TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 237



# RIGID AIRSHIPS.

By Friedrich Stahl.

From "Flug-Welt," 1920, Nos. 24 & 25; 1921, Nos. 1-4 & 6-13.



November, 1923.

TM 237

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL MEMORANDUM NO. 237

# R I G I D  A I R S H I P S.*

By Friedrich Stahl.

In contrast with the nonrigid airship, in the development of which men of all civilized countries have assisted, the rigid airship is exclusively the result of German genius. Its father is Count Zeppelin.

Chronologically, the airship of David Schwarz was built first (in 1897), but Zeppelin's plans go back to the seventies of the last century. The plans for the construction of the Schütte-Lanz airship did not mature until after the Echterdinge disaster in 1908.

Spurred on by German successes, the construction of rigid airships was also undertaken in foreign countries. The Spiess airship in France and the Vickers in England, were finished shortly before the war. Their performances and especially their small carrying capacity, did not encourage further production.

During the war, however, England succeeded in making serviceable airships, after spies of the Entente had obtained practical experience in airship construction by working in German airship yards and after Zeppelin airships had fallen into the hands of the enemy through forced landings.

The successes England gained with these airships, including

* From "Flug-Welt:" 1920, Nos. 24 & 25; 1921, Nos. 1-4 & 6-13.

the American trip of the R 34, may properly be placed to the credit of Germany. Performances equivalent to crossing the ocean had previously been accomplished under less favorable conditions. But little was known of these performances by the outside world in general; hence the indefinite and contradictory views which prevail regarding the development and efficiency of German airships. Many groundless prejudices were formed, which I hope to dispel.

Before considering the development of the rigid airships individually, I will here give a list of all the Z (Zeppelin) and S-L (Schütte-Lanz) airships, with their principal characteristics.

a) ZEPPELIN AIRSHIPS.

| Serial No. | Construction yard | Named by owner | Owned by |
|---|---|---|---|
| L Z 1 | Manzell | -- | Zeppelin |
| 2 | " | -- | " |
| 3 | " | -- | " |
| | After alterations Rudders remodeled | Z I " | Army " |
| 4 | Manzell | -- | Zeppelin |
| 5 | " | Z II | Army |
| 6 | Friedrichshafen | -- | Zeppelin |
| [illegible] | After alterations | [illegible] | German Airship Navigation Co. |
| 7 | Friedrichshafen | Deutschland | " |
| 8 | " | Ersatz " | " |
| 9 | " | Z II | Army |
| 1[illegible] | After alterations | " | " |
| 10 | Friedrichshafen | Schwaben | German Airship Navigation Co. |
| 11 | " | Viktoria-Luise | " |
| 12 | " | Z III | Army |
| 13 | " | Hansa | German Airship Navigation Co. |
| 14 | " | L 1 | Navy |
| 15 | " | Ersatz Z I | Army |
| 16 | " | Z IV | " |
| 17 | " | Sachsen " | German Airship Navigation Co. " |
| | After lengthening | | |

a) Zeppelin Airships (Cont.)

| Serial No. | Construction yard | Named by owner | Owned by |
|---|---|---|---|
| L Z 18 | Friedrichshafen | L 2 | Navy |
| 19 | " | Ersatz Z I | Army |
| 20 | " | Z V | " |
| | " | " | " |
| 21 | " | Z VI | " |
| 22 | " | Z VII | " |
| 23 | " | Z VIII | " |
| 24 | " | L 3 | Navy |
| 25 | Friedrichshafen | Z IX | Army |
| 26 | Frankfurt a. M. | Z XII | " |
| 27 | Friedrichshafen | L 4 | Navy |
| 28 | " | L 5 | " |
| 29 | " | Z X | Army |
| 30 | Potsdam | Z XI | " |
| 31 | Friedrichshafen | L 6 | Navy |
| 32 | " | L 7 | " |
| 33 | " | L 8 | " |
| 34 | Potsdam | LZ 34 | Army |
| 35 | Friedrichshafen | LZ 35 | " |
| 36 | " | L 9 | Navy |
| 37 | Potsdam | LZ 37 | Army |
| 38 | Friedrichshafen | LZ 38 | " |
| 39 | " | LZ 39 | " |

a) Zeppelin Airships (Cont.)

| Serial No. | Construction yard | Named by owner | Owned by |
|---|---|---|---|
| L Z 40 | Friedrichshafen | L 10 | Navy |
| 41 | Loewenthal | L 11 | " |
| 42 | Potsdam | LZ 72 | Army |
| 43 | Friedrichshafen | L 12 | Navy |
| 44 | Loewenthal | LZ 74 | Army |
| 45 | Friedrichshafen | L 13 | Navy |
| 46 | Loewenthal | L 14 | " |
| 47 | Friedrichshafen | LZ 77 | Army |
| 48 | Loewenthal | L 15 | Navy |
| 49 | Potsdam | LZ 79 | Army |
| 50 | Friedrichshafen | L 16 | Navy |
| 51 | Loewenthal | LZ 81 | Army |
| | After lengthening | " | " |
| 52 | Loewenthal | L 18 | Navy |
| 53 | Friedrichshafen | L 17 | " |
| 54 | " | L 19 | " |
| 55 | Potsdam | LZ 85 | Army |
| 56 | " | LZ 86 | " |
| | After lengthening | " | " |
| 57 | Loewenthal | LZ 87 | " |
| | After lengthening | " | " |
| 58 | Potsdam | LZ 88 | " |
| 59 | After lengthening | " | " |

a) Zeppelin Airships (Cont.)

| Serial No. | Construction yard | Named by owner | Owned by |
|---|---|---|---|
| L Z 60 | Potsdam | LZ 90 | Army |
| | After lengthening | " | " |
| 61 | Loewenthal | L 21 | Navy |
| 62 | Friedrichshafen | L 30 | " |
| 63 | Potsdam<br>" | LZ 93<br>" | Army<br>" |
| 64 | Loewenthal | L 22 | Navy |
| 65 | Friedrichshafen | LZ 95 | Army |
| 66 | Potsdam | L 23 | Navy |
| 67 | Loewenthal | LZ 97 | Army |
| 68 | " | LZ 98 | " |
| 69 | Potsdam | L 24 | Navy |
| 70 | Loewenthal | L 26 | " |
| 71 | Potsdam | LZ 101 | Army |
| 72 | Loewenthal | L 31 | Navy |
| 73 | Potsdam | LZ 103 | Army |
| 74 | Friedrichshafen | L 32 | Navy |
| 75 | Staaken | L 37 | " |
| 76 | Friedrichshafen | L 33 | " |
| 77 | Potsdam | LZ 107 | Army |
| 78 | Loewenthal | L 34 | Navy |
| 79 | Staaken | L 41 | " |
| 80 | Friedrichshafen | L 35 | " |

a) Zeppelin Airships (Cont.)

| Serial No. | Construction yard | Named by owner | Owned by |
|---|---|---|---|
| L Z 81 | Potsdam | LZ 111 | Army |
| 82 | Friedrichshafen | L 36 | Navy |
| 83 | Staaken | LZ 113 | Army |
| 84 | Loewenthal | L 38 | Navy |
| 85 | Staaken | L 45 | " |
| 86 | Friedrichshafen | L 39 | " |
| 87 | Staaken | L 47 | " |
| 88 | Friedrichshafen | L 40 | " |
| 89 | Staaken | L 50 | " |
| 90 | Loewenthal | LZ 120 | Army |
| 91 | Friedrichshafen | L 42 | Navy |
| 92 | " | L 43 | " |
| 93 | Loewenthal | L 44 | " |
| 94 | Friedrichshafen | L 46 | " |
| 95 | " | L 48 | " |
| 96 | Loewenthal | L 49 | " |
| 97 | Friedrichshafen | L 51 | " |
| 98 | Staaken | L 52 | " |
| 99 | " | L 54 | " |
| 100 | Friedrichshafen | L 53 | " |
| 101 | Loewenthal | L 55 | " |
| 102 | Friedrichshafen | L 57 | " |

a) Zeppelin Airships (Cont.)

| Serial No. | Construction yard | Named by owner | Owned by |
|---|---|---|---|
| L Z 103 | Staaken | L 56 | Navy |
| 104 | " | L 59 | " |
| 105 | Friedrichshafen | L 58 | " |
| 106 | " | L 61 | " |
| 107 | Loewenthal | L 62 | " |
| 108 | Staaken | L 60 | " |
| 109 | " | L 64 | " |
| 110 | Friedrichshafen | L 63 | " |
| 111 | Loewenthal | L 65 | " |
| 112 | Friedrichshafen | L 70 | " |
| 113 | " | L 71 | " |
| 114 | Loewenthal | L 72 | -- |
| 120 | Friedrichshafen | Bodensee | German Airship Navigation Co. |
| | After lengthening | " | " |
| 121 | | Nordstern | " |
| 126 | Los Angeles | | |
| 127 | Graf Zeppelin | | |
| 129 | Hindenburg | | |

a) Zeppelin Airships (Cont.)

| Serial No | Gas Capacity cu.m. | No. of cells | Length m. | Diameter m. | Useful load at 0° and 760 mm kg. | No. of engines |
|---|---|---|---|---|---|---|
| L Z 1 | 11300 | 17 | 128 | 11.65 | -- | 2 |
| 2 | 11300 | 16 | 128 | 11.65 | 2700 | 2 |
| 3 | 11300 | 16 | 128 | 11.65 | 2700 | 2 |
| | 12200 | 17 | 136 | 11.65 | 2700 | 2 |
| | 12200 | 17 | 136 | 11.65 | 2700 | 2 |
| 4 | 15000 | 17 | 136 | 13.00 | 4500 | 2 |
| 5 | 15000 | 17 | 136 | 13.00 | 4500 | 2 |
| 6 | 15000 | 17 | 136 | 13.00 | 4500 | 2 |
| | 16000 | 18 | 144 | 13.00 | 4000 | 3 |
| 7 | 19300 | 18 | 148 | 14.00 | 6500 | 3 |
| 8 | 19300 | 18 | 148 | 14.00 | 6500 | 3 |
| 9 | 16800 | 16 | 132 | 14.00 | -- | 3 |
| | 17800 | 17 | 140 | 14.00 | 6000 | 3 |
| 10 | 17800 | 17 | 140 | 14.00 | 6000 | 3 |
| 11 | 18700 | 18 | 148 | 14.00 | 6200 | 3 |
| 12 | 17800 | 17 | 140 | 14.00 | 6000 | 3 |
| 13 | 18700 | 18 | 148 | 14.00 | 6200 | 3 |
| 14 | 22465 | 18 | 158 | 14.86 | 8600 | 3 |
| 15 | 19500 | 16 | 142 | 14.86 | 7050 | 3 |
| 16 | 19500 | 16 | 142 | 14.86 | 7000 | 3 |
| 17 | 19500 | 16 | 140 | 14.86 | 7000 | 3 |
| | 20870 | 17 | 148 | 14.86 | 7500 | 3 |
| 18 | 27000 | 18 | 158 | 16.6 | 11000 | 4 |
| 19 | 19500 | 16 | 140 | 14.86 | 7000 | 3 |

a) Zeppelin Airships (Cont.)

| Serial No. | Gas Capacity cu.m. | No. of cells | Length m. | Diameter m. | Useful load at 0° and 760 mm. kg. | No. of engines |
|---|---|---|---|---|---|---|
| L Z 20 | 19500 | 16 | 140 | 14.86 | 7000 | 3 |
| | 20870 | 17 | 148 | 14.86 | 7400 | 3 |
| 21 | 20870 | 17 | 148 | 14.86 | 7500 | 3 |
| 22 | 22140 | 18 | 156 | 14.86 | 8000 | 3 |
| 23 | 22140 | 18 | 156 | 14.86 | 8000 | 3 |
| 24 | 22500 | 18 | 158 | 14.86 | 8700 | 3 |
| 25 | 22500 | 18 | 158 | 14.86 | 8700 | 3 |
| 26 | 25000 | 15 | 161.2 | | 11000 | 3 |
| 27 | 22500 | 18 | 158 | | 8700 | 3 |
| 28 | 22500 | 18 | 158 | 14.86 | 8700 | 3 |
| 29 | 22500 | 18 | 158 | 14.86 | 8700 | 3 |
| 30 | 22500 | 18 | 158 | 14.86 | 8700 | 3 |
| 31 | 22500 | 18 | 158 | 14.86 | 8700 | 3 |
| 32 | 22500 | 18 | 158 | 14.86 | 8700 | 3 |
| 33 | 22500 | 18 | 158 | 14.86 | 8700 | 3 |
| 34 | 22500 | 18 | 158 | 14.86 | 8700 | 3 |
| 35 | 22500 | 18 | 158 | 14.86 | 8700 | 3 |
| 36 | 25000 | 15 | 161.4 | 16.00 | 10000 | 3 |
| 37 | 22500 | 18 | 158 | 14.86 | 8700 | 3 |
| 38 | 32000 | 15 | 163.5 | 18.7 | 15000 | 4 |
| 39 | 25000 | 15 | 161.4 | 16.00 | 10000 | 3 |
| 40 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 41 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |

a) Zeppelin Airships (Cont.)

| Serial No. | Gas Capacity cu.m. | No. of cells | Length m. | Diameter m. | Useful load at 0° and 760 mm kg. | No. of engines |
|---|---|---|---|---|---|---|
| L Z 42 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 43 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 44 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 45 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 46 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 47 | 32000 | 16 | 163.5 | 18.7 | 15000 | 3 (210 HP)<br>1 (240 HP) |
| 48 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 49 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 50 | 32000 | 16 | 163 5 | 18.7 | 15000 | 4 |
| 51 | 32000<br>35800 | 16<br>18 | 163.5<br>178.5 | 18.7<br>18.7 | 15000<br>17500 | 4<br>4 |
| 52 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 53 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 54 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 55 | 32000 | 16 | 163.5 | 18.7 | 15000 | 4 |
| 56 | 32000<br>35800 | 16<br>18 | 163.5<br>178.5 | 18.7<br>18.7 | 15000<br>17500 | 4<br>4 |
| 57 | 32000<br>35800 | 16<br>18 | 163.5<br>178.5 | 18.7<br>18.7 | 15000<br>17500 | 4<br>4 |
| 58 | 32000<br>35800 | 16<br>18 | 163.5<br>178.5 | 18.7<br>18.7 | 15000<br>17500 | 4<br>4 |
| 59 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |
| 60 | 32000<br>35800 | 16<br>18 | 163.5<br>178.5 | 18.7<br>18.7 | 15000<br>17500 | 4<br>4 |
| 61 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |

a) Zeppelin Airships (Cont.)

| Serial No. | Gas Capacity cu.m. | No. of cells | Length m. | Diameter m. | Useful load at 0° and 760 mm kg. | No. of engines |
|---|---|---|---|---|---|---|
| L Z 62 | 55000 | 19 | 198 | 23.9 | 28700 | 6 |
| 63 | 32000<br>35800 | 16<br>18 | 163.5<br>178.5 | 18.7<br>18.7 | 15000<br>17500 | 4<br>4 |
| 64 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |
| 65 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |
| 66 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |
| 67 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |
| 68 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |
| 69 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |
| 71 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |
| 72 | 55000 | 19 | 198.0 | 23.9 | 30000 | 6 |
| 73 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |
| 74 | 55000 | 19 | 198.0 | 23.9 | 30000 | 6 |
| 75 | 55000 | 19 | 198.0 | 23.9 | 30000 | 6 |
| 76 | 55000 | 19 | 198.0 | 23.9 | 30000 | 6 |
| 77 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |
| 78 | 55000 | 19 | 198.0 | 23.9 | 31000 | 6 |
| 79 | 55000 | 19 | 198.0 | 23.9 | 31000 | 6 |
| 80 | 55000 | 19 | 198.0 | 23.9 | 31000 | 6 |
| 81 | 35800 | 18 | 178.5 | 18.7 | 17500 | 4 |
| 82 | 55000 | 19 | 198.0 | 23.9 | 32000 | 6 |
| 83 | 55000 | 19 | 198.0 | 23.9 | 32000 to 32500 | 6 |
| 84 | 55000 | 19 | 198.0 | 23.9 | 32000 to 32500 | 6 |

a) Zeppelin Airships (Cont.)

| Serial No. | Gas Capacity cu.m. | No. of cells | Length m. | Diameter m. | Useful load at 0° and 760 mm kg. | No. of engines |
|---|---|---|---|---|---|---|
| L Z 85 | 55000 | 19 | 198 | 23.9 | 32000-32500 | 6 |
| 86 | 55000 | 19 | 198 | 23.9 | 32000-32500 | 6 |
| 87 | 55000 | 19 | 198 | 23.9 | 32000-32500 | 6 |
| 88 | 55000 | 19 | 198 | 23.9 | 32000-32500 | 6 |
| 89 | 55000 | 19 | 198 | 23.9 | 32000-32500 | 6 |
| 90 | 55000 | 19 | 198 | 23.9 | 32000-32500 | 6 |
| 91 | 55500 | 18 | 196.5 | 23.9 | 36000 | 5 |
| 92 | 55500 | 18 | 196.5 | 23.9 | 36000 | 5 |
| 93 | 55800 | 18 | 196.5 | 23.9 | 37500 | 5 |
| 94 | 55800 | 18 | 196.5 | 23.9 | 37500 | 5 |
| 95 | 55800 | 18 | 196.5 | 23.9 | 39000 | 5 |
| 96 | 55800 | 18 | 196.5 | 23.9 | 39000 | 5 |
| 97 | 55800 | 18 | 196.5 | 23.9 | 39000 | 5 |
| 98 | 55800 | 18 | 196.5 | 23.9 | 39000 | 5 |
| 99 | 55800 | 18 | 196.5 | 23.9 | 39000 | 5 |
| 100 | 56000 | 14 | 196.5 | 23.9 | 40000 | 5 |
| 101 | 56000 | 14 | 196.5 | 23.9 | 40000 | 5 |
| 102 | 68500 | 16 | 226.5 | 23.9 | 52000 | 5 |
| 103 | 56000 | 14 | 196.5 | 23.9 | 40000 | 5 |
| 104 | 68500 | 16 | 226.5 | 23.9 | 52000 | 5 |
| 105 | 56000 | 14 | 196.5 | 23.9 | 40000 | 5 |
| 106 | 56000 | 14 | 196.5 | 23.9 | 40000 | 5 |

| Serial No. | Gas Capacity cu.m. | No. of cells | Length m. | Diameter m. | Useful load at $0^{\circ}$ and 760 mm kg. | No. of engines |
|---|---|---|---|---|---|---|
| L Z 107 | 56000 | 14 | 196.5 | 23.9 | 40000 | 5 |
| 108 | 56000 | 14 | 196.5 | 23.9 | 40000 | 5 |
| 109 | 56000 | 14 | 196.5 | 23.9 | 40000 | 5 |
| 110 | 56000 | 14 | 196.5 | 23.9 | 40000 | 5 |
| 111 | 56000 | 14 | 196.5 | 23.9 | 40000 | 5 |
| 112 | 68150 | 15 | 226.5 | 23.9 | 44000 | 7 |
| 113 | 68150 | 15 | 226.5 | 23.9 | 44000 | 7 |
| 114 | 68150 | 15 | 226.5 | 23.9 | 44000 | 7 |
| 120 | 20000 | 12 | 120.8 | 18.7 | 10000 | 4 |
| | 22560 | 12 | 130.0 | 18.7 | 11500 | 4 |
| | 22560 | 12 | 130.0 | 18.7 | 11500 | 4 |

a) Zeppelin Airships (Cont.)

| Serial No. | HP per engine | Total HP | Speed in m/sec | Date of first flight | In service till |
|---|---|---|---|---|---|
| L Z 1 | 14.7 | 29 | 8 | 7/2/00 | Spring, 1901. |
| 2 | 85 | 170 | 11 | 11/30/05 | 1/17/06 |
| 3 | 85<br>100<br>100 | 170<br>200<br>200 | 11<br>12.2<br>15 | 10/9/06<br>--<br>-- | --<br>--<br>Autumn, 1913. |
| 4 | 100 | 200 | 12.5 | 6/20/08 | 8/5/08 |
| 5 | 100 | 200 | 12.5 | 5/26/09 | 4/25/10 |
| 6 | 115 | 230 | 13 | 8/25/09 | -- |
| | 2 at 115<br>1 " 140 | 370 | 15.5 | -- | 9/14/10 |
| 7 | 120 | 360 | 16 | 6/19/10 | 6/28/10 |
| 8 | 120 | 360 | 16 | 3/30/11 | 5/16/11 |
| 9 | 140<br>140 | 420<br>420 | 21.7<br>21 | 10/2/11<br>-- | --<br>8/1/14 |
| 10 | 140 | 420 | 21 | 6/26/11 | 6/28/12 |
| 11 | 140 | 420 | 21 | 2/14/12 | Autumn, 1915. |
| 12 | 140 | 420 | 21 | 4/25/12 | Summer, 1914. |
| 13 | 165 | 495 | 21 | 7/30/12 | Summer, 1916. |
| 14 | 165 | 495 | 21.2 | 10/7/12 | 9/9/13 |
| 15 | 165 | 495 | 20.5 | 1/16/13 | 3/19/13 |
| 16 | 165 | 495 | 20.9 | 3/14/13 | Autumn, 1916 |
| 17 | 165<br>165 | 495<br>495 | 21<br>20 | 5/3/13<br>-- | --<br>Autumn, 1916. |
| 18 | 165 | 660 | 21 | 9/9/13 | 10/17/13 |
| 19 | 165 | 495 | 20.4 | 6/6/13 | 6/13/14 |

a) Zeppelin Airships (Cont.)

| Serial No. | HP per engine | Total HP | Speed in m/sec | Date of first flight | In service till |
|---|---|---|---|---|---|
| L Z 20 | 165<br>165<br>165 | 495<br>495<br>495 | 20.5<br>20.0 | 7/8/13<br>-- | 8/27/14<br>8/27/14 |
| 21 | 165 | 495 | 20.3 | 11/10/13 | 8/6/14 |
| 22 | 175 | 525 | 20.5 | 1/8/14 | 8/23/14 |
| 23 | 175 | 525 | 20.2 | 2/21/14 | 8/23/14 |
| 24 | 210 | 630 | 21.5 | 5/11/14 | 2/17/15 |
| 25 | 210 | 630 | 21.4 | 7/29/14 | 10/8/14 |
| 26 | 210 | 630 | 22.1 | 12/14/14 | 8/8/17 |
| 27 | 210 | 630 | 21.5 | 8/28/13 | 2/17/15 |
| 28 | 210 | 630 | 21.5 | 9/22/13 | 8/6/15 |
| 29 | 210 | 630 | 22.0 | 10/13/14 | 3/21/15 |
| 30 | 210 | 630 | 22.0 | 11/11/14 | 5/20/15 |
| 31 | 210 | 630 | 22.0 | 11/3/14 | 9/19/16 |
| 32 | 210 | 630 | 22.0 | 11/20/14 | 5/4/16 |
| 33 | 210 | 630 | 22.0 | 12/17/14 | 3/5/15 |
| 34 | 210 | 630 | 22.0 | 1/6/15 | 5/21/15 |
| 35 | 210 | 630 | 22.0 | 1/11/15 | 4/13/15 |
| 36 | 210 | 630 | 22.0 | 3/8/15 | 9/16/16 |
| 37 | 210 | 630 | 22.0 | 2/28/15 | 6/7/15 |
| 38 | 210 | 840 | 25.0 | 4/3/15 | 6/7/15 |
| 39 | 210 | 630 | 21.5 | 4/24/15 | 12/18/15 |
| 40 | 210 | 840 | 25.0 | 5/13/15 | 9/3/15 |
| 41 | 210 | 840 | 25.0 | 6/7/15 | Apr.,1917. |

a) Zeppelin Airships (Cont.)

| Serial No. | HP per engine | Total HP | Speed in m/sec. | Date of first flight | In service till |
|---|---|---|---|---|---|
| L Z 42 | 210 | 840 | 25 | 6/15/15 | 2/16/17 |
| 43 | 210 | 840 | 25 | 6/21/15 | 8/10/15 |
| 44 | 210 | 840 | 25 | 7/8/15 | 10/8/15 |
| 45 | 210 | 840 | 25 | 7/23/15 | Apr.,1917 |
| 46 | 210 | 840 | 25 | 8/9/15 | July, 1919 |
| ~~47~~ | 3 at 210<br>1 " 240 | 870 | 25 | 8/24/15 | 2/21/16 |
| 48 | 240 | 960 | 25 | 9/9/15 | 4/1/16 |
| ~~49~~ | 210 | 840 | 25 | 8/2/15 | 1/30/16 |
| 50 | 240 | 960 | 25 | 9/23/15 | 10/19/17 |
| 51 | 240<br>240 | 960<br>960 | 25<br>25 | 10/7/15 | 9/27/16 |
| 52 | 240 | 960 | 25 | 11/3/15 | 11/17/15 |
| 53 | 240 | 960 | 25 | 10/20/15 | 12/28/16 |
| 54 | 240 | 960 | 25 | 11/27/15 | 2/2/16 |
| 55 | 210 | 840 | 25 | 9/12/15 | 5/5/16 |
| 56 | 210<br>210 | 840<br>840 | 25<br>25 | 10/10/15 | 9/4/16 |
| 57 | 240<br>240 | 960<br>960 | 25<br>25 | 12/6/15 | 7/28/17 |
| 58 | 210<br>240 | 840<br>960 | 25<br>25 | 11/14/15 | 9/15/17 |
| 59 | 240 | 960 | 25 | 12/21/15 | 5/3/16 |
| 60 | 240<br>240 | 960<br>960 | 25<br>25 | 1/1/16 | 11/7/16 |

a) Zeppelin Airships (Cont.)

| Serial No. | HP per engine | Total HP | Speed in m/sec. | Date of first flight | In service till |
|---|---|---|---|---|---|
| L Z 61 | 240 | 960 | 25 | 1/10/16 | 11/28/16 |
| 62 | 240 | 1440 | 27.8 | 5/28/16 | Summer, 1920. |
| 63 | 210<br>240 | 840<br>960 | 25<br>25 | 2/23/16 | Summer, 1917.<br>" " |
| 64 | 240 | 960 | 25 | 3/3/16 | 5/14/17 |
| 65 | 240 | 960 | 25 | 1/31/16 | 2/22/16 |
| 66 | 240 | 960 | 25 | 4/8/16 | 8/22/17 |
| 67 | 240 | 960 | 25 | 4/4/16 | 7/5/17 |
| 68 | 240 | 960 | 25 | 4/28/16 | August, 1917. |
| 69 | 240 | 960 | 25 | 5/20/16 | 12/28/16 |
| 71 | 240 | 960 | 25 | 6/29/16 | Sept., 1917. |
| 72 | 240 | 1440 | 27 | 7/12/16 | 10/2/16 |
| 73 | 240 | 960 | 25 | 8/8/16 | August, 1917. |
| 74 | 240 | 1440 | 27 | 8/4/16 | 9/24/16 |
| 75 | 240 | 1440 | 27 | 11/9/16 | Summer, 1920. |
| 76 | 240 | 1440 | 27 | 8/30/16 | 9/24/16 |
| 77 | 240 | 960 | 25 | 10/16/16 | July, 1917. |
| 78 | 240 | 1440 | 27 | 9/22/16 | 11/28/16 |
| 79 | 240 | 1440 | 27 | 1/15/17 | July, 1919. |
| 80 | 240 | 1440 | 27 | 10/12/16 | Summer, 1918. |
| 81 | 240 | 960 | 25 | 12/20/16 | 8/10/17 |
| 82 | 240 | 1440 | 27 | 11/1/16 | 2/7/17 |
| 83 | 240 | 1440 | 28 | 2/22/17 | 10/8/20 |

a) Zeppelin Airships (Cont.)

| Serial No. | HP per engine | Total HP | Speed in m/sec. | Date of first flight | In service till |
|---|---|---|---|---|---|
| L Z 84 | 240 | 1440 | 28 | 11/22/16 | 12/29/16 |
| 85 | 240 | 1440 | 28 | 2/4/17 | 10/20/17 |
| 86 | 240 | 1440 | 28 | 12/11/16 | 3/17/17 |
| 87 | 240 | 1440 | 28 | 5/1/17 | 1/5/18 |
| 88 | 240 | 1440 | 28 | 1/3/17 | 6/17/17 |
| 89 | 240 | 1440 | 28 | 6/9/17 | 10/20/17 |
| 90 | 240 | 1440 | 28 | 1/31/17 | |
| 91 | 240 | 1200 | 27 | 2/21/17 | July, 1919. |
| 92 | 240 | 1200 | 27 | 3/6/17 | 6/14/17 |
| 93 | 240 | 1200 | 27 | 4/1/17 | 10/20/17 |
| 94 | 240 | 1200 | 27 | 4/24/17 | 1/5/18 |
| 95 | 240 | 1200 | 29.5 | 5/22/17 | 6/17/17 |
| 96 | 240 | 1200 | 29.5 | 6/13/17 | 10/20/17 |
| 97 | 240 | 1200 | 29.5 | 7/6/17 | 1/5/18 |
| 98 | 240 | 1200 | 29.5 | 7/4/17 | August, 1919. |
| 99 | 240 | 1200 | 29.5 | 8/13/17 | 7/19/18 |
| 100 | 240 | 1200 | 30.0 | 8/18/17 | 8/11/18 |
| 101 | 240 | 1200 | 30.0 | 9/1/17 | 10/20/17 |
| 102 | 240 | 1200 | 28.0 | 9/26/17 | 10/7/17 |
| 103 | 240 | 1200 | 30.0 | 9/24/17 | August, 1919. |
| 104 | 240 | 1200 | 28.0 | 10/10/17 | 4/7/18 |
| 105 | 290 | 1450 | 32.0 | 10/29/17 | 1/5/18 |

a) Zeppelin Airships (Contd.)

| Serial No. | HP per engine | Total HP | Speed in m/sec. | Date of first flight | In service till |
|---|---|---|---|---|---|
| L Z 106 | 290 | 1450 | 32 | 12/12/17 | 8/29/18 |
| 107 | 290 | 1450 | 32 | 1/19/18 | 5/10/18 |
| 108 | 290 | 1450 | 32 | 12/18/17 | 7/19/18 |
| 109 | 290 | 1450 | 32 | 3/11/18 | 7/22/20 |
| 110 | 290 | 1450 | 32 | 3/4/18 | July, 1919. |
| 111 | 290 | 1450 | 32 | 4/17/18 | July, 1919. |
| 112 | 290 | 2030 | 36 | 7/1/18 | 8/5/18 |
| 113 | 290 | 2030 | 36 | 7/29/18 | 7/1/20 |
| 114 | 290 | 2030 | 36 | 7/9/20 | |
| 120 | 240 | 960 | 37 | 8/20/19 | |
| 121 | 240 | 960 | | | |

a) Zeppelin Airships (Cont.)

Remarks.

| | |
|---|---|
| L Z 1 | Dismantled in construction yard. |
| 2 | Destroyed by storm after forced landing at Kiesslegg (Algäu). |
| 3 | Obsolete; dismantled in Metz hangar. |
| 4 | Forced to land at Echterdingen and afterward burned. |
| 5 | Forced to land at Weilburg; carried away and wrecked by storm. |
| 6 | Destroyed by fire in Baden-Oos hangar. |
| 7 | Wrecked at Wellendorf (Teutoburger Forest). |
| 8 | Destroyed while being brought out of Düsseldorf hangar. |
| 9 | Obsolete; dismantled in Gotha hangar. |
| 10 | Destroyed by fire at Dusseldorf. |
| 11 | Destroyed while being brought into Leignitz hangar. |
| 12 | Obsolete; dismantled in Metz hangar. |
| 13 | Obsolete; dismantled in Johannisthal hangar. |
| 14 | Wrecked at Heligoland. |
| 15 | Destroyed by storm at Karlsruhe after forced landing. |
| 16 | Obsolete; dismantled in Jüterborg hangar. |
| 17 | Obsolete; dismantled in Düren hangar. |
| 18 | Caught fire during flight and destroyed at Johannisthal. |
| 19 | Wrecked at Diedenhofen after forced landing. |
| 20 | Hit by gunfire and wrecked at Lipoviec (Mlawa). |
| 21 | Hit by gunfire over Lüttich and wrecked at Cologne. |
| 22 | Hit by gunfire and wrecked at St. Quirin on observation flight. |

a) Zeppelin Airships (Cont.).

Remarks.

| | |
|---|---|
| L Z 23 | Hit by gunfire and wrecked at Badonvillers on observation flight. |
| 24 | Wrecked on coast of Fanö, after failure of all its engines. |
| 25 | Destroyed by English aviators in Düsseldorf hangar. |
| 26 | Dismantled in Jüterborg hangar in consequence of the discontinuance of the Army airship service. |
| 27 | Driven by storm to Denmark and wrecked at Borsmose. |
| 28 | Hit by gunfire and wrecked at Mitau. |
| 29 | Hit by gunfire in raid on Paris and wrecked at St. Quentin. |
| 30 | Wrecked and burned in removing from Posen hangar. |
| 31 | Burned in Fuhlsbüttel hangar. |
| 32 | Shot down at Horn's Reef on reconnoitering trip. |
| 33 | Shot down and wrecked at Tirlemont. |
| 34 | Hit by gunfire in raid on Kovno; forced to land in East Prussia; carried away by wind and burned. |
| 35 | Hit by gunfire and wrecked at Thielt in raid on Poperinghe. |
| 36 | Burned in Fuhlsbüttel hangar. |
| 37 | Shot down by aviators at Ghent, after raid on Calais. |
| 38 | Destroyed in Brüssel-Evere hangar by English aviators. |
| 39 | Hit by gunfire in raid on Kovno and wrecked at Luck. |
| 40 | Struck by lightning and fell in flames near Cuxhaven. |
| 41 | Obsolete; dismantled in Hague hangar. |
| 42 | Dismantled in Jüterborg hangar in consequence of discontinuance of Army airship service. |

a) Zeppelin Airships (Cont.)

Remarks.

| | |
|---|---|
| L Z 43 | Hit in raid on England, landed and burned at Ostend. |
| 44 | Wrecked in Belgium by running into a mountain. |
| 45 | Obsolete; dismantled in Hague hangar. |
| 46 | Destroyed in Nordholz hangar. |
| 47 | Shot down at Revigny. |
| 48 | Forced down and sank at mouth of the Thames, after raid on England. |
| 49 | Hit by gunfire in raid on Paris and wrecked at Ath. |
| 50 | Destroyed in Nordholz from landing too hard. |
| 51 | Hit by gunfire in raid on Bukarest; forced to land and wrecked at Trovno. |
| 52 | Destroyed by fire in Tondern hangar. |
| 53 | Destroyed by fire in Tondern hangar. |
| 54 | Fell into North Sea. |
| 55 | Hit by gunfire in raid on Saloniki and wrecked at Wardar. |
| 56 | Wrecked at Temesvar by landing too hard. |
| 57 | Dismantled in Jüterborg hangar in consequence of discontinuance of Army airship service. |
| 58 | Adopted by Navy as experimental airship L 25; became obsolete and was dismantled in Potsdam hangar. |
| 59 | Was carried away and wrecked at Stavanger, as a result of engine trouble after raid on England. |
| 60 | Torn from its moorings at Wittmund by a storm and carried to sea unmanned. |
| 61 | Shot down near Lowestoft on coast of England. |
| 62 | Dismantled in Seerappen hangar. |

a) Zeppelin Airships (Cont.)

Remarks.

| | |
|---|---|
| L Z 63 | Dismantled in Trier hangar, due to discontinuance of Army airship service. |
| 64 | Shot down by torpedo boats near Terschelling. |
| 65 | Hit by gunfire while flying over Champagne front and wrecked at Namur. |
| 66 | Shot down by torpedo boats near Horn's Reef. |
| 67 | Dismantled in Jüterborg hangar, due to discontinuance of Army airship service. |
| 68 | Dismantled in Schneidemühl hangar, due to discontinuance of Army airship service. |
| 69 | Destroyed by fire in Tondern hangar. |
| 70 | Building discontinued to make room for building airships of 55000 cu.m. (1,942,325 cu.ft.) gas capacity. |
| 71 | Dismantled in Jüterborg hangar due to discontinuance of Army airship service. |
| 72 | Shot down in raid on London. |
| 73 | Dismantled in Königsberg hangar, due to discontinuance of Army airship service. |
| 74 | Shot down in raid on London. |
| 75 | Taken apart in Seddin hangar to be reassembled in Japan. |
| 76 | Hit by gunfire at Brentwood, England, forced to land and there dismantled. |
| 77 | Dismantled in Darmstadt hangar, due to discontinuance of Army airship service. |
| 78 | Shot down by English aviators at Scarborough on the coast of England. |
| 79 | Destroyed in Nordholz hangar. |
| 80 | Obsolete; dismantled in Jüterborg hangar. |

a) Zeppelin Airships (Cont.)

Remarks.

| | |
|---|---|
| L Z 81 | Dismantled in Dresden hangar, due to discontinuance of Army airship service. |
| 82 | Wrecked in fog at Rethem (Aller). |
| 83 | Was flown from Seddin to Mauberge and delivered to France. |
| 84 | Wrecked at Seemuppen, Russia. |
| 85 | Wrecked in Saone valley, after raid on England. |
| 86 | Shot down at Compeigne. |
| 87 | Destroyed by explosion and fire in Ahlhorn hangar. |
| 88 | Wrecked at Neuenwalde (Geestemünde). |
| 89 | Wrecked in Switzerland after raid on England and landing at Montigny le Roi, France. |
| 90 | Soon to be flown from Seerappen near Königsberg, to Rome, and turned over to Italian Government. |
| 91 | Destroyed in Nordholz hangar. |
| 92 | Shot down over North Sea by English fleet. |
| 93 | Shot down in France after raid on England. |
| 94 | Destroyed by explosion in Ahlhorn hangar. |
| 95 | Shot down at Ipswich. |
| 96 | Carried away and wrecked at Bouchon les Bains, France, after raid on England. |
| 97 | Destroyed by fire in Ahlhorn hangar. |
| 98 | Destroyed in Wittmund hangar. |
| 99 | Destroyed by English aviators in Tondern hangar. |
| 100 | Shot down near Terschelling. |
| 101 | Hit by gunfire in raid on England and wrecked at Tiefenort (Werra). |

a) Zeppelin Airships (Cont.)

Remarks.

| | |
|---|---|
| L Z 102 | Destroyed by fire in front of Jüterborg hangar. |
| 103 | Destroyed in Wittmund hangar. |
| 104 | Fell in flames over Otranto Strait (cause unknown). |
| 105 | Destroyed by explosion in Ahlhorn hangar. |
| 106 | Flown from Wittmund to Rome and delivered to the Italian Government. |
| 107 | Fell while flying over Heligoland. |
| 108 | Destroyed by English aviators in Tondern hangar. |
| 109 | Flown from Ahlhorn to Pulham and delivered to the British Government. |
| 110 | Destroyed in Nordholz hangar. |
| 111 | Destroyed in Nordholz hangar. |
| 112 | Shot down near Boston. |
| 113 | Flown from Ahlhorn to Pulham and delivered to the British Government. |
| 114 | Flown from Loewenthal to Mauberge and delivered to the French Government. |
| 115-119 | Not built. |
| 120 | Not operated after lengthening, because of prohibition by Entente. |
| 121 | Not operated because of prohibition by Entente. |

b) SCHUTTE-LANZ AIRSHIPS.

| Serial No. | Construction yard | Named by owner | Owned by |
|---|---|---|---|
| S L 1 | Rheinau | SL 1 | S.L. Airship Co. |
| 2 | Rheinau<br>After lengthening | 2 | Army<br>Army |
| 3 | Rheinau | 3 | Navy |
| 4 | Sandhofen | 4 | Navy |
| 5 | Darmstadt | 5 | Army |
| 6 | Leipzig | 6 | Navy |
| 7 | Rheinau | 7 | Army |
| 8 | Leipzig | 8 | Navy |
| 9 | Leipzig | 9 | Navy |
| 10 | Rheinau | 10 | Army |
| 11 | Leipzig | 11 | Army |
| 12 | Zeesen | 12 | Navy |
| 13 | Leipzig | 13 | Army |
| 14 | Rheinau | 14 | Navy |
| 15 | Rheinau | 15 | Army |
| 16 | Leipzig | E 9 | Army |
| 17 | Zeesen | 10 | Army |
| 18 | Leipzig | 11 | Army |
| 19 | Leipzig | 12 | Army |
| 20 | Rheinau | SL 20 | Navy |
| 21 | Zeesen | F 2 | Army |
| 22 | Rheinau | SL 22 | Navy |

b) Schutte-Lanz Airships (Cont.)

| Serial No. | Gas Capacity | No. of cells | Length m. | Diameter m. | Useful load at 0° and 760 mm | No. of engines. |
|---|---|---|---|---|---|---|
| S L 1 | 20500 | 11 | 131 | 18.4 | 4500 | 2 |
| 2 | 25000 | 15 | 144 | 18.2 | 8000 | 4 |
| | 27400 | 16 | 156 | 18.2 | 10435 | 4 |
| 3 | 32410 | 17 | 153.1 | 19.75 | 13200 | 4 |
| 4 | 32410 | 17 | 153.1 | 19.75 | 13955 | 4 |
| 5 | 32410 | 17 | 153.1 | 19.75 | 14260 | 4 |
| 6 | 35130 | 18 | 162.1 | 19.75 | 15800 | 4 |
| 7 | 35130 | 18 | 162.1 | 19.75 | 15560 | 4 |
| 8 | 35130 | 18 | 174 | 20.1 | 18680 | 4 |
| 9 | 35130 | 18 | 174 | 20.1 | 19820 | 4 |
| 10 | 38780 | 19 | 174 | 20.1 | 21000 | 4 |
| 11 | 38780 | 19 | 174 | 20.1 | 21000 | 4 |
| 12 | 38780 | 19 | 174 | 20.1 | 20800 | 4 |
| 13 | 38780 | 19 | 174 | 20.1 | 20000 | 4 |
| 14 | 38780 | 19 | 174 | 20.1 | 20500 | 4 |
| 15 | 38780 | 19 | 174 | 20.1 | 20500 | 4 |
| 16 | 38780 | 19 | 174 | 20.1 | 20500 | 4 |
| 17 | 38780 | 19 | 174 | 20.1 | 20500 | 4 |
| 18 | 38780 | 19 | 174 | 20.1 | --- | 4 |
| 19 | 38780 | 19 | 174 | 20.1 | -- | 4 |
| 20 | 56000 | 20 | 198.3 | 22.92 | 35300 | 5 |
| 21 | 56000 | 20 | 198.3 | 22.92 | 35400 | 5 |
| 22 | 56000 | 20 | 198.3 | 22.92 | -- | 5 |

b) Schutte-Lanz Airships (Cont.)

| Serial No. | HP per engine | Total HP | Speed in m/sec. | Date of first flight | In service till |
|---|---|---|---|---|---|
| S L 1 | 240 | 480 | 19.7 | 10/17/11 | 7/17/13 |
| 2 | 180<br>210 | 720<br>840 | 24.5<br>-- | 2/28/14<br>-- | --<br>1/10/16 |
| 3 | 210 | 840 | 23.5 | 2/4/15 | 5/1/16 |
| 4 | 210 | 840 | 23.6 | 4/25/15 | 12/15/15 |
| 5 | 210 | 840 | 23.1 | 6/ /15 | 7/5/15 |
| 6 | 210 | 840 | 25.8 | 9/19/15 | 11/18/15 |
| 7 | 210 | 840 | 25.0 | 9/3/15 | 3/6/17 |
| 8 | 240 | 960 | 25.8 | 3/30/16 | 11/20/17 |
| 9 | 240 | 960 | 25.8 | 5/24/16 | 3/30/17 |
| 10 | 240 | 960 | 25.0 | 5/17/16 | 7/28/16 |
| 11 | 240 | 960 | 25.5 | 8/2/16 | 9/3/16 |
| 12 | 240 | 960 | 24.08 | 11/9/16 | 12/28/16 |
| 13 | 240 | 960 | 25.0 | 10/19/16 | 2/8/17 |
| 14 | 240 | 960 | 25.0 | 8/23/16 | 5/11/17 |
| 15 | 240 | 960 | 25.0 | 11/9/16 | Summer, 1917. |
| 16 | 240 | 960 | 25.0 | 1/18/17 | Summer, 1917. |
| 17 | 240 | 960 | 25.0 | 3/22/17 | Summer, 1917. |
| 18 | 240 | 960 | -- | -- | 2/8/17 |
| 19 | 240 | 960 | -- | -- | -- |
| 20 | 240 | 1200 | 28.5 | 9/10/17 | 1/5/18 |
| 21 | 240 | 1200 | | 11/26/17 | February, 1918. |
| 22 | 240 | 1200 | 28.5 | 6/5/18 | June, 1920. |

b) Schutte Lanz Airships (Cont.)

Remarks.

| | | |
|---|---|---|
| S L | 1 | Destroyed by storm at Erpel (Schneidemühl). |
| | 2 | Wrecked by storm at Luckenwalde. |
| | 3 | Wrecked in the Baltic Sea. |
| | 4 | Destroyed by storm in Seddin hangar. |
| | 5 | Forced to land at Giessen, torn loose and wrecked by storm. |
| | 6 | Fell in flames near Seddin (Stolp). |
| | 7 | Dismantled in Jüterborg hangar, due to discontinuance of Army airship service. |
| | 8 | Dismantled in Seddin hangar. |
| | 9 | Fell in flames into Baltic Sea west of Pillau. |
| | 10 | Disappeared over Black Sea. |
| | 11 | Shot down in raid on London. |
| | 12 | Wrecked at Ahlhorn. |
| | 13 | Destroyed by fire at Leipzig. |
| | 14 | Damaged by landing too hard in Wainoden (Kurland) and dismantled. |
| | 15 | Dismantled in Sandhofen hangar, due to discontinuance of Army airship service. |
| | 16 | Dismantled in Opich hangar mear Cologne, due to discontinuance of Army airship service. |
| | 17 | Dismantled in Allenstein hangar, due to discontinuance of Army airship service. |
| | 18 | Destroyed by fire in Leipzig hangar, before completion. |
| | 19 | Not completed, on account of the damage to the Leipzig construction yard by fire of February 8, 1917. |
| | 20 | Destroyed by flames in Ahlhorn hangar. |

b) Schütte-Lanz Airships (Cont.)

Remarks.

S L 21 Dismantled in Zeesen construction yard, due to discontinuance of Army airship service.

22 Dismantled in Jüterborg hangar.

Unfortunately, it has not always been possible to obtain absolutely reliable data on each individual airship, especially on those built during the war. Some of the data on speed and useful load are either lacking or variously reported. Since it is difficult to determine speed and especially useful load accurately, small differences in the computation are all the more noticeable in a tabulation of this kind.

In the computation of the useful load, the temperature of the gas and of the air, atmospheric pressure and specific weight of the gas can be accurately determined, but not always the relative humidity of the air.

In "Motorwagen," 1919, No. 22, Prof. C. Ehrhardt, lecturer on aviation at the Darmstadt Technical High School, has discussed in detail the difficulties of determining accurately the gas capacity. Moreover, views vary as to just what constitutes the useful load and the dead load.

The determination of the speed is likewise subject to various influences which cannot be considered in such a tabulation. Gusty weather and the static condition of the airship exert considerable influence. Lastly, the resistance or drag due to the radio anten-

nae and the crew on the platform, the condition of the envelope and the revolution speed of the engine play an important role. The maximum speed is of no practical value, the determination of the "cruising speed" being much more important. The latter is the speed at normal engine power with the employment of radio apparatus, armament, etc.

Schwarz Airship.

In 1893, David Schwarz built a rigid aluminum airship in St. Petersburg (Petrograd). It could not be used, however, because the inside stay wires were broken by the gas pressure during inflation.

In 1895-1897, he built in Berlin a new airship 47.5 meters (155.84 feet) long and 13.5 meters (44.29 feet) in diameter. It had the shape of a projectile pointed in front and rounded at the rear end. The frame consisted of 12 main transverses, 16 main longitudinal lattice-girders and numerous intermediate transverses and longitudinals. The transverses were braced radially inside. The air-tight envelope, inclosing the whole undivided space of 3700 cu.m. (130,666 cu.ft.) was made of 2 mm. (.0787 in.) sheet aluminum. The car was rigidly attached to the hull by lattice-girders and braced by wires extending to the ends of the hull. The single Daimler engine developed 12 HP at 480 R.P.M. The gasoline consumption was 0.42 kg. (.926 lb.) per HP-hour. The airship had three propellers, two of which were mounted on brackets attach-

ed to the hull and had a diameter of 2 meters (6.56 feet). The third had a diameter of 2.75 meters (9.022 feet) and was mounted between the hull and the car on a shaft capable of being turned about a vertical axis so as to serve for steering, as the airship had no rudder. All the propellers were driven by means of belts. Another propeller, designed to be used helicopter-fashion, did not materialize.

At the suggestion of Captain Bartsch von Sigsfeld, the air was driven out of the hull by inflating cloth bags previously introduced into the hull. These bags were then ripped and removed through the bottom of the hull.

On the first trial trip, November 3, 1897, the airship rose, as a captive balloon, in a wind of 7.5 meters (24.61 feet) per second. During the immediately following flight, the driving-belts soon slipped off their pulleys and the rudderless airship, with only one man on board, was carried away by the wind and compelled to attempt a forced landing. The airship was so badly damaged in landing and by the further effect of the wind that it had to be broken up. Since then no metal airship has been built. The project of the Hungarian steel airship was never carried out.

## Zeppelin Airships up to Beginning of War.

Count Zeppelin did not allow himself to be dissuaded by the failure of the Schwarz airship from his long-conceived plan to build a rigid airship of what were then considered giant dimensions.

In 1898, after he had succeeded in founding the "Gesellschaft zur Förderung der Luftschiffahrt" (Association for the Promotion of Airship Flight), and had secured the necessary funds, the construction of an airship and of a hangar in Manzell was begun.

In 1887, in a memorial to King Karl of Würtemberg, Count Zeppelin had already outlined the great tasks, both military and economic to be performed by airships; namely: scouting and raiding in war; long-distance transportation and exploration of unknown regions in times of peace.

These ends could only be accomplished by means of several powerful engines for attaining a high speed and by increasing the lifting power, so as to be able to carry sufficient fuel for long trips, in addition to a considerable number of persons and bombs.

Count Zeppelin realized from the first that these conditions could only be fulfilled by large airships. In contradistinction to the builders of small nonrigid airships (who were really only endeavoring to solve the problem of making free balloons dirigible), he kept constantly in mind the development of the large airship.

Zeppelin's significance resides in the fact that he abandoned the old tradition of Meusnier (descended from 1784) and went his own way. In doing thus, he set much at stake. Often his life's work seemed annihilated and the development of the rigid airship hopeless, but he always managed to tide over his misfortunes and finally attained his goal.

His views have been vindicated. Rigid airships have been

successfully employed for raiding and scouting in war and have long since demonstrated their ability as a means of transportation between distant regions, as evidenced by the trip of the L 59 to Africa and back and the 100 hour voyage of the LZ 120. Nothing now stands in the way of their economic utilization.

The first Zeppelin airship had the shape of a cylinder pointed at both ends. It was 128 meters (419.95 feet) long and 11.65 meters (38.22 feet) in diameter. Each transverse frame was a regular 24-sided polygon. The longitudinal framework consisted of aluminum lattice-girders. For increasing the strength and rigidity, the transverses were braced inside by wires and divided the hull into 17 compartments, each containing a fabric gas bag. The whole hull was covered with water-tight cotton fabric.

Underneath the hull, there were two cars rigidly suspended and provided each with a 14.5 HP Daimler engine. Each engine drove two four-bladed aluminum propellers (one attached to either side of hull) of only 1.1 meter (3.61 feet) diameter, by means of bevel gears and long oblique tubular shafts. By the installation of a reversing gear, it was also possible to drive the propellers backward.

The function of a rudder were performed by four vertical steering surfaces, two in front above and below and one on either side of stern. For ascending or descending, the airship was trimmed by means of a sliding weight of about 100 kg (328.08 lb).

The first flight was made in the evening of July 2, 1900, with five persons on board. The flight had to be interrupted after 18 minutes, due to failure of the rudders. The alighting on Lake Con-

stance took place smoothly, however. It afterwards encountered a pile and suffered some damage. Distortions of the framework during flight rendered the removal of the gas necessary.

Various improvements were then undertaken. First of all, the walk-way, which had only been suspended on wire cables under the hull, was rigidly attached to the framework, thus considerably strengthening the latter. The lateral steering surfaces were discarded and were replaced by several vertical surfaces under the hull. Since the sliding weight had not proved satisfactory, a steering surface with a horizontal axis was installed in front of the forward car. The sliding weight was at first retained, however, though differently arranged.

The changes were completed by the end of September, 1900, but the airship suffered further injuries in its hangar by the tearing of suspension devices. It took till the middle of October to repair these damages. The second flight took place October 17, and lasted one hour and twenty minutes, the new arrangements proving successful. No speed measurements were undertaken, however, due to failure of the rudders.

A third flight was made October 24, but lasted only 24 minutes, since the frame again bent upward in the middle. The airship had developed a speed of about eight meters per second.

The funds supplied Count Zeppelin by the "Gesellschaft zur Förderung der Luftschiffahrt" had now given out, so that further flights had to be foregone. The association disbanded and Count Zeppelin acquired the airship, hangar and accessories as his own

property, in the hope of being able to resume the experiments later.

What had been accomplished? Count Zeppelin had, in spite of all the doubts of aviators and scientists, built a rigid airship and made several flights with it. It differed from previous airships in:

1. Size;
2. Aluminum frame;
3. Division of gas space into cells;
4. Independence of power plants of one another;
5. Rigid suspension of cars;
6. Attachment of propeller brackets to hull;
7. Introduction of elevator;
8. Introduction of walk-way.

The rigid frame gave the airship a permanent shape, which could only be obtained in a nonrigid airship by internal pressure. In the first frame, however, the top girders were not strong enough.

Count Zeppelin rightly put great faith in the division of the gas space. While a nonrigid airship, in the event of a tear, could no longer be kept in the air, an injury to one gas cell of a rigid airship resulted only in a decrease in the lift which could usually be offset by releasing ballast. The gas cells were all provided with safety valves, through which the gas escaped when the internal pressure became excessive from altitude or heat. In order to diminish the lift under certain circumstances, some of the cells were provided with valves which could be opened at will. The fabric used for the cells was not sufficiently gas-tight, so that the already

small lift constantly decreased.

The independence of the power plants had decided advantages. In case of the failure of some part, like the driving gear or the propeller, the airship was not thereby deprived of its entire engine power, but could proceed with the aid of the other engine.

The rigid suspension of the cars and the fixed distance between cars and hull enabled the installation of propellers on the latter. They were located at the so-called "center of drag," at which, according to the then prevalent view, the propellers were most efficient. This suspension method naturally had its disadvantages, since, in hard landings, the shock was transmitted to the hull and driving gear, which it was liable to damage.

The elevator experiments were encouraging. The altitude control by means of the sliding weight worked too slow.

The walk-way, which was still very crude and led only from one car to the other, enabled transfer of weight between the cars and the inspection of certain parts during flight. The frame was not built strong enough to make the hull perfectly rigid.

Thus certain principles had been established which were worthy of further development. The general efficiency of the airship was, nevertheless, very unsatisfactory. Its small carrying capacity was out of all proportion to its size and its small speed was insufficient to make headway against even a very moderate wind. Consequently, no one was found to furnish the funds necessary for the completion of his task. Even the "Verein deutscher Ingenieure" (Society of German Engineers) which had had a large share in founding the

"Gesellschaft zur Förderung der Luftschiffahrt," refused to aid him. In the still uncertain evolution of the airship, the greater value was generally placed on the small nonrigid type which, in case it were unable to proceed by its own power, could be packed up and transported by rail or wagon. It was considered that no great success could be obtained with the engines then in use.

All the Count's attempts to obtain funds, by advertising in the press, failed and he was compelled to dismantle both airship and hangar and sell them as junk.

Any one else would have given up, after these disappointments, but Count Zeppelin did not despair of the future. With the same energy, which resulted in the building of his first airship, he continued to strive to awaken interest in the building of another. He found an ardent supporter in the person of the King of Würtemberg. A lottery, instituted in Würtemberg at his suggestion, yielded a large sum. Other German states participated in this lottery or made small donations. Factories like those of Eveking, Daimler and Riedinger announced their readiness to place aluminum, engines and balloon fabric for further experiments at his disposal, so that the preparations for building the second airship were begun in 1904.

The construction of the LZ 2 was under the technical supervision of the engineer Dürr, who had taken the place of Kübler. The LZ 2 was completed in 1905 and had the same dimensions as the LZ 1, but differed considerably from its predecessor in structure.

In place of the lattice-girders, stronger triangular girders were employed; its cross-section had only 16 sides instead of 24;

and it had 16 gas cells instead of 17. The weak engines were replaced by stronger ones of 85 HP, each of which drove 2 three-bladed propellers of 3 meters (9.84 feet) diameter. The walk-way was raised from 0.8 m (2.62 ft) to 2 m (6.56 ft) and materially stiffened the hull by its stronger construction. The sliding weight was left off and the rudders and elevator improved.

The first ascent was to take place November 30, 1905, but it did not materialize, since a cable became entangled with the airship and brought it down again onto the lake, damaging the rudders which had been installed in front of the forward car.

Its first and only flight took place January 17, 1906. The airship obeyed its rudder perfectly, but at its flight altitude of 400 meters, could make no headway against the ever increasing wind and finally, when one engine had to be stopped on account of excessive heating, was slowly carried toward Algäu. Soon the other engine failed and the pilot, Lieut. Von Krogh, was compelled to land the airship like a free balloon.

A smooth landing was made in a meadow near Kisslegg in Algäu, but the airship was driven sidewise by the ground wind and finally came to a stop with its stern hanging in a tree. The damages being comparatively slight, it was hoped to prepare the airship for renewing its flight after the arrival of men and gas from Manzell. The airship, however, was so seriously damaged by a storm which arose in the night that it had to be dismantled.

Thus the question of the rigid airship seemed to have been disposed of once for all. The single short flight of the LZ 2 had in-

deed shown that Count Zeppelin had gotten further on the right track. The more powerful engines had produced the greater speed of 10 m (32.8 ft) per second. The strength of the frame and the dependable functioning of the rudders inspired confidence. Lastly, it had been possible to make the whole structure lighter and thus increase the lift.

The public, however, pronounced judgment only according to the apparent final result. The airship had made only one flight and, after its first landing, had been dismantled. Any such accident would not have resulted in the total destruction of a non-rigid airship.

Still Count Zeppelin would not allow himself to become discouraged. He could not believe that the misfortunes of the engines' failing and the rising of a storm would forever exclude his airship from further development. And his faith in the future finally triumphed.

Count Zeppelin contrived, in a very short time, to obtain the necessary money for building a third airship and had it finished late in the autumn of 1906. This time no unlucky star ruled over the airship. Both flights, of October 9 and 10, proceeded satisfactorily, up to four hours' duration, and demonstrated the practicability of Zeppelin's ideas.

The LZ 3 was constructed on the same plan as the LZ 2. The only innovation was the four nearly horizontal stabilizing planes arranged in pairs on either side of the stern. This innovation, which was only reluctantly adopted, meant a long step forward.

On both the former airships there had been a disagreeable rolling motion during flight. After the addition of these lateral fins, the airship was quite stable with respect to its longitudinal axis.

Funds were lacking for continuing the experiments, but further successes of the new airship were not long delayed. A new lottery was started and the government built a floating hangar on Lake Constance near Manzell. Like the 1899 hangar, it was anchored in such a way that it always swung in the direction of the wind. This was in order to minimize the chances of injury in bringing the airship in and out of the hangar. For bringing out the airship, it was moored to the floating floor of the hangar, which was towed out by a steam tug.

During the building of the hangar, a few alterations were made in the airship LZ 3. The walk-way, which had hitherto extended only from one car to the other, was extended both fore and aft. This made it possible to walk almost the whole length of the airship during flight. Extensive alterations were made in the steering gear. The rudders underneath the airship were removed and were replaced by box rudders placed between the stabilizing planes at the stern. The elevators underneath were removed and were replaced by sets of four elevators on either side both fore and aft.

The floating hangar was completed in the autumn of 1907, and the rebuilt LZ 3 was transferred to it from its former stationary hangar. The trial flights were awaited in suspense. This time the government was directly interested, having appropriated, in the spring of 1907, the sum of 500,000 marks for the Zeppelin experi-

ments. The government required certain performances, however, as, for example, a 24-hour non-stop flight of at least 700 km (435 mi.), a portion of it at an altitude of 1500 m (492.12 ft), to a previously specified destination and return to Manzell.

Would the airship be able to fulfill these conditions? Technical experts probably felt the least confident. Former flights had shown how the success of each one depended on circumstances. Could the engines stand the endurance test? Was the crew sufficiently trained and well enough acquainted with the airship to undertake such a flight? In the further narrative, we will see how far the airship was at that time from being able to fulfill such requirements.

On September 24, 1907, the experiments began and proceeded in fine shape. Count Zeppelin exhibited his airship to the representatives of civil and military bodies in five flights - on September 24, 25, 26, 28 and 30. All the parts worked well and demonstrated the wisdom of the alterations. The new elevators were an especial improvement. Only the functioning of the rudders was not entirely satisfactory. On the 30th, a seven-hour flight was made, covering a distance of about 350 kilometers, constituting the best endurance record made up to that time by any airship.

No further attempt was made that year to accomplish the 24-hour flight. The commission sent by the government to observe the performances of the airship had to acknowledge its capabilities, but could not escape the conclusion that only under the most favorable conditions was there any possibility of the airship (of

small carrying capacity) being able to succeed in the endurance test.

Count Zeppelin then proposed to give up further experiments with the LZ 3 and to build a larger airship with greater carrying capacity for undertaking the endurance flight. This plan was approved in October, 1907, at a conference in Berlin of representatives of the war department, the general army staff, the department of the interior, the treasury department and the department of education. After the "Reichstag" had made further appropriations, the construction of the LZ 4 was begun.

By assisting the second time, the government showed what a high value it set on the airship, both from the military and cultural points of view, and how determined it was to keep the lead Germany had obtained over other countries. All the more interest was aroused in the development of the airship, because at this time experiments had been begun in Germany on the Parseval military airship and in France the development of the nonrigid airship was making good progress.

The completion of the LZ 4 was delayed until June, 1908, because the floating hangar containing the LZ 3 was considerably damaged by a storm in December, 1907. Repairs had to be awaited, because the LZ 4 was to make its trial flights from the same hangar.

The LZ 4 began its trial flights June 30, 1908. With its greater gas capacity of 15000 cu.m., it had a considerably greater carrying capacity than the LZ 3. The stronger engines of 105 HP each produced, moreover, an increase of 1.5 m/sec in speed. The

cars were larger and accommodated a larger number of persons. At the middle of the walk-way a passenger cabin was added. From this point a climbing shaft led to an observation platform on top of the hull. The rudder arrangement underwent the greatest variety of changes. On the first flight, there were both a bow and a stern rudder. The bow rudder was then removed and the old box rudders again installed between the stabilizers. Since this arrangement was likewise unsuccessful, the small stern rudder was replaced by a large oval rudder. This improved the lateral steering, but still left much to be desired as compared with the excellent vertical steering.

On July 1, 1908, Count Zeppelin made his famous 12-hour flight over Switzerland, which was carried out without accident and attracted much attention. For the first time, the airship had flown a long way from its home port and over rough country. Much useful experience was thus obtained. After the King and Queen of Würtemberg had participated in a short flight on July 3, the LZ 4 was deflated, in order to begin the great flight with fresh gas.

For this purpose, the airship ascended on July 14. It was planned to follow the course of the Rhine over Basel, Strassburg and Mannheim as far as Mainz and to make the return flight across the interior over Stuttgart. At Constance, however, the trip had to be interrupted on account of damage to a radiator. On the following day the airship was again in condition and the attempt was repeated, in spite of unfavorable weather. While being brought out of the hangar, the airship hit against the wall of the hangar

and damaged the elevator and propeller. Also one gas cell was damaged, rendering it again necessary to deflate the airship.

On August 4, the damages had been repaired and the LZ 4 left Lake Constance early in the morning, carrying 12 persons, fuel for 24 hours and 600 kg (1322.76 lb) water ballast. After a smooth 11-hour flight over Schaffhausen, Basel, Strassburg, Speyer and Mannheim, it arrived north of Worms, where Count Zeppelin decided to make a landing. One engine had stopped and the airship, which had lost much gas, due to the heat of the sun and the high altitude, had become heavy. There was no ballast left and the one remaining engine was not powerful enough to hold the altitude with the aid of the elevator.

A smooth landing was made at Altrhein near Oppenheim. After being repaired and lightened by the removal of spare parts and several persons, the airship ascended again at about 10:30 p.m., flew over Mainz and then southward over Mannheim, when the forward engine stopped for the rest of the trip, due to the melting of a bushing. The LZ 4 proceeded slowly and reached the region of Stuttgart on the morning of August 5, where another smooth landing was made on solid ground near Echterdingen, after the airship could no longer make headway with a single engine against a freshening south wind. The airship was moored after a makeshift manner and held by a company of soldiers. In the afternoon a tempest arose. A sudden gust struck the airship broadside and tore it away from its mooring and the men holding it. After a short flight at a low altitude, it caught fire as it struck the ground and was completely consumed.

A common grief pervaded the German people. Even foreign countries did not withhold recognition of what had thus far been accomplished. Everybody had followed this flight with interest - and now the outcome! There was, however, one alleviating circumstance in this misfortune. Count Zeppelin was unharmed. He, with most of the crew, had left the airship and was not even an eye witness of the catastrophe.

At first thought, it seemed that the life-work of Count Zeppelin had gone for naught, since the government had conditioned its further support on the outcome of this flight. But the German people judged the matter impartially. They recognized the value of what Count Zeppelin had accomplished and knew how to show their appreciation. They supplied him with such abundant funds that he was able to carry out his plans on a large scale. Thus the Echterdingen disaster proved to be the decisive turning point in the development of the Zeppelin airship.

Technical experts, however, interpreted the state of affairs differently. They reasoned from the fact that the airship had not completed the stipulated endurance flight and that under like conditions a nonrigid airship would not be given over to destruction. Count Zeppelin was now, however, less dependent on the judgment of experts and the help of the authorities. He no longer needed to beg for funds and, freed from financial worries, was able to give his whole energy to the further development of his airship.

After the Echterdinger disaster, the year 1908 brought further successes which soon compensated for the loss of the LZ4. The LZ 3, which

had been damaged in 1907, and had been removed from its floating hangar to the stationary hangar at Manzell in exchange for the LZ 4, was soon repaired with the aid of the people's contributions. By lengthening it 8 meters (26.25 feet) its gas capacity was increased to 12200 cu.m (430,843 cu.ft) and its useful lift to about 500 kg (1102.3 lb). The old two-surface rudders, situated between the stabilizers, were increased by the addition of a third surface. No large stern rudder could be installed, on account of its weight. The elevators were made larger and a dorsal fin was added, in order to diminish the rolling of the airship.

In the trial flights, which began October 23, 1909, the LZ 3 proved to be extremely stable. The rudders and elevators worked satisfactorily. The speed, with both engines running, was 12.2 m/sec (40.03 ft/sec) and, with only one engine, it was 7.7 (25.26). All the flights were of long duration and were accomplished without accident. Worthy of mention is the six-hour flight of October 27, 1908, with Prince Henry of Prussia on board; the flight of November 7, 1908, to Donaueschingen to greet the Kaiser, with the Crown Prince on board; and the exhibition flight before the Kaiser on November 10, 1908.

In March, 1909, the LZ 3, which in the meanwhile had passed into the possession of the government as military airship Z 1, was manned by an Army crew and made 26 successful flights up to 12 hours' duration and 1500 meters (4921 feet) altitude. It also made several smooth landings on solid ground. In a flight to Munich, on April 1, 1909, the airship was carried east by a strong wind,

landed at Dingolfing, and on the afternoon of April 2, after the wind had subsided, proceeded to Munich and returned to Manzell in the evening.

After the completion of the Army airship hangar in Metz, the Z 1 was to be transferred to it on June 30, 1909. It was compelled by a pouring rain, however, to descend at Biberach and remain there four days until July 4, when it successfully completed its voyage.

The Z 1 was stationed at Metz until 1911, and there participated in many practice flights with other airships. During this year, as a consequence of rebuilding the rudders on the ground of the favorable results obtained with the airship "Schwaben," the speed of the Z 1 was increased to 15 m/s (49.2 ft/sec). It soon became obsolete, however, and was dismantled.

Let us return now to 1909. While the Z 1 was making its military practice flights, work was feverishly continued at Friedrichshafen. With the money contributed by the people, the new yard of the Zeppelin Airship Construction Company was built north of the city. At the same time, a canvas hangar was erected for the reception of the Z 1, so that the floating hangar could be placed at the disposal of the LZ 5, which was built in the old Manzell hangar, for its trial trips. After the frame of the LZ 5 was transferred to the floating hangar, the airship, which was to pass into the possession of the government as Z 2, was there completed. It did not differ essentially from the LZ 4. The passenger cabin in the middle of the walk-way was omitted. A few improvements were made in the steering gear and above all in the lubrication of the engine.

The latter condition was very important, since Count Zeppelin hoped to make with this airship an endurance flight surpassing, both in duration and distance, the stipulated conditions for the 24-hour flight. The essential conditions were good weather and the holding out of the engines.

The LZ 5 made its first trial flight on May 26, 1909. It gave no cause for uneasiness, so that Count Zeppelin decided to undertake the endurance flight at once. On May 28, the first attempt was made, but after a short time it was decided to return, as it had begun to rain. On the next day (May 29) the LZ 5 started again. The airship carried a crew of eight men, 600 kg water ballast and over 2000 kg (4409 lb) of fuel, sufficient for the simultaneous operation of both engines for 34 hours.

The intention was to reach Berlin and so the flight proceeded over Ulm, Treuchtlingen, Nuremberg, Erlangen, Bayreuth, Hof, Planen, Gera, Leipzig, the latter place being flown over at 5 p.m., May 30. Just as on the Mainz trip, a strong lift was produced by the expansion of the gas due to the heat of the sun. With the comparatively weak engines, the upward tendency had to be overcome by pointing the airship downward, thus retarding its progress, so that, after passing over Bitterfeld at 7 p.m., there was no prospect of reaching Berlin before midnight. Count Zeppelin, therefore, decided to turn back, especially because the fuel supply would not otherwise be sufficient for a non-stop return flight to Friedrichshafen, and he set a very great value on making a non-stop endurance flight with return to the starting point. With a northeast wind at its back, the

ship flew very swiftly until it reached the Thuringian Forest. Here the wind changed to the west and considerably retarded the airship. At 7 a.m., May 31, Crailsheim was reached, with only fuel enough left to run both engines 7 or 8 hours. At a low speed Stuttgart was flown over at 9 o'clock and Plochingen an hour later. With the increasing wind, there was no longer any possibility of reaching Lake Constance in five hours.

The LZ 5 therefore descended on a meadow near Göppingen, but its nose struck a pear tree, thereby damaging the hull more or less back as far as the forward car. The accident was due to the exhausted condition of the crew which, in their endeavor to make the endurance test successful, had had little rest for nearly 38 hours. On the first news of this accident, the flight, which had been followed with general solicitude, seemed to have terminated disastrously. But not so. The engineer Dürr, who had participated in the flight, succeeded in temporarily repairing the damaged nose with a wooden structure, so that the airship was enabled to make the short flight to Friedrichshafen. After necessary repairs, it ascended with a smaller crew toward evening of June 1 and, after making a stop at Schemmerberg, north of Biberach, reached Manzell early in the morning of June 2.

The result of this flight, like the result of the Munich flight of the Z 1, must have opened the eyes of the opponents of rigid airships, for what they had regarded as impossible with Zeppelin airships (the strength to resist the shock of hard landings and making repairs en route) has been demonstrated by the facts. There was a

tendency, however, to ascribe these "accidental successes" to favorable weather conditions. Naturally, these had something to do with the successful outcome of the flights, but such results would have been impossible without the excellent structural characteristics of the Zeppelin airships. Moreover, the engines had functioned perfectly throughout, showing that the right course was being followed in this respect.

After being repaired and taken over by the war department, the LZ 5 was named the Z 2 and was transferred to Cologne on July 31. On the way, it made a stop on the grounds of the International Airship Exhibition at Frankfort-on-the-Main.

For the first time, opportunity was here given a large concourse of men from all parts of Germany and from foreign countries to obtain a personal impression of the Zeppelin airship. This impression was voiced on the following day (August 1) by the "Frankfurter Zeitung" as follows:

"As the airship passed before our eyes in a flight of almost an hour and a half, we became so accustomed to the sight that all our doubts vanished. As it sailed majestically through the air, every one was brought under its spell. The impression was deeper than could have been made by a thousand ever-so-convincing pens. It was the power of actuality, of one's own experience.

"Thus it sailed triumphantly over the land. It descended slowly, the ropes were thrown out and it was drawn gently to the ground, without any of the oft-proclaimed difficulties of landing. There it lay, after a few surprisingly simple precautionary measures and only

its nose oscillated a little in the wind.

"One is impressed by the symmetry and sleekness of the whole structure, as well as by the care with which all the details have been worked out. Everywhere diligent, solid German workmanship is evidenced. Here old established safety limits have not been exceeded and the engineer and scientific expert have not been forgotten. How simply the propeller brackets are attached to hull! How neat and smooth is the driving gear! Here is weight where it belongs. The cars are neat and smooth. They are made entirely of sheet aluminum and very gracefully shaped.

"The smoothness of its exterior gives the airship the minimum air resistance. There is not much on the outside of the airship, but what there is, is sufficient and in the right place."

In a later edition of the same date, Dr. Alfons Paquet says: "Can the few bold aviators up there in their cars know how we feel here below? Have they not already cast off much in their enviable freedom and power? Can they understand how the sight of this wonder affects us earth-bound creatures? Can they suspect how the overpowering impression of the conquest of the air grasps and convulses us like an electric current flowing from heart to heart? A cheer for the great white ship! A cheer for the giant projectile which speeds through the sky and brings not destruction where it goes, but joy and brotherly love! A cheer for the fulfillment of man's dream!"

Soon after the transfer of the Z 2 to the Army, a new airship

was completed, which Count Zeppelin hoped would also be taken over by the Army, although no order had been given for its construction.

The LZ 6 differed from the Z 2 only in its somewhat more powerful engines, its two-bladed propellers and its steel-belt drive. In comparison with the former bevel driving gear, the steel-belt drive had the advantage of economy of power and weight. On its first trial trip (August 25), nothing detrimental was discovered. Count Zeppelin ventured therefore, although the new driving gear had not been sufficiently tested, to start (August 27) on the trip to Berlin, in order to fulfill the wish of the Kaiser and the inhabitants to have the airship reach Berlin August 28, and land on the Tegeler shooting range.

During the journey, it soon became evident that the new driving gear was not suitable for airships. It proved impossible to so adjust the pulleys on the engine shaft and propeller hub that the distance between them would always remain the same, thus preventing excessive stresses and consequent tearing of the steel belt. It was only due to the otherwise good characteristics of Zeppelin construction that the flight did not have an unfortunate outcome.

The LZ 6 had left Manzell August 27, 1909, at 4:35 a.m., piloted by Chief Engineer Dürr with nine persons on board. The intention was to land in Bitterfeld on the field of the Parseval Company, where Count Zeppelin awaited the airship, and thence to proceed on the afternoon of August 28, with the Count on board, to Berlin, and to land on the Tegeler shooting range in the immediate vicinity of the airship crew's barracks.

At first all went well and the LZ 6 reached Ulm in two hours. On account of a damaged propeller, a stop was made half-way between Nordlingen and Nuremberg in the vicinity of Gunzenhausen near Ostheim. After the substitution of a spare propeller carried on the airship, the journey was continued, but soon had to be interrupted again at Dutzenteich near Nuremberg, in order to repair the forward engine. After replacing the damaged parts, another start was made at 2:15 a.m., August 28.

In the meanwhile, the weather had grown bad. It began to rain and the airship could make but little headway against the fresh north wind. It got along better later in the day and, after losing a propeller in the vicinity of Schmolln near Ronneberg, landed at 6:30 p.m. at Bitterfeld, after a flight of 16 hours. The enthusiasm here was tremendous. Thousands of people had assembled from the immediate neighborhood and from the surrounding towns and for twelve hours had patiently awaited the arrival of the airship.

Berlin was consoled the following day, after having been informed that it would be impossible for the airship to arrive August 28, in accordance with the original schedule. On August 29, the weather had improved and the airship arrived over the capital city at noon. After sailing over the southern suburbs and then over the Tempelhofer Field, the Castle, Cathedral, City Hall, Brandenburg Gate, Reichstag and Tiegarten, it landed on the Tegeler shooting range. The enthusiasm of the inhabitants knew no bounds. Every one felt the importance of the occasion.

After the landing and the greeting of the crew by the Kaiser,

Burgomaster Reicke delivered a short address of welcome.

What Count Zeppelin had felt in the flight over Berlin, he expressed a few days later in a letter to Burgomaster Reicke. He said in part: "Not for several years of my life would I have been willing to miss the hours of gazing down on the giant city awaiting me in holiday attire and the feeling that the hearts of the millions of waving and shouting people were drawn toward me and my work with eager enthusiasm."

Only a short stop was made in Berlin, since on September 3-4, members of the Federal Council and the Imperial Diet were expected, to whom Count Zeppelin wished to exhibit the airship. The return trip was accordingly begun just before midnight on August 29, after replenishing with gas and fuel.

Near Wittenberg, the front starboard propeller broke, throwing fragments through the airship and damaging one gas cell. Engineer Dürr then brought the airship to land at Bülzig, since it would have been impossible to make the long flight to Lake Constance with the rear engine alone and the uncertain new power transmission. Moreover, it seemed advisable to make a thorough investigation of the damaged cell and, if possible, to make immediate temporary repairs.

Two three-bladed propellers from the Z 2 with their cardan driving gears were ordered from Cologne. Three days had elapsed by the time the missing parts had been received and installed and the gas cell and outer covering of the hull had been mended. The task had been a very difficult one, as the airship was tossed to and fro by

gusts of wind and was held only with the greatest difficulty. Much credit is due the crew which had been on the way since August 27, and had succeeded in mastering all the constantly arising difficulties. September 1, at 11 p.m., the LZ 6 made another start and, after a non-stop flight of almost 23 hours, reached Friedrichshafen at 9:40 p.m., September 2.

Thus the Berlin trip was successful after all. It demonstrated, however, that too much should not be expected of an airship in its still imperfect state of development, and especially with innovations which had not been sufficiently tested. On the other hand, it also demonstrated that the Zeppelin airship, in spite of its technical defects, possessed excellent qualities.

I have purposely gone into the details of the first long distance flights over German territory, in order to show what advantages the Zeppelin airships possessed, even at that time, and what ability the Count and his coworkers had exhibited in mastering difficult situations. This was shown in the unplanned stops of the LZ 4 at Oppenheim and Echterdinger, of the Z 1 at Dingolfing and Biberach, of the Z 2 at Schemmerberg and of the LZ 6 at Ostheim and Bulzig. In technical circles the ability of the Zeppelin airships to make such landings had been constantly disputed.

The possibility of temporarily repairing the hull was demonstrated in connection with the Göppinger accident. At Bülzig it was also demonstrated that it was possible to repair individual parts without any protecting shelter.

The collision of a nonrigid airship with a tree would at

least result in the immediate loss of all the gas and probably further damages would be unavoidable. In any event, it would not be able to continue its journey. And what would become of a nonrigid airship, if portions of the propeller should penetrate the envelope during flight? The gas would immediately escape and the airship plunge to the ground. Such an accident caused the destruction of the French nonrigid airship "Republique" which fell 400 meters at Trevel, September 25, 1909, after a propeller blade had flown off and penetrated the hull. In such a case, an airship divided into a number of cells would lose only a certain part of its lift and in most instances would be able to offset the gas loss by releasing ballast.

Still it would be a one-sided view that would cause us to decide for or against either the rigid or the nonrigid airship. As a matter of fact, the technical defects of either airship can be eliminated in the course of time, as the result of experience. Both types have exhibited striking advantages and are well worth developing. It is too soon to talk of the worthlessness of either one. Should it prove in the course of development that, due to certain inherent defects of the type, the desired results cannot be obtained, we would always be at liberty to refuse it our support.

It seems strange, therefore, that the war department has shown a certain aloofness toward the Zeppelin airship. After taking over the Z 1 and Z 2, it refrained from the adoption of any more Zeppelin airships. I will explain the reasons for this course later.

In contrast with the reserve of the war department, stood the

general enthusiasm of all Germany, due to our successes in the field of airship travel. The present general indifference toward our aviation problems is something to be ashamed of. We must always emphasize the fact that a goodly share of the total development was made by us and we have reason enough for continuously emphasizing this fact and keeping it in our memory, until we are again called to participate practically in its further development.

But to return to the LZ 6. After being overhauled, it was stationed at the International Airship Exhibition at Frankfort-on-the-Main, where it took part in the "Kaiser Maneuvers" and demonstrated its reliability in numerous short and long flights. After returning to Manzell, experiments with radiotelegraphy were begun, both sending and receiving instruments being installed in the rear car. It was found possible to receive messages from a distance of 500 km. No objectionable phenomena occurred. While sending messages from the airship, climbing and the release of gas were avoided, so that the sparks could not set fire to the airship.

The low speed of the LZ 6 led the Zeppelin Company to install a third engine on a platform erected in the middle of the walkway. As this did not give the expected increase in speed, it was soon abandoned. Moreover, the presence of an engine at this point was precarious on account of the danger from gas. When the airship is ascending, gas escapes through the safety valves in the bottom of the cells into the walk-way, where it forms a highly explosive mixture with the air.

In October, 1909, trial flights were made in Cologne with the

Army airships P 1, M 2, and Z 2, in which the Z 2 compared unfavorably with the other two in its carrying capacity and speed, as also in its responsiveness to the rudder. On account of its smaller size, however, it was easier to handle on the ground and required a smaller number of men to take care of it. Thus it happened that the LZ 6, notwithstanding its many long flights, was not accepted by the Army administration. The latter took the standpoint that it would again try the Zeppelin airships only after considerable improvement in speed and carrying capacity should be attained.

The Zeppelin Company could be put in a position to meet these requirements only by receiving orders for building airships, since it did not have sufficient funds for building and trying out experimental ships. Practical operation, however, was the only way in which the airships could be developed and improved. Designs, which promised the best results on paper, often turned out to be failures. The task of assisting in the further speedy development of the Zeppelin airships fell to the "Deutsche Luftschiffahrts-Aktien-Gesellschaft" (Delag), which was founded in November, 1909.

The "Delag" owed its origin to the men who, supported by the general enthusiasm over the Zeppelin successes, had been able to secure the funds for the installation of airship ports in widely separated places. They assumed the task of inaugurating air traffic with Zeppelin airships. For lack of sufficient hangars, no regular air traffic between cities could at first be established, so that it was limited to round trips in the immediate vicinity of an airship port.

The first Delag airship, LZ 7, named "Deutschland," was built in the new Friedrichshafen yard and made its first trial trip June 19 1910. The need of a greater carrying capacity was met by increasing the gas capacity over 400 cu.m (14126 cu.ft) to 19300 cu.m (681580 cu.ft) by increasing the diameter one meter (3.28 ft) to 14 m (45.9 ft), and the length 14 m (45.93 ft) to 148 m (485.56 ft). By adding a third engine, the speed was increased from about 13 m. (42.65 ft) to 16 m (52.5 ft) per second. The engine in the front car drove 2 two-bladed propellers, while the 2 engines in the rear car each drove a four-bladed propeller. Tubular shafts and bevel gears were employed and reversing gears were provided for both rear propellers. The elevators were given their former shape and location. The rudders were modified again and were made simpler by the elimination of the large oval stern rudder. In the middle of the ship, the walk-way was widened into a comfortable cabin for 16 persons. The "Deutschland" was short-lived. On June 28, 1909, only nine days after its first ascent, it was wrecked by a storm in the Teutoburger Forest.

The loss of the "Deutschland" was mainly due to a partial failure of the engines. The resulting loss of speed left the airship at the mercy of the storm. A whirlwind lifted the ship high up, thereby occasioning a great loss of gas, the effect of which could not be offset quickly enough by operating the elevators and releasing ballast. Fortunately no life was lost. Confidence in the idea of a passenger airship, however, was given a severe shock. This accident handicapped the Zeppelin project all the more, because two

months earlier, on April 25, 1910, the Army airship Z 2 had fallen victim to a storm at Weilburg.

It was important to have another passenger airship soon, in order to dispel the prejudices occasioned by these accidents. It would have taken too long to build a new airship and it was accordingly decided to rebuild the LZ 6, which had not been used after its trial flights in October, 1909. After lengthening it 8 meters (26.25 feet) and adding an 18th cell, it had a length of 144 meters (472.44 feet) and a gas capacity of 16000 cu.m (565000 cu.ft). In addition to the two Daimler engines of 115 HP each, a 140 HP Maybach engine was installed. The innovations of the "Deutschland" were retained as regards the engine arrangement and power transmission. The radiators which, on former airships, were located behind the engines, were likewise installed, the same as on the "Deutschland," outside the cars and alongside the walk-way. The latter was extended beyond the cars. The elevators remained unchanged in the same location, but the rudders were again altered. The "Deutschland" had six rudders, all located above the stabilizers, while the LZ 6, in contrast with the LZ 7 (which had only one stabilizer on either side) retained its former arrangement of two pairs of stabilizers, the rudders coming partly between the stabilizers and partly under them. The LZ 6 was not destined, however, for a long life. After it had made, from the new hangar at Baden-Oos, 36 trips on 18 different days between August 23, and September 14, 1910, it was destroyed by fire in the hangar, through the carelessness of a mechanic while cleaning a car.

It was now impossible to resume passenger trips in the year 1910. The airship "Ersatz Deutschland" (LZ 8) which was made from the material and on the same plan as the LZ 7, could not be finished before the next spring. On April 11, 1911, "Ersatz Deutschland" moved into the Düsseldorf hangar. It was not used very much, on account of bad weather and the difficulty of getting it into and out of the narrow hangar. On May 16, when it was desired to remove the airship to Baden-Oos, it was driven against the hangar and damaged so seriously that it had to be demolished.

I must say a few words here regarding the hangar problem, since it is closely connected with the development of Zeppelin airships, as well as with the above-mentioned accident. Airship traffic can be carried on only where the longitudinal axis of the hangar is situated in the prevailing wind direction. Otherwise, even a very light wind will render it impossible to bring the airship in and out of the hangar. In a valley or alongside a mountain range, there is no difficulty in maintaining air traffic, provided the hangar is parallel with the valley or the side of the mountain. In other places the best way to locate the hangar can be determined only by extended observations of local weather conditions. Thus, for example, the location of Düsseldorf was unfavorable, while that of Baden-Oos was ideal. The construction of revolving hangars was very expensive and not practicable, considering the financial status of airship traffic at that time. The only thing to do, therefore, was to restrict airship traffic to favorably lo-

cated havens, until it should be possible to build hangars with two doors and with sufficient width. In this connection, great care must be exercised that auxiliary measures, like tracks and wind shields, do not form additional sources of danger for the airship.

It was with these facts in mind that the Delag, after the loss of "Ersatz Deutschland," in the late summer of 1911, again undertook to resume passenger flights from Baden-Oos with the airship "Schwaben." The Delag was perfectly aware that this experiment was the last it could venture to undertake. In case of failure, the fate of the Delag would be sealed and perhaps that of the Zeppelin Airship Construction Company also.

The "Schwaben" came up to the expectations. Its properties were better and it was also luckier than its predecessors. It blazed the way for the further development of Zeppelin airships. In spite of its small size, its carrying capacity was no less and its steering gear worked better. It also attained an adequate speed, which, in comparison with other types, the Zeppelin airships had hitherto failed to do. It made as much as 19.3 m/sec (63.32 ft/sec) or about 70 km (43.5 mi.) per hour, thereby surpassing the "Deutschland" by about 15 km (9.32 mi.). This improvement was attained, in the first place, by employing the more powerful and reliable Maybach engines and, in the second place, by eliminating all unnecessary head resistance. Under this head comes the transference of the elevators to the stern. In thus bringing all the steering surfaces to the stern, the many experiments regarding

their location came to an end.

At first no one credited the results, the high speed, especially, being considered impossible. Doubt and prejudice gradually gave place, however, to perfect confidence, as representatives of the central authorities took part in the trips and satisfied themselves of the genuineness of the performances. Many were convinced, moreover, that the Zeppelin was destined to be the airship of the future.

Between the middle of July and the end of November, the Schwaben made 130 trips without an accident. Flights were made over South Germany, the coast of the North Sea, Berlin, Saxony and Thuringia.

The successes of the Schwaben soon began to show results. The war department awarded the contract for another Z 2, which could still be delivered in 1911, after the LZ 9, already built by the Zeppelin Company, for experimental purposes, had undergone the requisite modifications. It was in every respect a sister ship of the Schwaben. The reduction of the head resistance by the removal of the passenger cabin increased the speed of this airship to 21 m/sec (68.9 ft/sec). The Z 2 rendered the war department good service for a long time, but when the war broke out, it was dismantled as obsolete.

By reason of the success of the Schwaben and the building of airship hangars in Frankfort-on-the-Main and in Hamburg, the Delag was soon able to add a second and a third airship. The LZ 11

("Viktoria Luise") was finished in February and the LZ 13 in July, 1912. They differed from the Schwaben in their greater length - 148 m (485.6 ft), and gas capacity of 18700 cu.m (660390 cu.ft). The passenger cabins were roomier and nearer the forward car. The rudders and elevators were made smaller without impairing their efficacy. They all lay entirely below the stabilizers. This arrangement was retained on the 13 following airships.

The success of the Z 2 led the war department to order another airship, the LZ 12, which was taken over in the early summer of 1912. It was an exact duplicate of Z 2 and, like the latter, was equipped with a radio outfit in the walk-way, the power being derived from the forward engine.

The Navy now began to take an interest in airships and ordered the LZ 14, which began its trial flights as the L 1 in October, 1912. It had a length of 158 m (518.37 ft), making it 10 m (32.81 ft) longer than the previous Zeppelins. Its diameter was increased from 14 (45.9 ft) to 14.86 m (48.75 ft). Its gas capacity was 22465 cu.m (793351 cu.ft), and its carrying capacity was increased from 6000 (13228 lb) to 8600 kg (18960 lb). Its speed was also slightly increased, in spite of its larger size.

The L 1 was the fourth airship built at the Friedrichshafen yard in 1912. The capacity of the yard was increased, so that it was able to build seven airships in 1913: five (LZ 15 or Ersatz Z 1, LZ 16 or Z 4, LZ 19 or Z 1, LZ 20 or Z 5, LZ 21 or Z 6) for the Army; one (LZ 18 or L 2) for the Navy; and one (LZ 17 or "Sachsen") for the Delag.

Ersatz Z 1, Z 4, Z 5 and Z 1, were sister ships. They had a larger diameter, 14.86 m (48.75 ft), and a shorter length, 140 m (459 ft), than the Delag ships. The war department, in spite of its constant demand for increasing the carrying capacity, desired to restrict the length, for greater ease of managing on the ground, and sought to increase the carrying capacity by reducing the dead load.

The adoption of the now sufficiently tested "goldbeater's skins" (made from the large intestines of cattle and hogs and lighter than the rubber fabric previously employed) helped in this respect. Goldbeater's skins are, moreover, less dangerous, since they do not have the electrical properties of rubber fabric, which, e.g., caused the burning of the Schwaben.

The demand for flight at higher altitudes could only be satisfied with the lapse of time, by increasing the gas capacity. The LZ 21 was therefore given a gas capacity of 20870 cu.m (737024 cu.ft) with a length of 148 m (485.6 ft). The Sachsenn (LZ 17) had the same dimensions as the Army airships Z 1, Z 4, and Z 5. A later type was represented in the meantime by the LZ 18 or L 2.

The L 2 was the first airship to have the walkway inside. This arrangement was adopted for the purpose of increasing the speed by decreasing the drag due to the keel-like walkway of previous airships.

The L 2 had a gas capacity of 27000 cu.m (953500 cu.ft), with a length of 158 m (518.4 ft) and a diameter of 16.6 m (54.5 ft) (an increase of almost 2 m (6.5 ft) ). The carrying capacity was corre-

spondingly increased, thus rendering it possible to install a fourth engine and to carry two crews for long voyages. The four 165 HP engines were placed in pairs in the two-power cars, each engine driving a four-bladed propeller. It was possible to reverse all the propellers and also to drive two propellers with one engine. The latter provision was of importance for enabling the airship to keep its course in case of the stopping of both starboard or both larboard engines.

The rudder and elevator controls, the telegraph instruments for transmitting orders to the engineers, the ballast and valve controls, compass, gas and air thermometers, variometer, etc., were no longer placed in the forward power car but in a separate control car located still farther forward. This car was protected from the wind by glass windows. The radio outfit and the rest room for the unoccupied crew were placed amidships.

During a trial trip on October 17, 1913, the L 2, shortly after ascending, fell in flames at Johannisthal. Since the radio station was not yet in operation, the blame can only be laid to the construction. After the removal of the hanging walkway, the power cars had been brought nearer the hull. Their forward side was encased in glass in order to protect the engineers from the wind. Behind these wind shields a suction was created which drew the explosive mixture of gas and air under the airship into the cars, where only a spark from the magneto would suffice to set it on fire and put the whole airship in flames. Doubtless, such an explosive mixture was pres-

ent, since during the ascent of the L 2, gas escaped from the safety valves on the lower side of the gas cells into the walkway and thence in the vicinity of the power cars. Had it not been for the glass wind shields, the explosive mixture would have been immediately carried away by the draft. Numerous tests made on previous trips had failed to disclose the presence of any of the explosive mixture in the power cars, so that may be reasonably assumed that this danger could be eliminated by extending the wind shield over the top of the power car. This otherwise objectionless method of construction was, however, abandoned and the plan with the underneath walkway was resumed. The subsequent development of the airship showed, however, that only a slight modification would have sufficed to prevent the explosive mixture from entering the protected cars.

After the war department had experimented with several Zeppelins, and had studied out the necessary equipment, it was able to adapt them for observation and attack. For the former purpose, the installation of machine guns was necessary, in order to drive off attacking airplanes. For the latter purpose, devices were necessary for carrying and dropping bombs.

Since it was impossible to fire from the cars at any aircraft above the airship, it was necessary to install a machine gun on the top of the airship. The Z 4 was the first to have such a platform, which was placed about over the forward car. Exhaustive experiments had shown that firing from this point was objectionless. Only while the airship was climbing, it was desirable to avoid firing, if possible. For greater safety, the balloon fabric in the immediate

vicinity of the platform was impregnated with some non-inflammable substance.

The bomb-dropping device was very simple at first. On account of the small weight of bombs which it was possible to carry, the bomb racks were at first placed in the middle of the walkway and provided with wires for releasing them from the sighting room which was also in the walkway.

Thus, on the one hand, the total weight of the airships was increased by these indispensable accessories, while on the other hand, it was sought to reduce the dead load in every way possible, the use of the light goldbeater's skins being of considerable help. The lightening thus effected was small, however, in comparison with that required for attaining a sufficiently high altitude for war purposes.

It was therefore decided to make the next airships, LZ 22 and LZ 23 (Z 7 and Z 8), 156 m (511.8 ft) long, thus increasing the flight altitude 200-300 m (656-984 lbs). The Z 5 and Sachsen, already in service were likewise lengthened from 140 (459) to 148 m (485.6 ft). The war department had an interest in the Delag airships (Viktoria-Luise, Hansa and Sachsen) and supported the company by a yearly subsidy, on condition that their airships should meet certain requirements and should be at the command of the war department in case of war.

L 3 (LZ 24) and Z 9 (LZ 25) were finished shortly before the war. Both differed little from Z 7 and Z 8, but carried about 700 kg (1543 lb) more, with an additional gas capacity of only

360 cu.m (12713 cu.ft). They were equipped with 210 HP engines, instead of the former 165 HP engines.

On the Z 9 the stern steering apparatus was considerably simplified by making the elevators continuations of the horizontal stabilizing surfaces and the rudders continuations of the vertical fins. The lateral steering, which had never before been entirely satisfactory, now gave no more cause for complaint, even when only one propeller was running. With the Z 9, after repeated changes, the experimental stage, as regards the steering gear of the Zeppelin airships, was brought to a close. Only slight changes, chiefly in the tension of the surfaces, have since been made.

The military airships were not yet sufficiently developed for war, but their cooperation was needed and they were set to work. It was found, however, that they could not make, as had been hoped, long observation flights by day over the interior of the enemy's country. They were not able to attain sufficient altitude and most of them soon became the victims of infantry and machine-gun fire. Only in the East, where the defense was less, could such flights be made with impunity. Hence, airships were soon used for night bombing raids. Even here, however, the constantly improving defense necessitated flight altitudes of much more than 2000 m (6561.6 ft).

At the beginning of the war, the Navy had only the L 3. Like the Army, which had lost four airships during the first month of the war, it desired to increase the number of its airships. Since the type L 3 to Z 9 showed considerable improvement in lift, ten airships of this type were built by February, 1915. The construction company was better prepared for this accomplishment, since an

airship yard had been installed in Potsdam, where the Z 5 and Sachsen had been lengthened.

At the same time, new designs were made for more efficient 25000/m cu.m (882875 cu.ft) and 30000 cu.m (1059450 cu.ft) airships. The first airship of the former type, the LZ 26 (Z 12), was finished in December, 1914, in the Frankfort hangar. This airship combined an increased speed with a surprisingly large carrying capacity. Its gas capacity was only 2500 cu.m (88288 cu.ft) greater. The greater lift was mainly due to the reduction in the number of gas cells from 18 to 15 and to their being made of goldbeaters' skins. The Z 12 was a transition type between the former airship types and the L 2. The walkway between the two cars was located in the usual way, underneath the hull and was widened in the middle to provide room for the radio instruments, a rest room and the bomb-dropping device. Above the cars and in its extensions both fore and aft, the walkway was inside the hull. The cars were not inclosed and were hung a little lower than on the L 2. The same distance from the hull was still maintained when the ship was provided with closed cars. In contrast with the L 2, however, a space of almost 1 meter (3.3 feet) was left between the bottom of the hull and the top of the closed car. Thus, any gas escaping from the hull was carried away by the wind and could not enter the car. The rear propellers were mounted, as previously, on lateral brackets attached to the hull and were driven by tubular shafts, but the front propeller was mounted on the rear end of the lengthened engine shaft. By the latter arrangement a saving of power was effected and the air resist-

ance or drag, due to the brackets and extra shafts, was diminished. The only disadvantage was that the forward propeller could not run while the landing was being made. Beginning with the L 3, the propellers were all two-bladed and made of wood.

The Z 12 was the first airship fitted with a look-out basket. This was a small observation car in the form of a boat which could be lowered by means of a cable and winch in the rear car to 1000 meters below the airship. The winch could be operated by a motor or by hand in case of failure of the motor. The observer in the look-out basket was connected by telephone with the control car and, when the airship found itself in or above clouds, could be let down to the lower edge of the clouds and from there direct the navigation of the ship. The basket was carried by the wind far back under the stern of the airship, so that it did not interfere with the dropping of bombs. Due to its smallness, the discovery of the basket in the night by means of searchlights was practically impossible and shooting at an airship hidden by the clouds, with only the sound to go by, stood small chance of being successful. This device rendered it possible, after the first failures in August, 1914, to continue the raids on moonless nights and even in cloudy weather. This was the real reason for equipping the military airships with look-out baskets. Aside from war raids, in which the airship sailing above the clouds was directed to its goal by the observer in the basket, any airship encountering clouds could thus be steered to its haven. But few airships, however, were equipped with such a look-out basket. Most commanders with ships of moderate lift preferred to do without

it, since it weighed about 500 kg (1102.3 lb).

The 25000 cu.m (882875 cu.ft) type continued to exist in modified form only in the L 9 (LZ 36) of the Navy and in the LZ 39 of the Army. These airships, unlike the Z 12, had the whole walkway inside the hull. The radio station, formerly in a widening of the walkway, was transferred to the forward power car and fed by the engine there located. The control and power car were suspended separately and simply communicated with each other through a door. This separate suspension was vindicated by a peculiar accident which happened subsequently to the LZ 39. This airship was seriously injured in the stern by a shell fragment. As a consequence of the loss of gas, it could only be kept afloat in a very oblique position. This resulted in the shifting of the power car, so that the propeller struck the bottom of the hull, causing the whole power car to break loose and plunge to the ground. The control car was saved from falling with it by being separately suspended.

The new 32000 cu.m (1130080 cu.ft) type was completed simultaneously with the L 9 and LZ 39. It was only 2.1 m (6.89 ft) longer than the 25000 cu.m (882875 cu.ft) type, but had a diameter of 18.7 m (61.35 ft) instead of 16. The shape of the airship, which otherwise held to the innovations of the L 9, was considerably improved. Most important of all was the increased taper of the stern. The power plant consisted of four 210 HP engines, one of which was installed in the forward car and three in the rear car. The forward engine, as also one of the engines in the rear car, transmitted its power to a propeller situated at the rear end of the car on an ex-

tension of the engine shaft. The other two engines drove, by means of tubular shafts, propellers located on brackets on either side of the airship. These propellers could be reversed. The speed was 26 m/sec (85.3 ft/sec) or about 3 m (9.84 ft) more than that of the L 9. This gain was due partly to the increase in engine power and partly to the more favorable shape of the airship.

Contrary to expectation, the handling of the big airship on the ground was only slightly more difficult than that of the earlier types. This was partly due to the transfer of the walkway to the inside of the hull, thereby reducing the surface exposed to lateral winds.

With the introduction of the 32000 cu.m (1130080 cu.ft) airships, of which 10 went to the Navy and 12 to the Army, airship aviation received a great impulse. The period from the summer of 1915 to the spring of 1916 witnessed great successes without noteworthy losses. Wherever they were sent (in the west to Paris and London and other parts of France and England; in the east to Riga and Rowno; in the southeast to Saloniki), they proved equal to their tasks. Their carrying capacity enabled the transportation of sufficient fuel for long trips, in addition to 2000-3000 kg (4409-6613.8 lb) of bombs, more than could be carried by a whole squadron of airplanes at that time. Before dropping their bombs, they could reach an altitude generally beyond the range of the anti-aircraft guns of that time. There were as yet no aviators to be feared at night. The airships were abundantly provided with machine guns to repel any airplane attacks at dawn. As a rule, there were two or three guns

on the upper platform and one or two in both the forward and rear cars.

Data on the carrying capacity are given in the following table. The variations in the data for the same airships are due to variations in temperature and atmospheric pressure. For example, the lift of a 32000 cu.m (1130080 cu.ft) airship is reduced about 100 kg (220.5 lb) by a rise of 1°C in the temperature of the air and about the same by a decrease of 2.5 mm (.0984 in.) Hg in the barometric pressure. The amount of fuel to be carried was determined by the distance of the goal, the speed of the airship and the direction and velocity of the wind. The amount of water ballast required for attaining the desired altitude was calculated, after making allowance for the weight of fuel to be consumed before reaching the goal. The balance of the carrying capacity was then available for bombs. A definite standard could not be adopted, since the conditions (such as the dropping out of an engine and the consequent reduction in speed and dynamic lifting power, changes in the direction and velocity of the wind, temperature variations and the weighting of the airship with precipitations of rain or snow) differed for every trip. Often the desired altitude could be reached only after throwing overboard a portion of the munitions or fuel carried in cans.

Table

| Airship | Gas capacity cu.m. | Date of raid | Object of raid | Crew | Fuel kg. |
|---|---|---|---|---|---|
| Z 4 | 19500 | 9/9/14 | Russian camp at Insterburg | 10 | 1075 |
| Sachsen | 20870 | 9/2/14 | Antwerp | 11 | 1600 |
| Z 9 | 22500 | 8/24/14 | Antwerp | 13 | 2270 |
| Z 10 | 22500 | 3/20/15 | Paris | 12 | 2440 |
| | | 3/17/15 | Paris, Calais | 15 | 2605 |
| | | 5/16/15 | Calais | 14 | 1970 |
| Z 12 | 25000 | 7/22/15 | Malkin | 11 | 1350 |
| | | 8/11/15 | Bialystok | 11 | 1420 |
| LZ 35 | 22500 | 3/20/15 | Paris | 11 | 2555 |
| 38 | 32000 | 4/29/15 | Harwich, Ipswich | 14 | 3200 |
| | | 5/31/15 | London | 12 | 3080 |
| 39 | 25000 | 12/17/15 | Rowno | 10 | 2850 |
| 74 | 32000 | 9/7/15 | London | 14 | 3060 |
| 77 | 32000 | 2/1/16 | Paris | 13 | 2050 |
| 79 | 32000 | 1/31/16 | Paris | 12 | 2820 |
| 85 | 32000 | 1/31/16 | Saloniki | 16 | 3440 |
| 86 | 32000 | 4/2/16 | Minsk | 15 | 2400 |
| 90 | 32000 | 3/31/16 | Norwich | 14 | 3550 |

Table (Cont.)

| Airship | Water ballast kg. | Bombs kg. | Altitude of attack m. | Maximum altitude m. | Distance flown km. | Time Hr. | Time Min. |
|---|---|---|---|---|---|---|---|
| Z 4 | 1950 | 900 | 2100 | 2575 | 365 | 6 | 40 |
| Sachsen | 1625 | 950 | 1950 | 2500 | 661 | 11 | 25 |
| Z 9 | 1320 | 1750 | 2000 | 2400 | 562 | 8 | -- |
| Z 10 | 2720 | 995 | 2000 | 2400 | 433 | 8 | 32 |
| | 2080 | 3000 | 2200 | 2675 | 708 | 10 | 1 |
| | 3380 | 1600 | 3050 | 3150 | 450 | 7 | 42 |
| Z 12 | 3480 | 1650 | 3000 | 3300 | 491 | 5 | 59 |
| | 3300 | 2000 | 3000 | 3600 | 608 | 9 | 34 |
| LZ 35 | 2810 | 818 | 2000 | 2450 | 760 | 11 | 7 |
| 38 | 4200 | 2447 | 3200 | 3550 | 800 | 12 | 47 |
| | 6620 | 1357 | 3300 | 3900 | 685 | 9 | 37 |
| 39 | 3000 | 975 | 2000 | 2200 | 478 | 12 | 50 |
| 74 | 4050 | 2000 | 3100 | 3500 | 1063 | 14 | 43 |
| 77 | 7100 | 2600 | 2900 | 3600 | 900 | 15 | -- |
| 79 | 7100 | 1500 | 3100 | 3900 | 780 | 10 | 50 |
| 85 | 6090 | 2000 | 2900 | 3900 | 1425 | 18 | 29 |
| 86 | 6300 | 2060 | 2750 | 3500 | 600 | 10 | 43 |
| 90 | 4460 | 2450 | 2500 | 3275 | 1496 | 18 | 33 |

As already mentioned, the 32000 cu.m (1130080 cu.ft) airships met the requirements until the spring of 1916. The constantly improving enemy defense in the west, however, compelled the airships to seek higher altitudes of about 3500 m (11483 ft). As shown by the above table, the 32000 cu.m. ships were able to do this, but on-

only after throwing over some of their load. In order to reach these altitudes, even before the raids, it was necessary to build still larger airships. This was done by adding two new 5 or 10 m (16.4 or 32.8 ft) sections, one between the bow and forward car and the other between the rear car and the stern. This gave a gas capacity of 35800 cu.m with a total length of 178.5 m (585.6 ft) (most of the hangars having a utilizable length of 184 m (603.7 ft) ). The increase of about 2500 kg (5511.6 lb) in carrying capacity enabled the attainment of about 700 meters higher altitude. Since the distance between the two cars remained the same, the heavy stern load was diminished by the increase in length toward the rear.

The Navy acquired five airships of this type and the Army seven. During 1916, the gas capacity of six 32000 cu.m (1130080 cu.ft) airships, in the possession of the Army, was increased to 35800 cu.m (1264277 cu.ft).

At the same time the individual parts were continually being improved. Externally the airships were made darker, thereby rendering them less easy to locate with searchlights. They were painted gray with spots in imitation of clouds with the avoidance of all bright parts on the cars. Many efforts were made to lessen the noise, but without much success. Airships, even more than airplanes, made themselves known by their noise while still a long way off, thus rendering it easy for enemy listening posts to discover them in the night sky by means of searchlights. The rattling and singing of the driving gear was considerably lessened, but not the noise made by the propeller. Some further reduction in the noise was accomplished by

improving the exhaust manifolds, but no way was found to prevent the hull itself from taking up the vibrations and acting in some sort like a drum. The increasing number of enemy aviators necessitated the best possible armament. Two or three machine guns were installed on the top platform in order to increase the firing field, which was, however, obstructed in the rear by the rudders and stabilizing surfaces. The guns in the cars were rotatable, so as to be able to fire in all directions. Their firing field was, however, obstructed above by the hull, toward the rear by the propeller, and toward the front by the suspension cables, and on the rear car also by the lateral driving shafts. In attacking an airship, airplanes usually approached from the rear, thus rendering the arming of the stern desirable. It was not practicable to build a second platform on top and nearer the stern, on account of its weight and the danger from gas, so that it was decided to install a machine gun inside the stern.

In order to make escape possible in case the airship took fire, each member of the crew was provided with a parachute, which was attached outside the car or to the top platform. When captive balloons were shot down, the observer saved himself in nearly every instance. On airships, however, full advantage was not taken of them, because the commanders frequently dispensed with them on account of the additional weight.

The bomb-dropping device, which was at first very primitive and had to be operated by pulling on a wire, was now arranged to be operated by electricity from the pilot car. Here was a switchboard

with which all the bomb releases were connected, so that the officer in charge of the bomb-dropping could release, by pressing an electric button, as many bombs as he considered desirable, on the basis of observations made through a spyglass hanging near the switchboard. The actual release of a bomb was indicated by the flashing or extinguishing of a small glow lamp on the switchboard. Altogether, bomb releases were provided, along the walk-way between the two cars, for 100 light incendiary bombs and 50 heavy explosive bombs.

Furthermore, airships were given, through the remarkable development of radiotelegraphy, aid which they could no longer dispense with. Even before the war, all airships were equipped with radio instruments. At the outbreak of the war, however, they were for the most part removed, in order to save weight. The Navy, however, continued to use them. In 1915, when the airship raids first included several airships, did the Army airships again feel the need of radio instruments. The importance of having them on board had come to be recognized through the experiences of the Navy airships, which had continually kept in touch with the central station, from which they received timely warnings of changes in the weather and changes in their orders, and to which they could impart their own views and wishes. In the meanwhile, lighter radio instruments had been invented, with which it was possible to transmit messages to a distance of 1000 km (621.4 mi.) and to receive signals from radio stations several thousand kilometers away.

A distinct advance for airships was marked by the invention of the so-called "radio-compass," with which it was possible to deter-

mine the location of the airship when, due to fog or low-lying clouds, the earth was invisible or when, as it sometimes happened, the enemy darkened their villages and railway lines. The airship then gave several radio signals from which the receiving radio-compass stations determined its location and communicated it to the airship. The disadvantage of this method was that it also enabled the enemy radio-compass stations to locate the airship. The loss of the LZ 77 at Revigny was largely due to this fact. On the way to its goal, the airship had to signal quite often for its location, thus enabling the enemy to follow its course and destroy it by adopting defensive measures at the right time. It was only toward the end of the war that the difficult problem of installing radio-compasses on airships was solved, thus enabling the reverse process to be followed, in which the airship gave no signals, but simply received signals given out by certain ground radio stations at stated intervals, and then determined its own location from the data thus obtained.

In spite of all the improvements, the 35800 cu.m type fell short of the demands made upon it during the year 1916, although it met with some success. The difficulty of operating over the sea constantly increased, due to the appearance of numerous enemy submarines and the development of seaplanes which took off over German waters from so-called "mother-ships". Airships had been especially successful over the sea. Whenever the weather was at all suitable, there were always several airships engaged in observing enemy warcraft. These airships sometimes remained in the air for 30 hours

at a time, patrolling the North Sea from the English Channel and the coast of England to Norway, and thus protecting the German coast against surprise attacks. The airships could also watch the enemy mine layers and give warnings by radio. Airships were more successful than airplanes in searching for mines, because, by slackening their speed, they could remain longer over the mine field and thus determine the position of the mines more accurately. This work made it compulsory to remain at a low altitude and the heavy load required on long observation trips did not always leave it possible, on the sudden appearance of submarines and airplanes, to seek safety in altitude.

The difficulties encountered during a raid have already been referred to repeatedly. The defense, by means of anti-aircraft guns, incendiary bullets, searchlights and airplanes was so strong and so well coordinated that it was a miracle for an airship to escape.

Unless the employment of airships was to be utterly abandoned, there was no other course open but to increase their gas capacity again. It would have beem technically possible to increase the length of the last type still further, but this would have been only a temporary makeshift which would soon have been rendered useless by the further development of the enemy aircraft defense.

The Navy, for which the presence of utilizable airships was vital, decided therefore on the construction of an entirely new type, which, however, on account of its larger dimensions, could not be housed in the existing hangars. Hand in hand therefore with the preparations for building the new airships, there were built at

most of the naval airship ports, new hangars 240 m (787.4 ft) long by 35 m (114.8 ft) high and 40 to 60 m (131 to 196.8 ft) wide.

The Army was likewise interested in the further development of airships, though not so much as the Navy, since in land fighting they could only be employed for making raids. With the extraordinary development of aerial weapons, there seemed, moreover, to be a prospect that, with the definite abandonment of the airship, its tasks could, in the course of time, be assumed by the airplane. For this reason, the war department built airship hangars of the above dimensions only to a limited extent and adopted an attitude of watchful waiting in regard to the adoption of the new type of airship.

The first airship of the new type, L 30 (LZ 62), was finished the last of May, 1916. It had a length of 198 m (649.6 ft), a diameter of 23.9 m (78.4 ft) (an increase of 5 m (16.4 ft) over that of previous airships) and a gas capacity of 55000 cu.m (1942325 cu.ft). Externally it was noticeable for its favorable shape (with its blunt nose and slender pointed stern resembling the Schütte-Lanz airship), which had been found, as the result of years of scientific investigation, to offer the least resistance to the air. The cylindrical portion, which in previous ships was longer than the distance between the cars, was only 35 m (114.8 ft) long. In this connection, the main advantage of the former type, namely the employment of a large number of similar cells and the rapid quantity production of the transverse frames or rings, was relinquished in favor of greater speed.

The frame was strengthened by using thicker metal and especially by internal bracing of the main transverse frames. The ridge girder and walk-way girders were likewise strengthened. An innovation was added in the form of a central cable running the whole length of the airship from tip to stern through the gas cells and firmly attached to all the transverse frames. With unequally filled gas cells and the attendant differences in pressure, any excessive buckling of the braces of the transverse frames and resulting ruptures were thus avoided.

In all there were 19 gas cells varying in capacity from 375 to 4150 cu.m (13243 to 146557 cu.ft). Each cell was provided at the top with an outlet tube. Nine cells were provided with outlet valves, which could be operated from the forward car. Each cell was provided near the bottom with two safety valves through which a portion of the gas could escape whenever its tension became too great, due to a decrease in the atmospheric pressure or a rise in temperature. In former airships the gas then escaped slowly into the atmosphere through the porous outer envelope. After the outer envelope, however, had now been covered with dope for the purpose of reducing the drag and was consequently no longer porous, the gas had to be conducted into the outer atmosphere through ventilating shafts installed between the gas cells. This arrangement had the disadvantage that the gas, escaping in greater quantities from these shafts, formed an explosive mixture with the air and became a source of danger, although not so great as that of the envelope of explosive gas formed around the gas cells in former airships.

Instead of four, there were now six 240 HP engines in four cars, three of them in the rear car, one in the forward car and one in each of the side cars. The engines were mounted on elevated supports, so as to make it more convenient to work on the crankcase. In the rear car, the power of two engines mounted abreast was transmitted in the former manner by means of tubular shafts to lateral propellers mounted on brackets. These propellers could be reversed. All the other engines drove propellers at the rear end of the cars. The speed attained, with all six engines running, was about 28 m/sec (91.9 ft/sec), the increase being due partly to the increase in engine power and partly to the improved shape of the airship.

The side cars were each reached by a ladder from a passage-way leading from the main walk-way. They were very small and only afforded room for the necessary engineers and the machine-gun operator.

With the increased gas capacity of the airship, the capacity of both the normal and the trimming ballast bags was also increased. There were 14 of the former, with a capacity of 1000 liters (35.3 cu.ft, 264.2 gal) each, and 8 of the latter with a capacity of 250 liters (8.8 cu.ft, 66 gal) each. There were 8 fuel tanks holding 670 liters (23.65 cu.ft, 177 gal) each, and 32 holding 290 liters (10.24 cu.ft) each, it being possible to throw the latter overboard.

The first 55000 cu.m (1942325 cu.ft) airships had hardly reached the front when new difficulties arose. The supplying of enemy aviators with phosphorous projectiles gave them a weapon against which there was no protection for the airship. It would have been possible to surround the gas cells with a layer of nitrogen, but

this would have necessitated a considerable increase in the size of the airship. The increasing difficulty of handling an airship on the ground formed an obstacle to such an increase. Already many days of otherwise favorable weather had to be wasted, merely because a moderate wind was blowing in a direction unfavorable for removing the airship from its hangar. Although of great value for the regular operation of large airships, there were no revolving hangars excepting the one begun in Nordholz by the Navy just before the war. It is true the war department began two revolving hangars in Düsseldorf and Schneidemühl in 1916, but work on them was soon discontinued, when it was found that airships were continually becoming less important as instruments of war.

After the adoption of phosphorous projectiles there remained nothing else to do, if airships were not to be dispensed with entirely or still greater difficulties experienced in handling them on the ground, except to build lighter ones of the same size capable ofaattaining higher altitudes than could be reached by airplanes in their state of development at that time. The war department saw in this attempt only a passing improvement and held the opinion that the airship tasks could be performed by large airplanes. It did not, however, give up airships entirely, but ordered no new ones and sent the old ones only where the weak defense rendered success probable.

It was otherwise with the Navy, for which the retention of airships was vital. It was therefore obliged to find a way, at all hazards, to maintain the vitality of airships. The sixth engine was first dispensed with, for the sake of attaining a higher cruising

altitude. This step only slightly reduced the speed, due to the fact that the loss in power was offset by improving the shape of the cars and eliminating all unnecessary drag. The loss of an engine was a disadvantage as regards sureness of functioning, but confidence in the reliability of the Maybach engines could dispel any apprehension.

The sixth engine was left out of the rear car. The two engines remaining in this car were both connected with a propeller of larger diameter at the rear end of the car. The lateral propellers were removed, together with the brackets and tubular shafts, thereby considerably diminishing the drag. The other power plants remained unchanged, excepting that reversing gears for going backward were installed in the side cars.

A further lightening was effected by reducing the number of gas cells from 19 to 14, and increasing their capacity. This had the disadvantage that sometimes, when a large cell was damaged, the loss in lift was so large that it could be offset neither by releasing ballast nor aerodynamically and could consequently no longer remain in the air. Furthermore, defensive armament was omitted, at least on raids. The omission of all the machine-guns with their shields, ammunition and spare parts effected a considerable saving in weight, though dearly bought. Although there was hardly any chance that an ever-so-well-armed airship could protect itself in the night, since the airplanes were usually invisible, the airship might at dawn encounter hostile airplanes against which it would have been able to defend itself. The importance, however, of having the airship succeed in its main object led to the policy of seeking safety only at

altitudes unattainable by airplanes. Here the airship was safe and needed no armament.

It was possible to lighten an airship in still other ways, namely, by removing some of the bomb releases rendered unnecessary by the smaller number of heavier bombs carried, by removing all parts not absolutely necessary for a raid, reducing the size of the rear car and the weight of all structural parts, thus continually increasing the attainable altitude of successive airships. They were thus enabled to attain an altitude of 5400 to 6000 m (17716 to 19685 ft), with a crew of 20, fuel for a ten-hour return trip and 2000 kg of bombs.

All these measures helped the Navy airships to further successes and to a reduction of the ever great losses when making raids. The fears of the War Department were unfortunately confirmed in the course of time. Enemy airplanes developed rapidly and were soon able to reach the highest altitudes attained by the airships. The Army accordingly desisted from the further employment of airships. The Navy, however, continued to use them, though mainly for observation and only occasionally for raids.

The hundred-hour observation flight of a 55000 cu.m (1942325 cu.ft) airship (the LZ 120), over the Baltic Sea in the summer of 1917, demonstrated the availability of airships as a means of transportation to distant lands which, on account of the war, could be reached in no other way. It was accordingly decided to carry help to the hard-pressed African garrison, in the form of machine-guns, ammunition and medicaments.

By the addition of 30 m (98.4 ft) in length and two more gas cells to the 55000 cu.m type, it was given a carrying capacity of 50 metric tons (110231 lbs), so that it was able to carry 12 tons of freight in addition to fuel for 120 hours.

The L 59 left Jambol in Hungary, November 21, 1917, and reached the vicinity of Khartum in a day and a half. There, after it had covered more than half of the distance to East Africa, it received a radio order from the Nauen station to return, because, according to information which had been received in Berlin, the situation of Lettow Vorbeck was considered hopeless. As subsequently discovered, the report was exaggerated, making it all the more regrettable that such a brilliant voyage should be interrupted in this manner. The moral effect on the whole world could not be too highly estimated, even if the L 59 had arrived too late. The performance of the airship can, nevertheless, be properly estimated. It had covered 6800 kilometers (4225 miles) in a non-stop flight of 95 hours. After landing, there was enough fuel left on board to enable the airship to fly two days longer at a diminished speed.

The airships LZ 120 and L 59 thus made two world records in 1917, as regards both duration and length of voyage. These brilliant exploits were not surpassed even by the American trip of the English airship R 34 in 1919, although the voyage of the L 59 was made under difficult conditions during the war, while that of the R 34 was made only after the most thorough preparation and with all possible aid from radiotelegraphy and the weather bureau.

During the winter of 1917-18, another important improvement was

made. It had been found that the airships lost speed at high altitudes, due to the strong winds and to the loss in engine power resulting from the decrease in the density of the air. These disadvantages were eliminated by the invention of the Maybach high-altitude engine, which first developed its full power in rarefied air.

The year 1918 again gave the Zeppelin Airship Construction Company the task of building a larger type, since the enemy anti-aircraft guns were constantly becoming more efficient and enemy airplanes were tirelessly attaining the flight altitudes of the airships. The larger airships, from the L 70 on, showed an increase in flight altitude of about 600 meters (1968.5 feet) up to a ceiling of about 6500 meters (21325 feet). But even this was not enough, for the L 70 was shot down on its first raid. In order to reach the altitude of 8000 meters, it was necessary to build a new type of greater diameter, with 10 engines and 100000 cu.m (26247 cu.ft) gas capacity. During these undertakings, Captain Strasser, the chief of the naval airship service, met a hero's death on the L 70. With him the naval airship service lost its most zealous advocate and the outlook was very dark regarding the further development of naval airships as instruments of war, when the revolution broke out.

The fate of the remaining Zeppelin airships is well known. The LZ 113 and L 72 were turned over to France, the L 64 and L 71 to England, the L 61 and LZ 120 to Italy. The L 30 was dismantled as obsolete. The L 37 was taken apart and sent to Japan. For the airships L 41, 42, 52, 56, 63 and 65, destroyed in their hangars by the

Navy personnel in the summer of 1919, the allied countries demand reimbursement. Whether in money or in substitute airships or in some other way, will soon be decided in the different countries.

Even though the outcome of the war left no hope for the retention of military airships, it did seem at first that the Entente would have no objection to a restricted air traffic. In the spring of 1919, the Zeppelin Airship Construction Company accordingly began the construction of a commercial airship, with which the German Airship Company (Deutsche Luftschiffahrts-Aktiengesellschaft) intended to inaugurate a trial service, in order subsequently, on the basis of the experience obtained, to add further airships and open up air traffic lines even beyond the boundaries of Germany.

The performances of the "Bodensee" were really astounding. The small size of the airship, 120 m (393.7 ft) long, reminded one of the first Zeppelins. With a gas capacity of only 20000 cu.m (706300 cu.ft), it had a carrying capacity of about 10000 kg (22046 lbs). (With the same gas capacity, the Hansa had a carrying capacity of only 6000 kg (13228 lbs). Four engines gave the airship a speed of 130 km/hr (80.8 mi/hr). (The Hansa had a speed of only 70 km (43.5 mi) with three engines.) The fullest advantage was taken of everything that was learned during the war, even to the smallest details. The shape and disposition of the cars and rudders, walk-way and power transmission were copies from the most recent airships. The passenger cabin was placed in immediate connection with the control car. It had room for 20 persons and was provided with every convenience, including a heating plant.

During the period from August 24, to December 1, 1919 (98 calendar days), the Bodensee made 103 trips, amounting to 52000 km (32311 mi), in 532 hours. 78 trips were made between Friedrichshafen and Staaken near Berlin. The following table compares the performances of the Bodensee with those of the earlier passenger airships.

Table

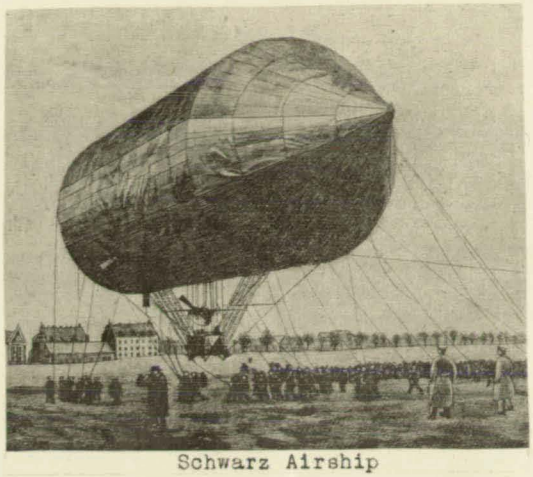
| Name of airship | Date of first flight | Number of days in service |
|---|---|---|
| Deutschland | 6/19/10 to 6/28/10 | 10 |
| LZ 6 | 8/21/10 " 9/14/10 | 23 |
| Ersatz Deutschland | 3/23/11 " 5/16/11 | 53 |
| Schwaben | 6/26/11 " 6/28/12 | 362 |
| Viktoria-Luise | 2/16/12 " 7/31/14 | 1244 |
| Hansa | 7/16/12 " 7/31/14 | 735 |
| Sachsen | 5/3/13 " 7/31/14 | 447 |
| Bodensee | 8/24/19 " 12/1/19 | 98 |

Table (Cont.)

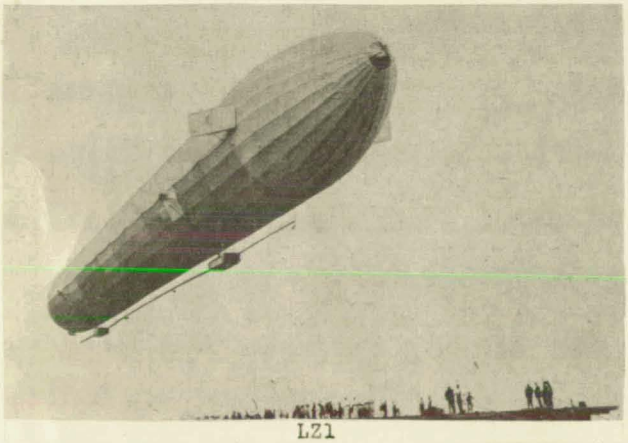
| Deutschland | Number of days flown | Number of trips | Hours flown | Kilometers flown | Passengers |
|---|---|---|---|---|---|
| Deutschland | 5 | 7 | 20.30 | 1035 | 142 |
| LZ 6 | 18 | 34 | 66.11 | 3132 | 726 |
| Ersatz Deutschland | 17 | 22 | 47.11 | 2379 | 129 |
| Schwaben | 143 | 218 | 479.32 | 27321 | 1553 |
| Viktoria-Luise | 316 | 489 | 981.17 | 54312 | 2995 |
| Hansa | 255 | 399 | 840.37 | 44437 | 2187 |
| Sachsen | 233 | 419 | 740.57 | 39919 | 2465 |
| Bodensee | | 103 | 532.00 | 52000 | 2253 |

In December, 1919, the Bodensee was lengthened 10 meters (32.8 feet), and given a gas capacity of 22250 cu.m (785759 cu.ft). The number of gas cells was increased from 11 to 12 and the carrying capacity from 10000 to 11000 kg (22046 to 24250 lbs). The Bodensee now had the same dimensions as the "Nordstern" (North Star) built in October to December, 1919. With these two airships, carrying 30 passengers each, it was intended to open an airship line in the spring of 1920, between Switzerland and Stockholm, by way of Berlin. The Entente, however, refused their permission and both airships are still lying inactive in their hangars. Their fate has also been decided by the latest disarmament note. They must be turned over to the Allies and when these lines appear, the Nordstern will have already landed in France.

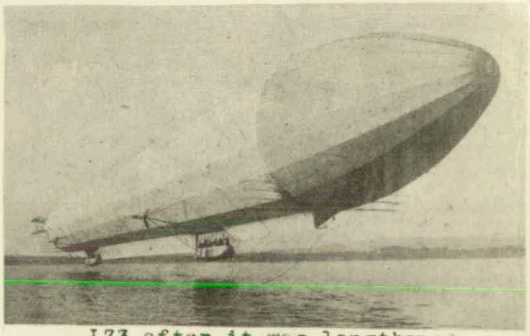
Translated by
National Advisory Committee
for Aeronautics.



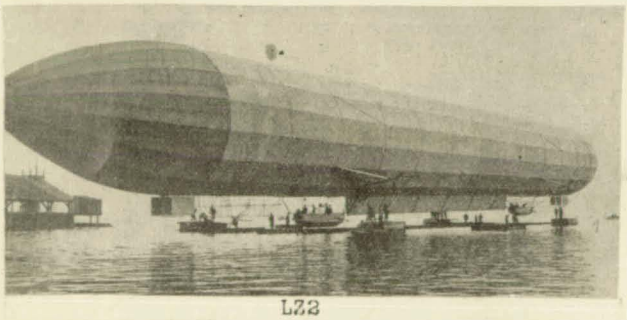
Schwarz Airship



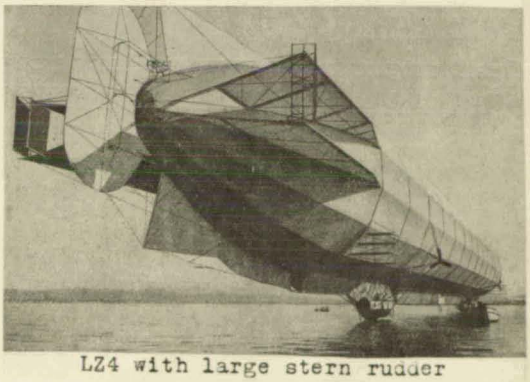
LZ1



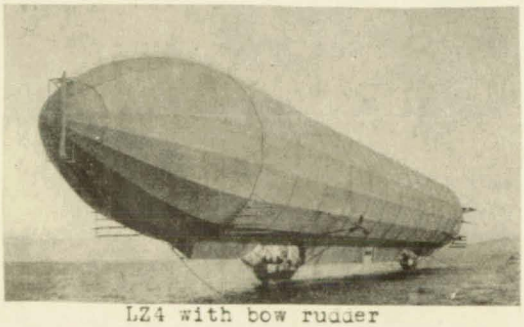
LZ3 after it was lengthened



LZ2



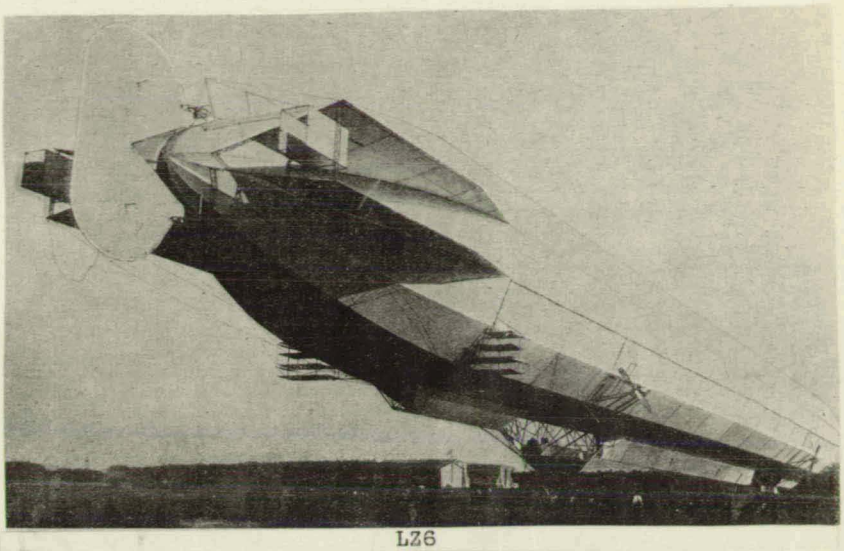
LZ4 with large stern rudder



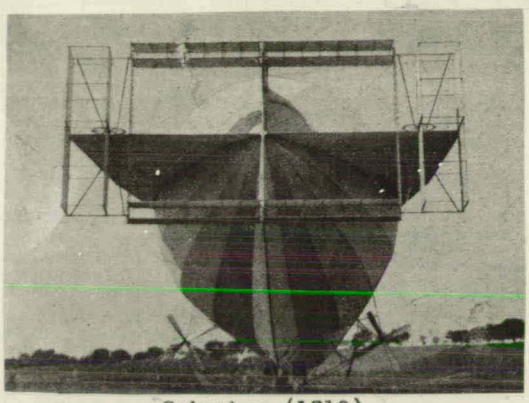
LZ4 with bow rudder

LZ4 with small stern rudder

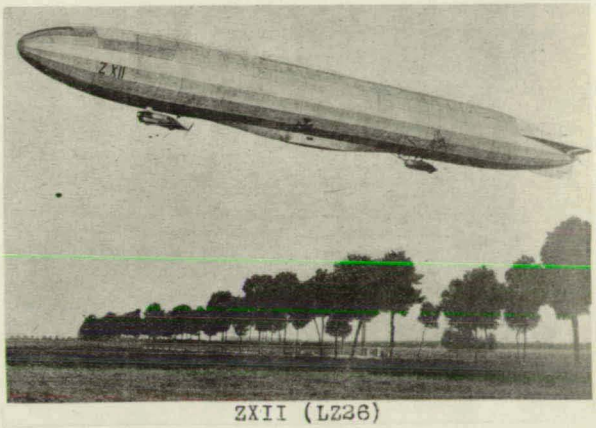
Ascent of LZ5 after temporary repairs



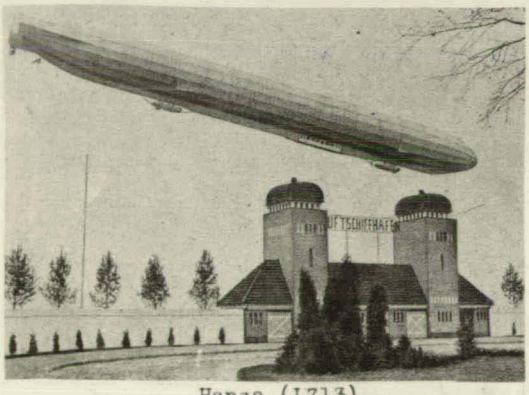
LZ6



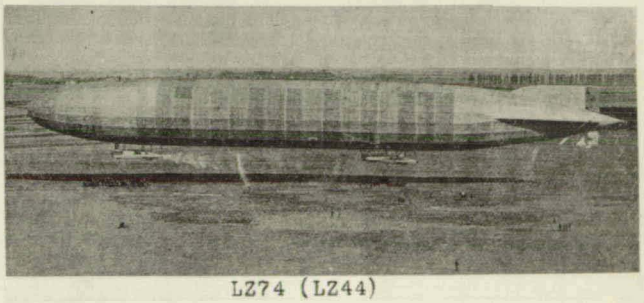
Schwaben (LZ10)



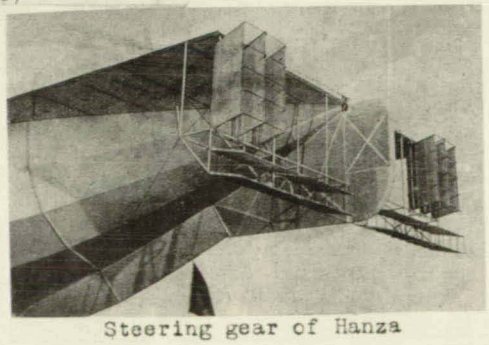

ZXII (LZ36)



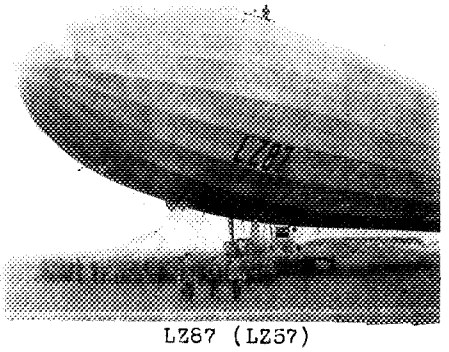
Hanza (LZ13)



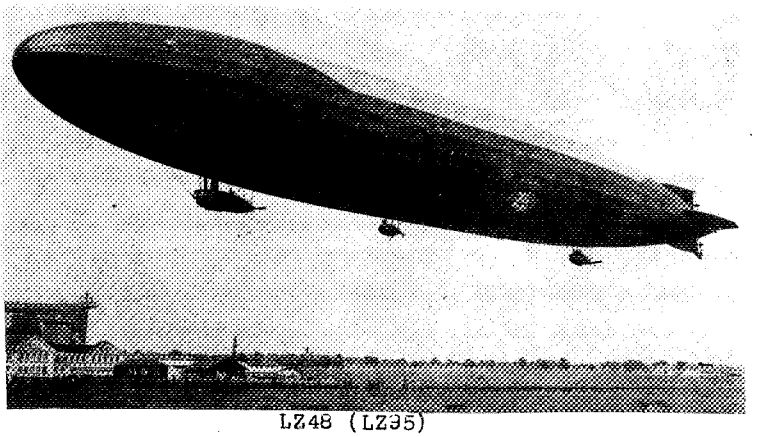
LZ74 (LZ44)



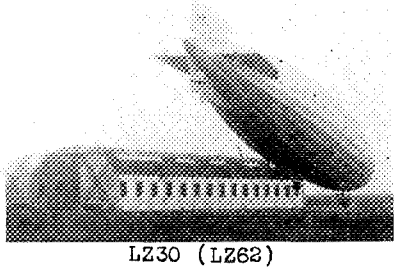
Steering gear of Hanza



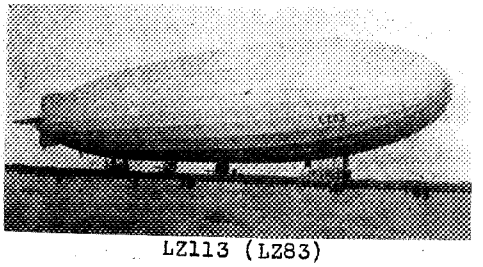
LZ87 (LZ57)



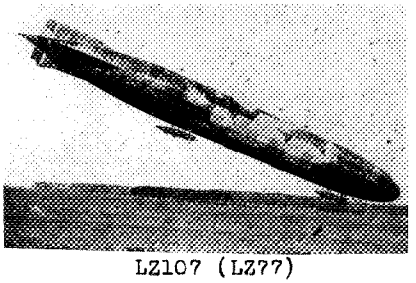
LZ48 (LZ35)



LZ30 (LZ62)

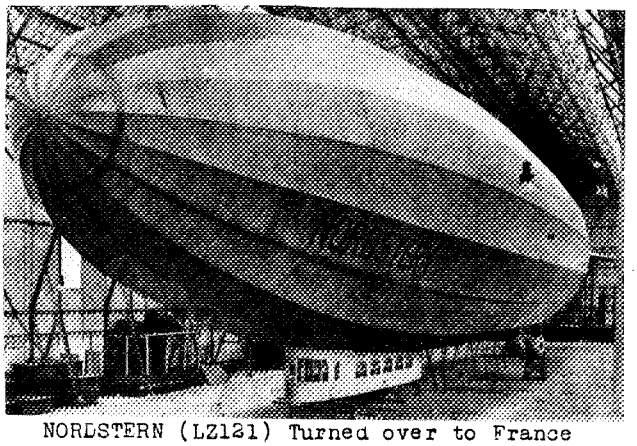


LZ113 (LZ83)



LZ107 (LZ77)

L71 (LZ113) Last Airship ushered into service during the war.



NORDSTERN (LZ121) Turned over to France