700
200,000	730	730	180	161,260	58,740
250,000	780	780	190	195,480	79,520
300,000	830	830	200	229,630	100,370
350,000	880	880	210	263,230	121,770
400,000	930	930	220	296,910	143,090

Volume cu.m.	Number of Passengers	Weight of Passengers	Weight of Cabin kg.	Weight of Baggage kg.	Weight of Foodstuffs kg.
50,000	19	1,420	480	480	120
100,000	148	11,100	3,730	3,730	900
150,000	295	22,150	7,390	7,390	1,770
200,000	448	33,630	11,210	11,210	2,690
250,000	607	45,540	15,170	15,170	3,640
300,000	766	57,470	19,150	19,150	4,600
350,000	930	69,730	23,230	23,230	5,580
400,000	1,092	81,930	27,300	27,300	6,560

The following table is made up from the preceding.

Volume cu. m.	Volume of Gas per passenger cu. m.	Weight of Fuel per passenger/km, kg.	Number of Passengers per 1000 cu. m.
50,000	2,630	0.2020	0.38
100,000	676	0.0412	1.48
150,000	508	0.0270	1.97
200,000	446	0.0216	2.24
250,000	412	0.0186	2.43
300,000	392	0.0166	2.55
350,000	376	0.0152	2.66
400,000	366	0.0140	2.73

From Fig. 3, we see that for a given length of flight, there is much advantage in increasing the cubature, both on account of the greater number of passengers per unit volume, which means a smaller cubature per passenger, and also on account of the smaller weight of fuel per passenger, which means a lower rate of transport. In the case considered of a trip of 5,000 km., there is an appreciable advantage in increasing the cubature up to 200,000 cubic meters, as was already stated for the unit weight of the dead load, but beyond that cubature the advantage is smaller.

Translated by Paris Office, N.A.C.A.

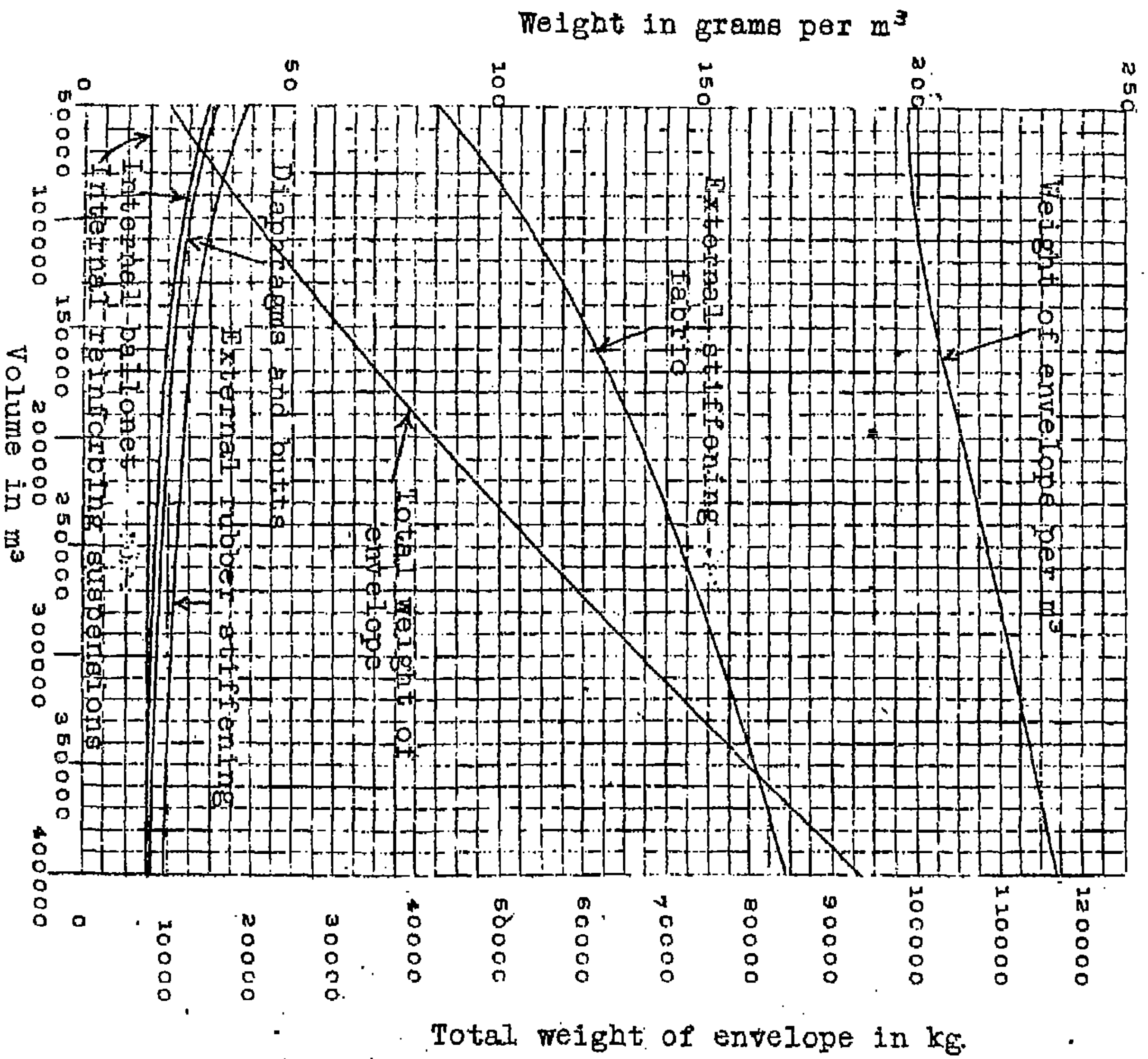
Weight in grams per m³
0
50
100
150
200
250
Weight of envelope per m³
External stiffening fabric
Total weight of envelope
Diaphragms and butts
External rubber stiffening
Internal ballonet
Internal reinforcing suspensions
Volume in m³
50000
100000
150000
200000
250000
300000
350000
400000
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
110000
120000
Total weight of envelope in kg.

Fig. 1

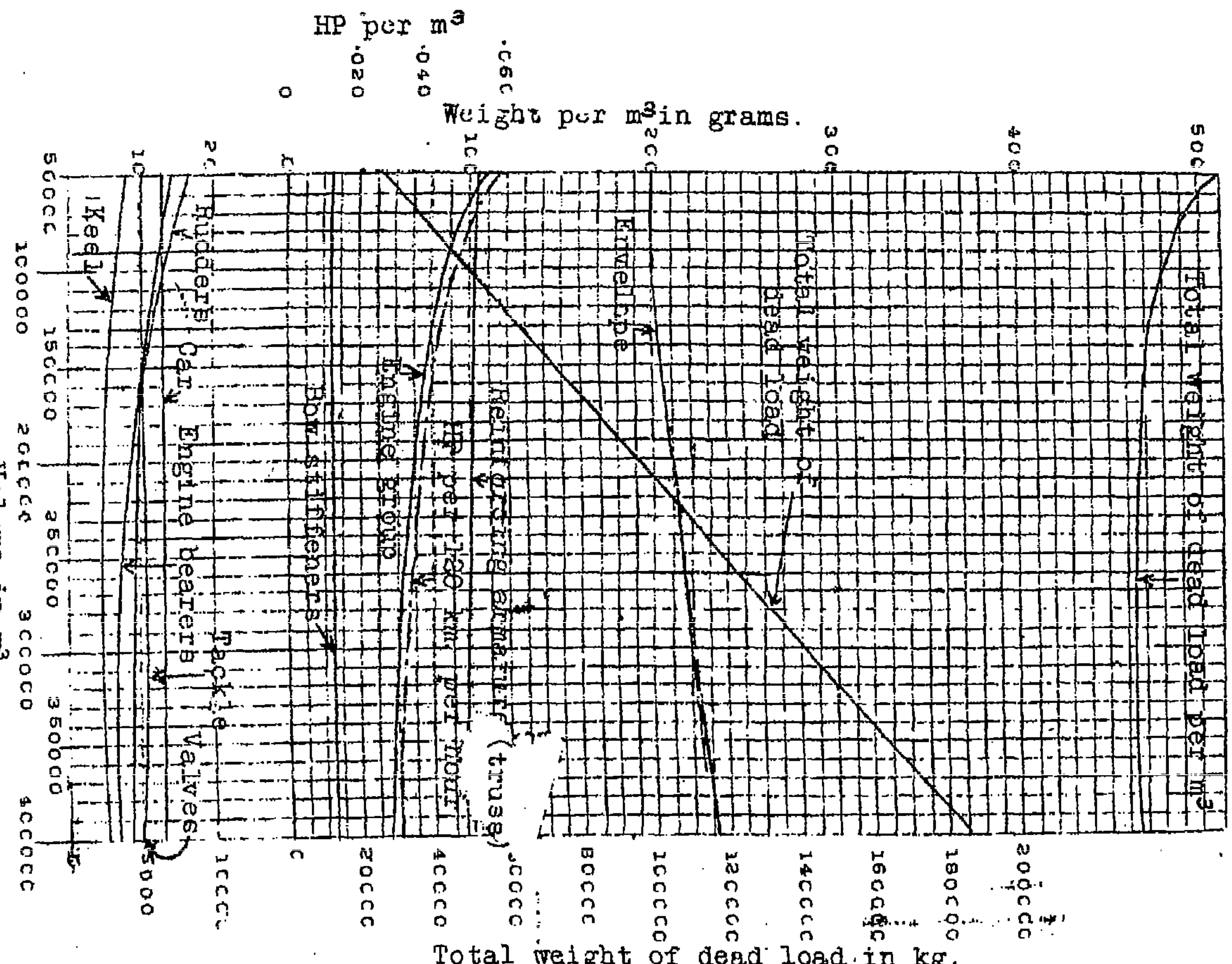
HP per m³
Weight per m³ in grams.
Total weight of dead load in kg.
Volume in m³
Keel
Rudders
Car
Engine bearers
Tackle
Valves
Bow stiffeners
Engine group
HP per 120 km per hour
Reinforcing girder (truss)
Envelope
Total weight of dead load
Total weight of dead load per m³

Fig. 2.

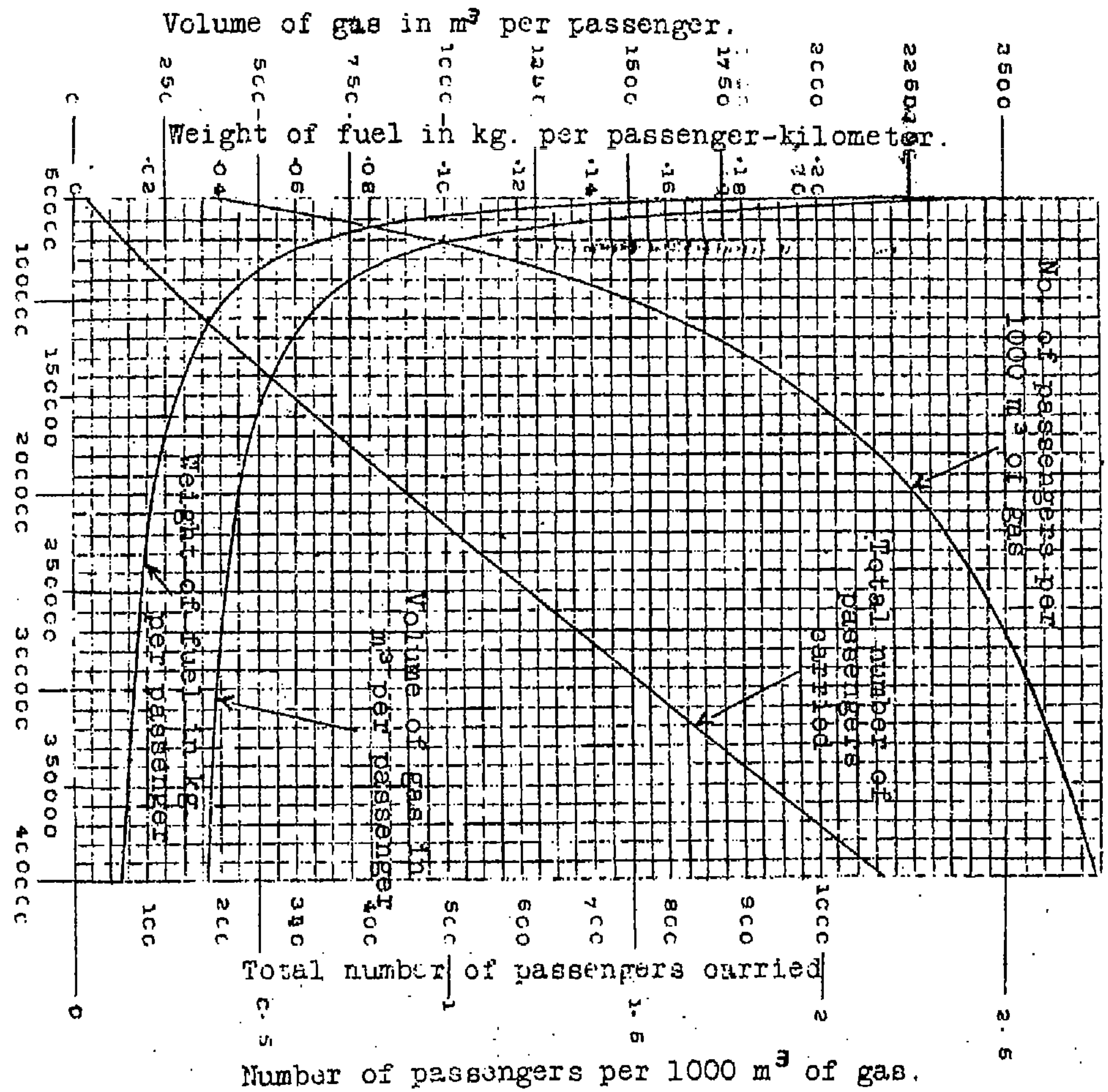
Volume of gas in m³ per passenger.
Weight of fuel in kg. per passenger-kilometer.
Volume in m³
Total number of passengers carried
Number of passengers per 1000 m³ of gas.
No. of passengers per 1000 m³ of gas
Total number of passengers carried
Volume of gas in m³ per passenger
Weight of fuel in kg per passenger

Fig. 3.