

N O T I C E

THIS DOCUMENT HAS BEEN REPRODUCED FROM
MICROFICHE. ALTHOUGH IT IS RECOGNIZED THAT
CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED
IN THE INTEREST OF MAKING AVAILABLE AS MUCH
INFORMATION AS POSSIBLE

THE DEVELOPMENT OF THE ZEPPELIN DIRIGIBLE
FOR LONG DISTANCE TRANSPORTATION

Albert Ehrle

Translation of In: Dritte Oeffedntliche Sitzung der Deutschen
Akademie der Luftfahrtforschung am 17 June 1938, zum Gedenken an die
hundertste Wiederkehr des Geburtstages des Grafen Zeppelin, Gerlin,
1938, pp 33-47

(NASA-TM-76143) THE DEVELOPMENT OF THE
ZEPPLIN DIRIGIBLE FOR LONG DISTANCE
TRANSPORTATION (National Aeronautics and
Space Administration) 18 p HC A02/MF A01

N80-27303

Unclas
CSCL 01C G3/03 28023



STANDARD TITLE PAGE

1. Report No. NASA TM-76143	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle THE DEVELOPMENT OF THE ZEPPELIN DIRIGIBLE FOR LONG DISTANCE TRANSPORTATION		5. Report Date April 1980	6. Performing Organization Code
		8. Performing Organization Report No.	10. Work Unit No.
7. Author(s) Albert Ehrle		11. Contract or Grant No. NASw-3199	13. Type of Report and Period Covered Translation
		14. Sponsoring Agency Code	
9. Performing Organization Name and Address Leo Kanner Associates, Redwood City California		12. Sponsoring Agency Name and Address National Aeronautics and Space Administration, Washington, D.C. 20546	
15. Supplementary Notes Translation of In: Dritte Oeffedntliche Sitzung der Deutschen Akademie der Luftfahrtforschung am 17 Juni 1938, zum Gedenken an die hundertste Wiederkehr des Geburtstages des Grafen Zeppelin, Berlin, 1938, pp 33-47			
16. Abstract In the last decade regular passenger transportation across the ocean was established in Germany with dirigibles, first to South America and then also to North America. This was the beginning for extensive plans and the development in dirigible construction received new impulses. The explanation of technical problems to be solved is preceded here by a survey of the path taken in constructing dirigibles for long-distance transport up to now.			
17. Key Words (Selected by Author(s))		18. Distribution Statement Unclassified-Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 18	22. Price

THE DEVELOPMENT OF THE ZEPPELIN DIRIGIBLE
FOR LONG DISTANCE TRANSPORTATION

Albert Ehrle

The German Academy of Aviation Research

In the last decade regular passenger transport across the ocean ^{/33*} was established in Germany with dirigibles, first to South America and then also to North America. This was the beginning for extensive plans and the development in dirigible construction received new impulses. The explanation of technical problems to be solved will be preceded here by a survey of the path taken in constructing dirigibles for long distance transport up to now.

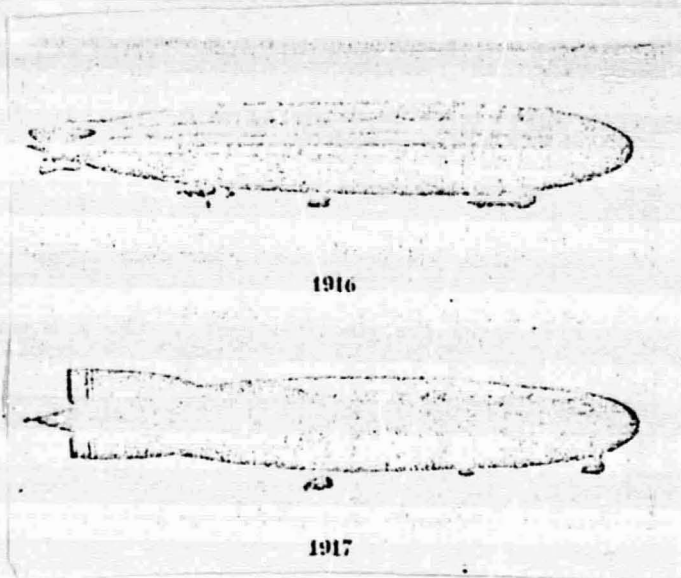


Figure 1: Zeppelin dirigibles
gas content .55,200 to 56,000m³
diameter23.9m
length196.5m

ORIGINAL PAGE IS
OF POOR QUALITY

The first example of the zeppelin dirigibles, which could be considered a long-distance vehicle, was the 56,000 cbm airship. The LZ 62 in 1916 was the first airship of this design. By the end of 1917 thirty-six airships had been built along these lines. The last examples attained a maximum speed of 32 m/sec and a useful load of 39 t - understood for a barometer reading of 760 mm, 0°C air and gas temperature and ^{/34} hydrogen gas filling - with a calculated possible range of 12,000 km.

*Numbers in the margin indicate pagination in the foreign text.

This ship type underwent 2 remarkable changes. At the end of 1917 the Africa ship L 59 was constructed by increasing the gas content to 68,500 cbm and in 1918 the LZ 112-L 70 was built with a content of 62,200 cbm and a maximum speed at normal altitude of more than 35 m/sec. by increasing the number of engines and more than 36 m/sec. at greater altitudes by higher compression in the engines.

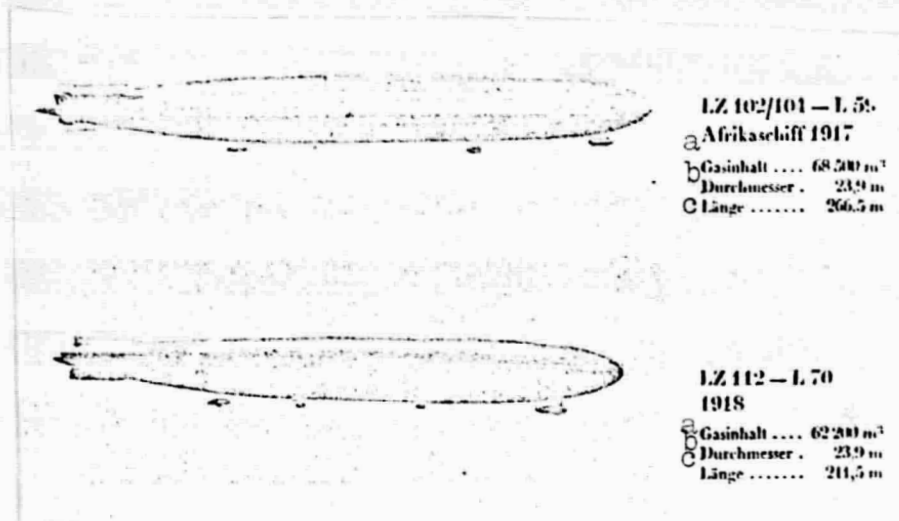


Figure 2

Key

- a. gas content
- b. diameter
- c. length

The trip of the L 59 to Africa will always remain a milestone, since it was the first long-distance trip of a dirigible with a considerable cargo. The L 59 rose into the air on November 21, 1917, in Jamboli in Bulgaria. The transport target was the Maconde Highlands in German East Africa. Over Khartoum the dirigible was called back by a radio signal from Nauen and again landed in Jamboli on November 25. The trip had lasted for 95 hours and the distance travelled was 6,750 km. The disposable load consisted of a 22 man crew and approx. 23 t gasoline and oil; a cargo of 14 t was to be delivered at the destination. There were still 9 tons of gasoline upon landing.

In the period after the war the two small transport dirigibles "Bodensee" and "Nordstern", of no further concern here, were followed by the reparation dirigible, LZ 126, the first German dirigible to cross the North Atlantic, and LZ 127 "Graf Zeppelin" which became the actual pacemaker for transatlantic dirigible transport with and without passen-

gers. "Graf Zeppelin" commenced its first trip on September 18, 1928. By May in 1937 it had covered more than 1.6 million kilometers and had transported a total of about 13,000 passengers. Circling the globe and the research trip to the arctic are the best known of its various trips.

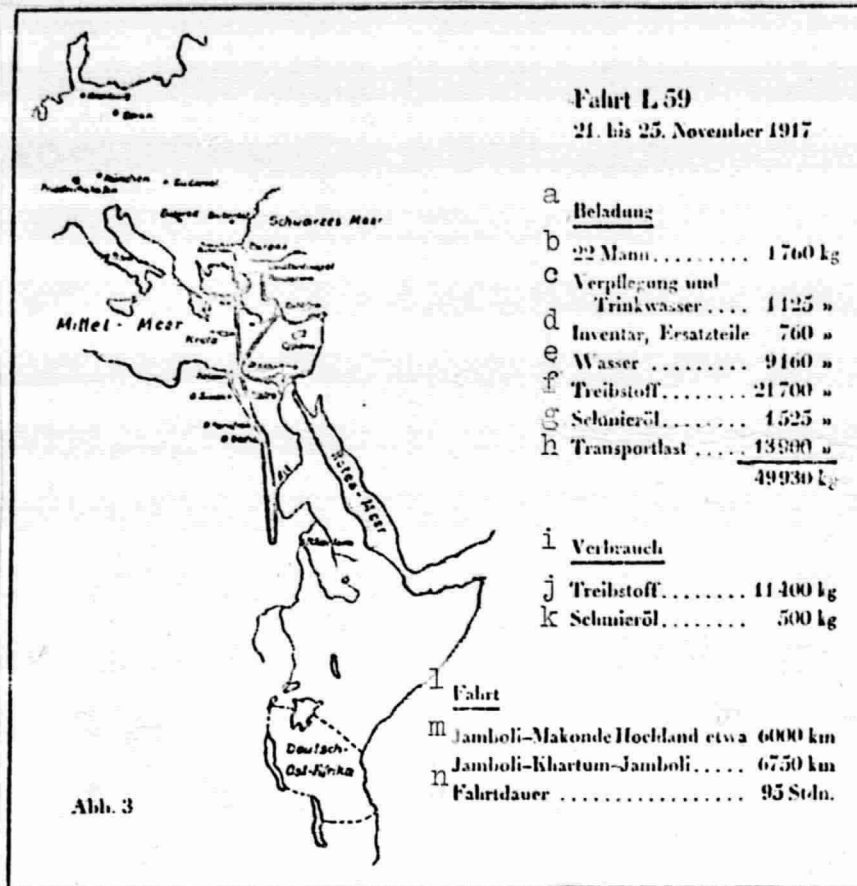


Figure 3: Trip of the L 59 on November 21-25, 1917

Key:

- | | |
|---------------------------------|---|
| a. load | h. cargo |
| b. 22 man crew | i. consumption |
| c. supplies and drinking water | j. fuel |
| d. inventory, replacement parts | k. lubricating oil |
| e. water | l. trip |
| f. fuel | m. Jamboli-Maconde Highland
approx. 6,000 km |
| g. lubricating oil | n. travelling time - 95 hrs. |

On the basis of knowledge gained with the LZ 127 the LZ 128 was to follow with 165,000 cbm gas content, with larger passenger accommodations and with increased travelling speed; but for the rest, hydrogen was to be retained as lifting gas and normal fuel for engine operation as in the case of the LZ 127. This project was not completed, but

rather the LZ 129, the dirigible "Hindenburg". With a total gas content of 200,000 cbm it left open the possibility for employing helium, and in place of the gas engines it was fitted with diesel engines. It served for a year mainly on the North America route. On May 6, 1937, it was destroyed in Lakehurst by fire.

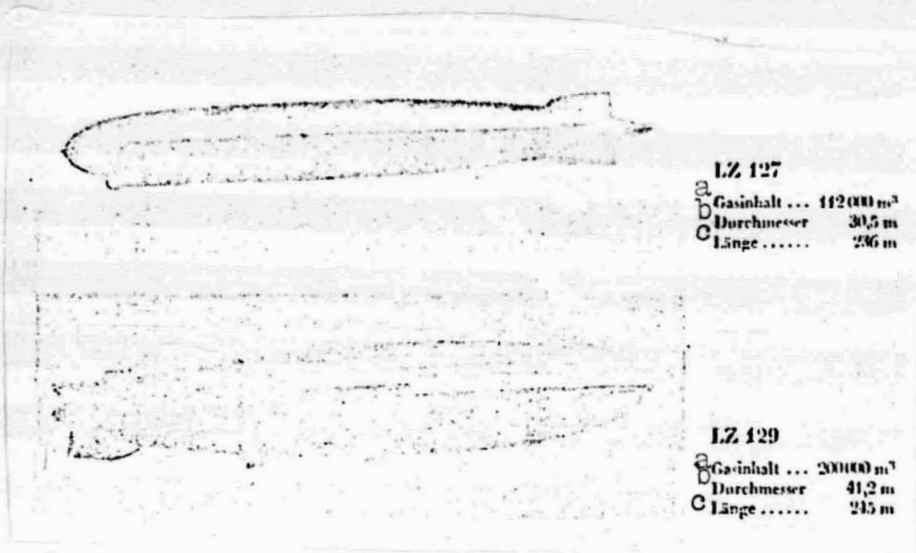


Figure 4

ORIGINAL PAGE IS
OF POOR QUALITY

Key:
a. gas content
b. diameter
c. length

At that time a sister ship, the LZ 130, was being completed. Corresponding to the lifting capacity of hydrogen gas it was to contain 70 passenger beds. In the meantime it has been converted to helium; in addition to a series of other reductions in weight it was fitted with new, lighter passenger accommodations with only 40 beds.

The comparative structural weight is of concern now in the airship, i.e. the weight for fulfilling each individual transport task. One weight classification for this purpose, i.e. the weights of the support structure, the thrust equipment and the operational equipment provide information on the state of development of design and airship planning and on the influence of ship size on construction weight. The weights

of materials for operation form a second class with reference to the weight of the engine; this number supplies a measure for improvement /37 in respect to wind resistance and to propeller effectivity and engine equipment. A third class, that of weight for cargo transport, e.g. for the accommodation and entertaining of the passengers, is already determined to a great extent by other non-technical aspects; it is therefore practical to neglect this weight in the airship weight.

The actual comparison should be limited to the first and last airship, the 56,000 cbm and the 200,000 cbm airship for reasons of brevity. The gas content, as a characteristic reference quantity for the ship, supplies a simple and distinct common denominator; the individual weights now appear in grams per cubic meter.

From this compilation it can be seen that in the period from 1917 to 1937 with increase in ship size from 56,000 to 200,000 cbm, the net /38 weight per cubic meter without useful equipment increased by approx. 20%. The support framework contributes 84 g/cbm to this increase and the operational equipment contributes 19 g/cbm, while hull and gas containers remained the same and the machine was reduced by 20 g/cbm.

The question now has to be answered to what degree reasons in connection with ship size have caused these alterations, but also to what degree increased demands and altered viewpoints are responsible.

To begin with individual points, we find a substantial weight change in the support structure from 43.5 to 94 g/cbm in the case of the main rings. The dimensions are determined mainly by the function as partition walls, so that the fourth power of the diameter may be selected as special reference quantity. Using this as a reference, we find that in the largest main ring in each case, the support weight has been reduced by 37% and the weight of ring framework with the portion /39 of supporting axial element has decreased by 10%. This is an expression of the improvement in support material and design and in the circular design and a whole by means of support of the framework with an axial element. For the related total weight of all main rings, their number

a Zeppelin-Luftschiffe für Fernverkehr 1916 bis 1936							
b Gewicht in kg							
	50 000 m ³		LZ 102/101	LZ 112	LZ 120	LZ 127	LZ 129
	1916	1918	L 59	L 70	Los Angeles	Graf Zeppelin	Hindenburg
c Trätkörper							
d Gerippe							
e Hülle und Netze	23 350	17 250	20 130	18 960	23 350	30 690	78 430
f Tragsanlage							
g Maschine							
h Motoren und Zubehör ..							
i Luftschrauben	7 890	5 620	5 430	6 725	9 530	11 320	15 950
j Gondeln							
k Behälter							
l für Betriebsstoff							
m für Wasser	1 200	720	1 230	970	1 240	3 450	3 200
n für Ballastgewinner							
o Betriebsausrüstung							
p Navigationseinrichtung ..							
q Funkausrüstung	2 382	1 675	1 141	1 631	3 355	5 069	9 250
r Elektrische Anlagen							
s Besatzungsräume							
t Zweckausrüstung							
u Nutzlast	350	115	—	35	1 900	2 800	11 300
v Fahrgasträume							

Figure 5: Weight in transport

Key:

- a. zeppelin dirigibles for long-distance transport between 1916 and 1936
- b. weight in kg
- c. support structure
- d. ribs
- e. hull and framework
- f. lifting gas equipment
- g. machine
- h. engines and accessories
- i. propellers
- j. gondola

- k. containers
- l. for fuel
- m. for water
- n. for ballast extraction
- o. operational equipment
- p. navigational equipment
- q. radio equipment
- r. electrical devices
- s. accommodations for the crew
- t. useful equipment
- u. useful load
- v. passenger accommodations

a Zeppelin-Luftschiffe für Fernverkehr 1916 bis 1936							
1 Gewicht in g pro m ³ Gasinhalt							
	56 000 m ³		LZ 102/103	LZ 112	LZ 126	LZ 127	LZ 129
	1916	1918	1.59	1.70	Los Angeles	Graf Zeppelin	Hindenburg
C Tragkörper							
d Gerippe	423,1	308,0	293,9	301,9	313,4	353,1	392,3
f Hülle und Netze							
f Traggasanlage							
g Maschine							
h Motoren und Zubehör ..	142,9	100,4	79,3	108,1	127,9	101,1	79,8
i Luftschrauben							
j Gondeln							
k Behälter							
l für Betriebsstoff	21,7	12,9	18,0	12,7	16,6	30,8	16,0
m für Wasser							
n für Ballastgewinner							
o Betriebsausrüstung							
p Navigationseinrichtung ..	43,2	29,9	16,7	26,2	45,0	45,3	46,3
q Funkausrüstung							
r Elektrische Anlage							
s Besatzungsräume							
t Zweckausrüstung							
u Nutzlast	6,4	2,6	—	•	•	•	•
v Fahrgasträume	•	•	•	0,6	25,5	25,0	56,5

Figure 6: Weight and gas content

Key:

1. weight in g/m³ gas content

(for remainder of key please refer to Figure 5)

ORIGINAL PAGE IS
OF POOR QUALITY

determined by the division of gas storage and the special demands for strength of certain main rings such as the placement of rudders, would also be influential.

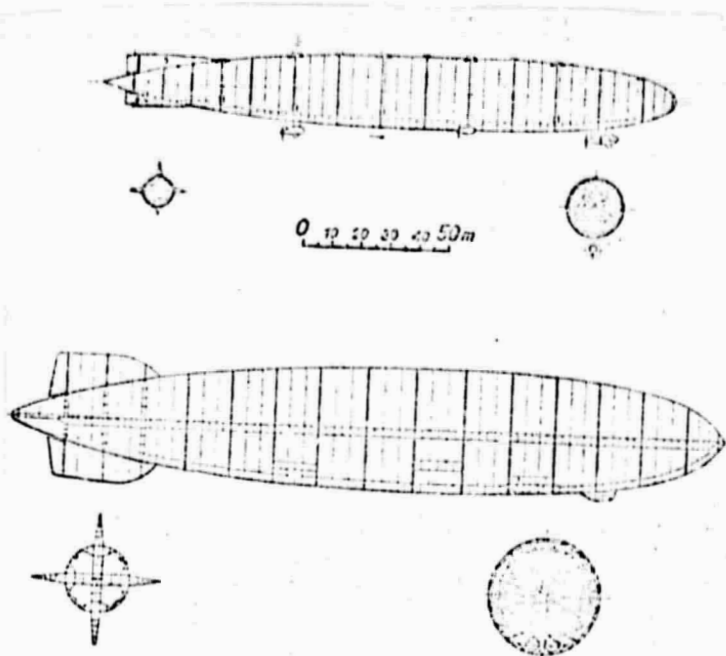


Figure 7: Framework of a 56,000 m³ and a 200,000 m³ dirigible

The shell construction of the auxiliary wings, longitudinal supports and field framework, including the main rings with a weight of 110 and 120 g/cbm, is subjected to stress mainly through transverse forces and bending moments from the distribution of lift and load and forces of the ambient air. The forces of the ambient air contribute the greater portion. These are mainly determined by travelling speed, i.e. the dynamic pressure, with a maximum value taken into account in airship dimensions. For the LZ 129 this was approx. 25% greater. If the surface is selected as a special reference quantity and calculated on the same dynamic pressure, the longitudinal support weight has a factor of 0.7 and the framework weight has a factor of 1.4 in the midsection of the LZ 129 dirigible. The strength of wires used in the framework, however, has improved only little since the war, but the quality value for the longitudinal supports has increased by a factor of approx. 1.75. When conclusions are drawn from these numbers on the strength of the shell construction, it has increased by 30 to 40% in the LZ 129 since the war dirigibles, i.e. the basis for dimensions has been changed. This is a

defined pattern of load cases; our knowledge of these has been greatly expanded by intensive measurements of the relationships between forces in the air. Conclusions on the strength requirements of the airship 41 as such, however, may only be drawn on the basis of experience and measurements gained during travelling. The LZ 120 presented the first opportunity for such research with the arrangement of recording measuring devices at suitable points in the airship for obtaining and evaluating the stresses. In the LZ 129 these measurements were continued and expanded.

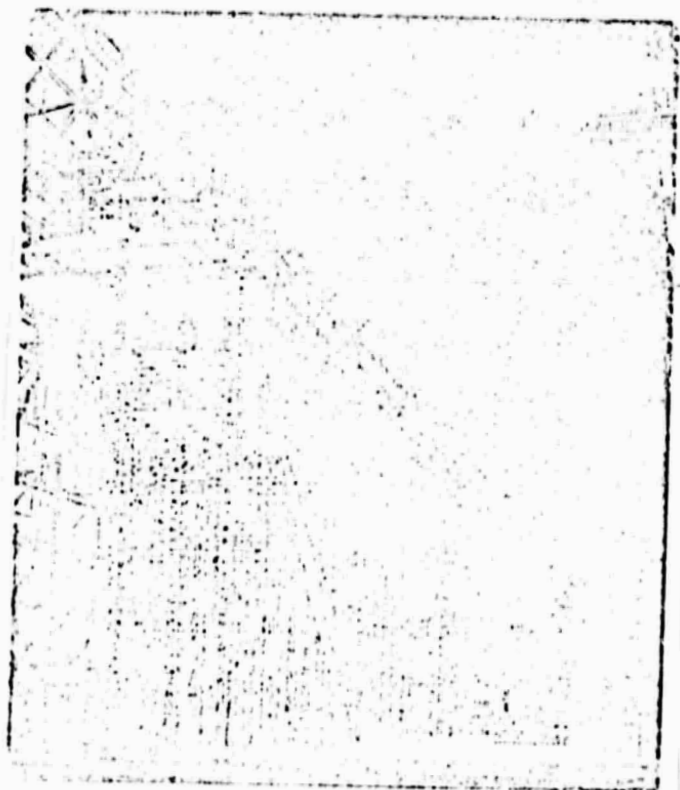


Figure 8: Framework of the LZ 129

ORIGINAL PAGE IS
OF POOR QUALITY

A long period of operation will still be necessary in order to determine accurately where the chosen load cases and safety factors have to be corrected. They are apparently even too high, for there is nothing in the eight years of LZ 127 operation to indicate insufficient strength.

Similar conclusions can be drawn for the tail section. In this case special studies and travel experience is required in addition to such stress measurements, in order to gain fact data on the demands placed on the fin and rudder sections by individual conditions during normal travelling, travelling with disruptions in lift and trim system

and approach for landing. The tail section of the LZ 129 weighs almost three times as much as earlier airships, specifically 39 as compared to 13.5 g/cbm. The wing span from one fin edge to the other was expanded by a factor of 1.8 for increased dynamic pressure and proved more than sufficient.

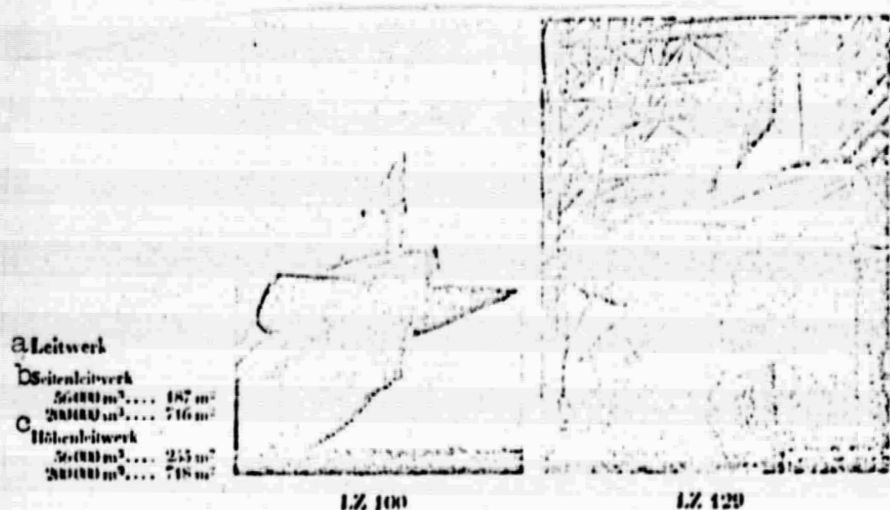


Figure 9

Key:

- a. tail section
- b. rudder unit
- c. elevator unit

The cubic meter weight of hull and lifting gas equipment has been altered only little from approx. 50 or 60 g/cbm, i.e. the commercial dirigibles weigh more per square meter of surface. The weight increase /42 is shown in hull life expectancy. In spite of regular trips to the tropics and long docking there on a mast the upper fields of the LZ 127, subjected to hail, did not have to be recovered until 530,000 and 740,000 km had been travelled. The lower hull fields were replaced only after 1.5 million km and the mid fields have not yet been replaced at all.

Just as increased demands are placed on the hull for long resistance to weather conditions, the gas ballonets should retain gas impermeability. The demand increases coincided in this case with the change in cellulose application. Up to the LZ 127 the gas ballonets were still produced from so-called fabric skin with a cotton material serving as lining for

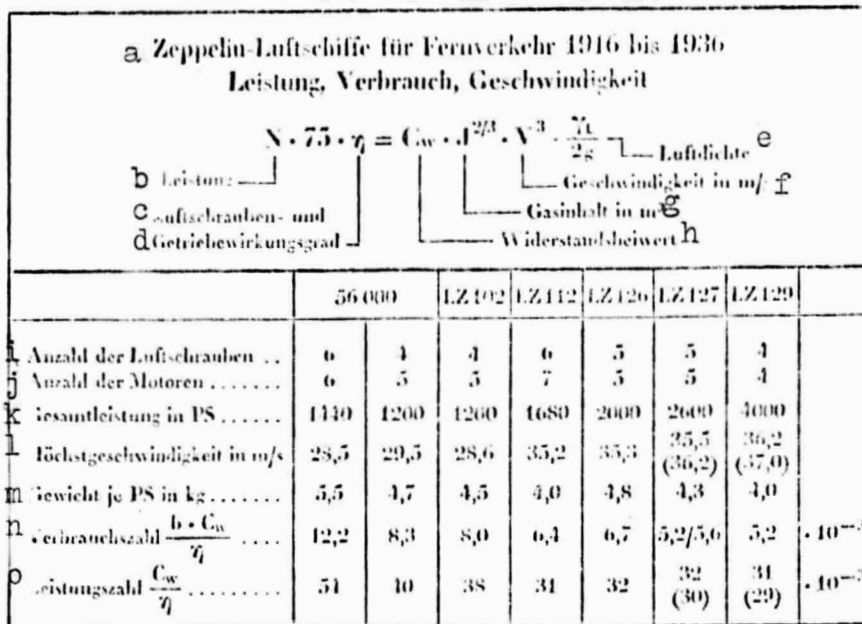
the fine skin of the oxen intestine which was impervious to gas. This was subsequently replaced by sealing films.

The amount of material for the hull and the ballonets remains constant; developmental work must be concentrated on the practical distribution of material types and on improving the material and substances for impregnation; for example, instead of cotton as lining material, silk can meet today's demands placed on the ballonnet without increasing weight.

The entire weight of the machine is distributed to approx. 46% on the motor, to 8% each on the gears with shaft and bearings and on the propeller and to 19% each on the accessory devices and the gondola car with suspension and entrance. The fuel supply for an ocean crossing requires $2\frac{1}{2}$ to 4 times the fixed weight of the machine. For estimating necessary thrust 2 values are required, which may not be easily obtained exactly and in the same manner - travelling speed and machine performance. The measurement of speed can be carried out during a short trip in a straight line at good, undisrupted speed or the average value can be determined in a longer, smooth, fairly slow trip, taking directional changes into consideration. The machine performance must be determined via consumption as was done in the measurements of the LZ 127 and LZ 129.

The maximum speed and effective engine output of earlier airships is known. The comparison would therefore not be strictly consistent, but rather in favor of the newer dirigibles. The maximum values determined for these have therefore been inserted into the table.

The weight of the containers for water and fuel including the lines, but without the spatial installations, has hardly changed, measured in cubic meters with increasing airship size. Only in the LZ 127 was there a greater weight, solely caused by the gaseous fuel in the container weight without the indirect weight reductions. Ballast extraction, even when this is actually part of the machinery, will later be included in these calculations.



ORIGINAL PAGE IS
OF POOR QUALITY

Figure 10: Performance values

Key:

- a. zeppelin dirigibles for long-distance travel from 1916 to 1936
- b. performance, consumption, speed
- c. performance
- d. effectivity of propellers and gears
- e. air density
- f. speed in m/sec
- g. gas content in m³
- h. coefficient of resistance
- i. number of propellers
- j. number of engines
- k. total performance in HP
- l. maximum in m/sec
- m. weight per HP in kg
- n. consumption value
- o. performance value

The operational equipment of the airship requires no substantial alteration when the transport task remains the same, but the weight has actually increased from 1.6 to over 9 t. Several things must be mentioned in connection with this. A maiden voyage will always permit greater savings, often even demand them, than the actual transport service, with respect to the amount of equipment as well as to stability and durability of individual parts. The navigational aids and instruments have also been substantially improved in the period since the war and new applications for other devices have been found. Such expansion and supplementation may contribute to an increase in performance and safety. The larger vehicle, however, may also lead to some increased demands, which may not

be fully justified. Finally a reaction of the useful load on individual 44 parts of the operational equipment cannot be avoided.

The following improvements deserve individual attention. The driver gondola car has become more spacious. Since it is the front landing piece, it must also be built more solidly in the larger airship. An electric servo motor is used for steering today in addition to manual controls. A central monitoring of ballonnet pressure and condition of filling appeared necessary for the double ballonets of the helium-hydrogen gas dirigible; it has also demonstrated its worth for the normal individual ballonnet equipment. The gyro compass, the sonic altimeter, the drift meter, the large headlight etc. were added to the instruments. The landing devices were expanded by the devices for pole and rail car mooring and by replacement of the tube buffers by buffer wheels. A weight increase of several hundred kilograms was added to each group by these improvements. The increased weight of the electrical equipment, climbing from 70 to 140 kg to over 3 t, is especially noticeable. This does not belong entirely to operational equipment, since the connection value in the LZ 129 for ship equipment amounted to 20 kW, for the kitchens 13 kW and for the other accommodations 7 kW. The generator, originally driven by wind engines dependent on headwinds, is supplied today by diesel engines with full reserves. Reductions in weight are only possible by saving electricity, e.g. by utilizing exhaust heat for the kitchen oven.

The accommodations for the crew in a transport airship are of course larger than in a military vehicle. For officers and crew there is one mess each, connected to the warm heating of the passenger rooms. The crew sleep in two-bed cabins along the walkway. The LZ 129 had 52 beds. The entire fitted weight for these, for the messes and the washing and auxiliary rooms amounted to almost 2 t.

The useful load of the military airship contributed only about 150 kg to the net weight. The Africa Ship required almost no weight for fittings for the 14 t cargo. The LZ 126 had 20 seats and beds of sufficient comfort for its purposes, but not for regular passenger travel.

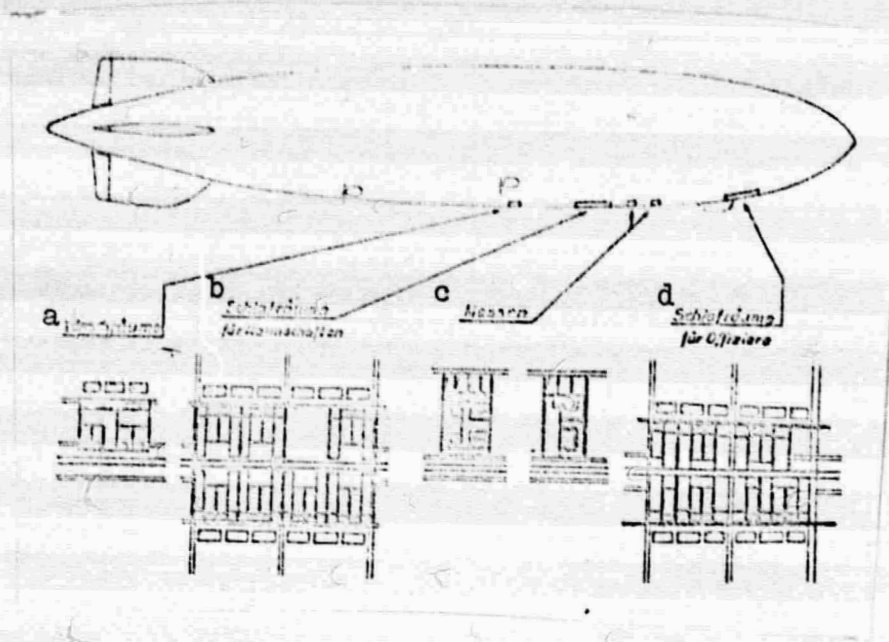


Figure 11: Crew accommodations

Key:

- a. restrooms
- b. bedrooms for the crew
- c. diningrooms
- d. bedrooms for the officers

The weight for the passenger fittings in the LZ 126 was 1,900 kg. The LZ 127 had a lounge and diningroom with 20 seats and additionally ten cabins with two beds each, which could also be converted for day use, weighing a total of 2,800 kg. The arrangement in a gondola-type construction provides a very good view. At full capacity the accomo- /45
dations were considered somewhat insufficient, but they were comfortable and sufficient for three-quarter capacity. The possibility for travelling comfort demonstrated in the dirigible gave rise to extensive wishes and demands. In the LZ 129, which was first equipped for 50, but later for 70 passengers, an attempt was made a fulfilling these wishes by means of lounges of large dimensions. The rooms required 400 square meters of floor space, which could now also be arranged in the interior of the ship. Special attention was paid to lovely and expensive decorations. This was good for advertising, but the practical experience was not entirely satisfying. The inside cabins were not popular and the roomi-
ness of the accommodations as such also caused increased weight. In

addition to the weight of fittings of 90 kg-230 kg more than in the LZ 127 there was per passenger 25 kg in inventory, 65 kg in food, drinks and potable water and 45 kg for service personnel including accommodations and food; this resulted in a total of 460 kg, including passenger weight. In future dirigibles weight may be saved in the superstructure and individual parts, but on the whole a less elaborate spatial arrangement will have to be developed. /46

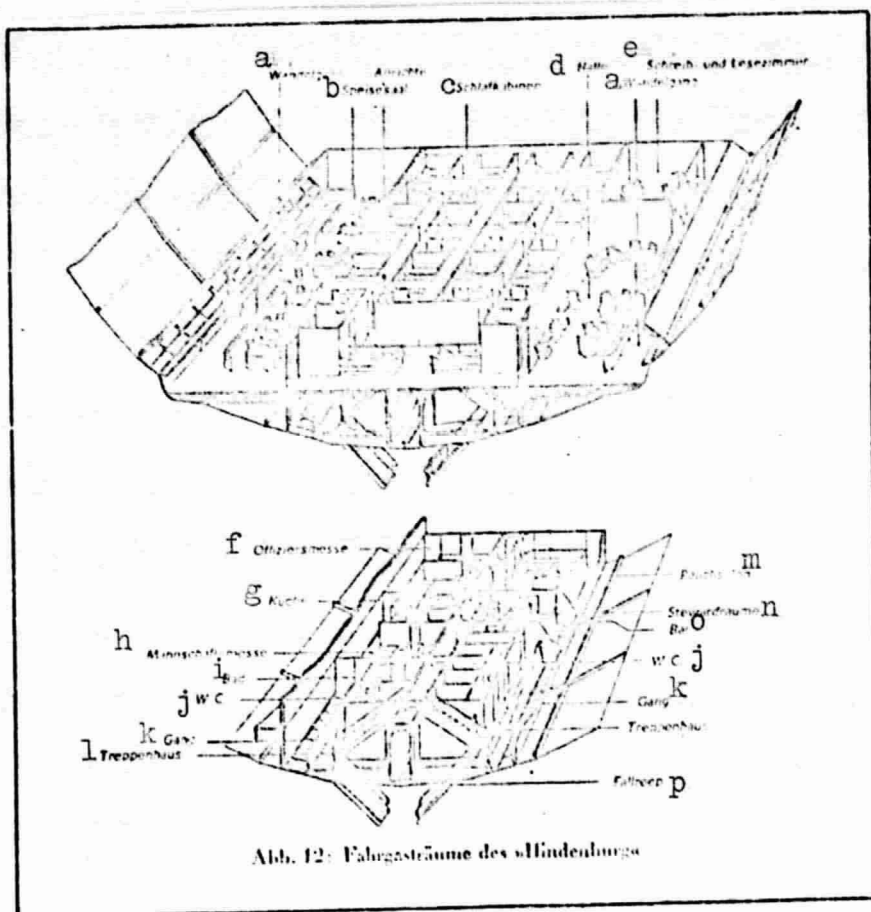


Abb. 12: Fahrgasträume des "Hindenburg"

Figure 12: Passenger accommodations in the "Hindenburg"

Key:

- | | |
|-----------------------------|------------------|
| a. covered walk | j. restroom |
| b. diningroom | k. passageway |
| c. cabins | l. stairwell |
| d. hall | m. smoking salon |
| e. writing and reading room | n. steward rooms |
| f. officers' mess | o. bar |
| g. kitchen | p. gangway |
| h. crews' mess | |
| i. bath | |

ORIGINAL PAGE IS
OF POOR QUALITY

In summary it can be seen that the weight of individual parts of the support structure in relation to ship content has increased with ship size, but all other parts of the ship should have been reduced in order to avoid a weight gain due to increased demands or added improvements. In the case of the main rings the increase was softened by improvements in material and design; in the case of the fuel the reduction was intensified by the progress from a gasoline engine to a gas engine and then to a diesel engine. Further, the considerable weight increase for passengers was demonstrated. The L 59 employed for this innovation was developed from a proven dirigible series, while the LZ 129 was the first model after the largest step yet taken in the ship content /47

The path from that maiden voyage of the L 59 to the ship model LZ 129 is now clear and looks better than the pure weight values would first allow. With the knowledge and improvements available today, 200,000 cbm would suffice for 50 passengers and the same supplies as in the LZ 129 even with helium as the only lifting gas, but for hydrogen gas a ship size of 160,000 cbm would already be sufficient.