

# 1632 Airship Ground Handling: Appendix and Bibliography

by [Iver Cooper](#) | Dec 16, 2020 | [1632 Tech](#), [Gazette Extras](#)

Here I cover some topics that I couldn't fit into the article, and also provide the bibliography.

## Ground Handling of Royal Anne

If the Royal Anne (650 x 70 ft) in canon is modeled as a cylinder with hemispherical ends, the profile area is 44,448 square feet (4129 m<sup>2</sup>). A 7 m/s cross wind (mean Beaufort Force IV, "moderate breeze") would produce a force of 80,928N.

To resist that force, the ground crew on the windward lines or holding the cars would have to be able to exert the same force. If the wind must overcome the force of friction, then that's equal to the weight of each crewperson (figure 70 kg \* 1G acceleration = 700N), times the coefficient of static friction. My guess is that for ordinary shoes on soil, that will be around 0.7. Plainly, it would take close to 200 pullers. So that means that such a wind will move the Royal Anne off-track and note that once it starts moving, the coefficient of friction is reduced a bit. The ground crew will slow down the crabbing movement but they won't stop it. Give the crew some sort of special shoe with a 1.0 coefficient, and you still need a little over a hundred with heels (and toes) dug in.

Drop the wind speed to 5 m/s (mean Beaufort Force III, "gentle breeze") and the wind force is 41,290N. At this point, a ground crew comparable to that of the Graf Zeppelin is adequate.

What the crew would probably want to do, if possible, is turn the airship so it faces into the wind. At that point, the projected area is reduced to 358 m<sup>2</sup>, and the drag coefficient (referenced to that area) to something like 0.2, so the wind force would be 2% of the worst case scenario.

## The Patrie

Supposedly, it came off the ground spike which anchored it. However, it appears that a gust caused the airship to swing broadside and tilt over, causing ballast bags to fall out of the airship, rendering it very light, so much so that 200 soldiers couldn't keep it near the ground. (Camplin 287). One could not reasonably expect a ground spike to hold under these circumstances. Of course, it would've been nice if it kept the airship from tilting over....

## Packed Volume vs. Inflated Volume

The packed volume of a 50 ft diameter balloon is 2.2 cf according to Eagle Balloons, How to Build Your Own Hot-Air Balloon: Volume 1 – Design Criteria p. 75., assuming an "ideal fabric" and a packing factor of 2. If the balloon is a natural shape, a 50 foot max diameter corresponds to a gore length of 76.4 ft and a volume of 56,156 cf inflated. Notice the ratio of inflated to packed.

For a 300 ft diameter balloon, packed volume would be 900 cf, but gore length would be 458.8 and volume over 12,000,000 cf.

I don't presently have packed volume data for nonrigid airships; the nose stiffeners would tend to hinder packing somewhat.

### The Hangars on Lake Constance

Curiously, the British observer Colonel Trench, visiting Lake Constance, reported that the floating hangar was formed of girder iron framework, covered with corrugated iron sheeting, with a vertical side 50 feet tall and total height from floor to ridge of 70 feet. It had an interior floor width of 85 feet, and was supported on four rows of closed iron pontoons. Halfway up the framework there were supposed to be hinged platforms 13 feet wide. See Seligmann, Spies in Uniform 122 (2006). So was it wood or iron construction?

There is some uncertainty as to how long this pivotable floating hangar was used. According to De Syon (35), it was used to launch the LZ4 in June 1908, and a photo seemingly shows this:

<http://www.airships.net/wp-content/uploads/lz4-bodensee.jpg>

And that looks very much like the hangar of the LZ1

<http://www.airships.net/wp-content/uploads/lz1-hangar.jpg>

But Belafi has it dismantled and reassembled on shore (but extending over the water) in time to assemble the LZ2. This second airship hangar (1904) was 126 meters long, with 50 meters protruding into the water. (While the hangar was thus partly over the lake, there was no possibility of the hangar rotating to face the wind.) From the entrance, rails, mounted on pontoons, extended another 100 meters onto the lake. From those rails the LZ2 would be towed by a tugboat onto open water. (Belafi). In 1909, it was replaced by a new (third) hangar.

To add to the mystery, this undated photo shows two hangars, one (looking like original hangar) halfway over the land, and the other (painted white) floating on the water away from the shore.

<http://welweb.org/ThenandNow/images/2nd%20shed.jpg>

### Other Floating Hangars

The US Navy launched Hangar Barge Number One in 1915 to house its first airship, the DN-1. According to Aerial Age, "The hangar is of steel, 60 by 140 feet, and it draws eighteen inches of water." (Mize). An April 21, 1917 photograph shows the DN-1 making its landing approach, directly in line with the open end of the hangar. Since the other end was permanently closed by curved metal framing, the DN-1 would have had to have been backed out of the hangar for takeoff. The DN-1 was a flop and by 1918 the hangar had been relocated to land.

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Floating hangars are still in use today for seaplanes, but they are of course much smaller than airship hangars and don't need to rotate with the wind because a seaplane is much more maneuverable.

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## Waterside Hangars

The British Cavendish dock, prepared for the ill-fated British Mayfly, floated, but it did not rotate. Rather, it was adjacent and parallel to the dock. A series of electric winches would be used to ease her out, in theory, even against a beam wind. Nonetheless, while trying to move her out, the Mayfly was caught by a beam gust and broke in two.

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## Later Rotating Hangars

Besides the rotating hangar at Biesdorf, several others were built during or just before WW I.. Germany had sixteen more, with France had one at Reims (130 x 30 x 20 meters). (D'Orcy 217-221).

"Nobel" at Nordholz (near Cuxhaven) was the only double hangar. It weighed 4200 tons. The dimensions according to D'Orcy were 180 x 75 x 30 meters, and Wikipedia, 200 x 70 x 30. The hangars could be turned all the way around in an hour. (Wikipedia). The discrepancy is partially explained by the report (Elric888) that the hangar was lengthened at the rear; The information is sparse, but it apparently ran on a circular, two railed track. Underneath the hangar bed there was a a truss structure, and below that, at one end, eight powered wheels (four axles). (Slide). I assume that there was a matching unpowered wheelpack at the other end.

## Circular or Many-Sided Hangars

In 1909, Ernst Meier proposed that an airship hangar be circular, with a diameter greater than the length of the airship (Wilkinson 15). Rather than rotate the hangar, the airship would be rotated within the safety of the hangar, to align with the most favorable of the many doors on the perimeter of the hangar. Others have made similar proposals. (Wisniewski, US Patent 1,101,372, 1914; Schwerdtfeger, US 1,666,354, 1928; Smith, 1,861,069, 1932).

The basic problem with the concept was that a much larger building was needed to house a single airship of a given length. The whole interior space must be kept clear so the airship can be rotated when needed, and hence it can't really be shared.

If a circular hangar were ever constructed, the structural design might be inspired by Madison Square Garden. That is a circular building with a diameter of 127 meters (420 feet) spanned by 48 radial cables that run from an outer concrete compression ring to a central steel tensile ring. (Underwood).

## Hangar with Retractable Roof

Retractable roof structures date back at least to Roman time; the veterarium was a retractable canvas shade that covered some of the seats at the

Coliseum. Retractable roof structures are found today on certain "mass event" buildings such as sports stadiums and performance halls, where they provide natural lighting and ventilation on a nice day.

D'Orcy presents a photograph of a model of a German airship shed with a "disappearing roof." It is in the open position, and it can be seen that the roof is split in half lengthwise, and the two halves are both pivoted outward and pulled away on some kind of support. It looks very heavy and cumbersome to me and I am not aware of any being built.

What was the motivation for making the roof openable? So the airship could land in or takeoff from directly inside the hangar? So the temperature inside the airship envelope could be equilibrated with ambient temperature before the airship was removed from the hangar? To permit rapid escape of hydrogen if a gas cell was ruptured?

A retractable roof could be some kind of flexible membrane (like canvas) that is folded or rolled up, or be composed of rigid elements connected so that the elements fold up accordion style, or slide back into stacks.

## Adiabatic Heating

One source of temporary buoyancy is adiabatic heating as a result of rapid descent. (Camplin 258).

## Balloon Barges

In 1861, the Union had a "balloon barge", the George Washington Parks Custis. An illustration shows the balloon Washington tethered by lines to the barge.

## Bibliography

[AHT] Airship Heritage Trust, R33, 1921-28, The Breakaway  
<http://airshipsonline.com/airships/r33/R33-breakway.html>

Admiralty, Handbook on the S.S. Class Airships (Jan. 1917).

[Aeronautics] "Landing and Mooring Gear for Airships: Vickers's Patent Masts and Their Operation, Aeronautics 17(298): 90-92 (July 24, 1919),

Allen, The Story of the Airship (2008).

Althoff, SKy Ships: A History of the Airship in the United States Navy (2016)

Azo Materials,

"Stainless Steel – Grade 304 (UNS S30400)"

<http://www.azom.com/properties.aspx?ArticleID=965>

"Aluminium – Advantages and Properties of Aluminium"

<http://www.azom.com/properties.aspx?ArticleID=1446>

Bart, Race to the Top of the World (2013).

Belafi, The Zeppelin

).

Bianculli, Iron Rails in the Garden State: Tales of New Jersey Railroading (1908).

Bluefield, Over Empires and Oceans.

Bolster, Handling Apparatus for Airships, US Patent 1972863 (Sept. 11, 1934).

Bridgeland, Outrage at Sea (2002).

Brown-Cave, Lighter-Than-Air Craft, J. Soc'y Automotive Engineers, 5: 167 (Aug. 1919).

Burton, The Zeppelin Grows Up, in Pop Sci (Oct.. 1929)

Camplin, Rediscovering the Arcane Science of Ground Handling Large Airships (Unpublished Doctoral thesis, City University London, 2007)

<http://openaccess.city.ac.uk/8521/>

Dale, Coastal Defense and Zeppelin Raids, 1914-18

D'Orcy, D'Orcy's Airship Manual (1917).

DeFerrari, "Million Dollar Bridge" (2009)

<http://www.streetsofashington.com/2009/11/million-dollar-bridge.html>

[EE] "Small Dirigible for Commercial Use", Everyday Engineering Magazine, 550 (Sept. 1919).

Elric888, Dawn over Nordholz

<http://elric888.deviantart.com/art/Dawn-Over-Nordholz-193773252>

[ESG] Engineering Specialties Group, Communication Tower Foundations Selection Criteria.

[www.engineeringspecialtiesgroup.com/wp-content/uploads/2012/12/Communication-Tower-Foundation-Selection-Criteria.pdf](http://www.engineeringspecialtiesgroup.com/wp-content/uploads/2012/12/Communication-Tower-Foundation-Selection-Criteria.pdf)

[Flight] German Airship Sheds, Flight p. 999 (Oct. 2, 1914).

[https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwj\\_pKGV2PPNAhWIFh4KHQjIAUAQFggcMAA&url=https%3A%2F%2Fwww.flightglobal.com%2FflightPDFArchive%2F1914%2F1914%2520-%25200999.PDF&usq=AFQjCNFdXb9KTHMW\\_4ZVxdMd8jWPfd0XcA&sig2=rFKPScW5ge41Sog74tNrg&bvm=bv.127178174,d.dmo](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwj_pKGV2PPNAhWIFh4KHQjIAUAQFggcMAA&url=https%3A%2F%2Fwww.flightglobal.com%2FflightPDFArchive%2F1914%2F1914%2520-%25200999.PDF&usq=AFQjCNFdXb9KTHMW_4ZVxdMd8jWPfd0XcA&sig2=rFKPScW5ge41Sog74tNrg&bvm=bv.127178174,d.dmo)

Fulton, Airship Progress and Airship Problems (2008(reprint of 1929 document)).

Fuhrmann, The Evolution of Streamlined Airship Hangars, Proceedings, Vol. 2, 5th Intl Congr. Construction History (3-7 June 2015)..

GEFA-FLUG, Flight Manual Hotair-Airship AS105GD.

gettyimages, "An airship shed at Dusseldorf"

<http://www.gettyimages.com/pictures/an-airship-shed-at-dusseldorf-news-photo-3324335>

Global Security, Airship Anchors

<http://www.globalsecurity.org/military/world/airship-anchors.htm>

Goodyear Aerospace Corp, Study of Ground Handling Characteristics of a Maritime Patrol Airship, NASA-CR-166253 Final Report (March 1981).

Green, Chap. 4, Mechanical Properties of Wood, in Forest Products Laboratory, Wood Handbook: Wood as an Engineering Material (1999).

Grossman, A Visit to the Zeppelin mast in Recife, Brazil (May 24, 2015)

<http://www.airships.net/blog/zeppelin-mast-recife-brazil-pernambuco>

Hoerner, Fluid-Dynamic Drag (1965).

Holden, Ballooning as a Science and a Sport, Munsey's Magazine 761 (Sept. 1901).

Hoskins, The First Steam Voyage to India, Geographical Review 16(1) 108-116 (Jan. 1926).

Katabatic Power, Wind Speed Extrapolation

<http://es.ucsc.edu/~jnoble/wind/extrap/>

Krell, Airship Sheds, in Aeronautics in the Army: Hearings Before the Committee on Military Affairs, House of Representatives, Sixty-third Congress, First Session, in Connection with H. R. 5304, May 16, 1913, Entitled "An Act to Increase the Efficiency of the Aviation Service of the Army, and for Other Purposes." August 12, 14, 15, and 16, 1913, pp.175-8.

Hofmann, The relative importance of wind and ship waves in the littoral zone of a large lake, Limnol. Oceanogr. 53(1): 368-380 (2008).

Jatulis, Static behavior analysis of masts with combined guys, J. Civ. Eng'g & Mgmt, 13:3: 177-82 (2007).

Kronenburg, Architecture in Motion: The History and Development of Portable Buildings (2013).

Lavis, Railway Estimates, Design, Quantities and Costs (1917).

Layman, Shipboard Aviation of the Smaller Navies, 1919-39, Part One, The Navy (Navy League of Australia, Jan. 1987).

Lehman

Linhard, The Last Masts  
<http://www.uh.edu/engines/epi1338.htm>

Lost and Forgotten Berlin, Airship Turning Hanger Kalshorst  
<https://lostandforgottenberlin.wordpress.com/2014/10/07/airship-turning-hanger-kalshorst/>

Magoun, The Frigate Constitution and Other Historic SHips (1928).

Mahovic, Typology of Retractable Roof Structures in Stadiums and Sports Halls, (2015)  
[iu-cg.org/paper/2015/IU\\_CG\\_03-2015\\_mahovic.pdf](http://iu-cg.org/paper/2015/IU_CG_03-2015_mahovic.pdf)

Mize, Floating Hangar  
<http://www.barnstormers.com/eFLYER/2012/241-eFLYER-FA01-floating.html>

Modesto Radio Museum, “Tallest Wooden Radio Tower in the World”  
<http://www.modestoradiomuseum.org/wooden%20tower.html>

Nicholson, Design of wind turbine tower and foundation systems: optimization approach (MS Thesis, U. Iowa 2011), <http://ir.uiowa.edu/etd/1042>

[NLHS] Navy Lakehurst Historical Society, “From the Mailbag”, response to George Myers  
<http://www.nlhs.com/from-the-mailbag.html>

OSU [Ohio State University], Ohio State Engineer, 16(2):9 (Nov-Dec. 1932).  
<http://hdl.handle.net/1811/34964>

[Patoka] Patoka ... A Newport News Shipbuilding ‘Tall Ship’

Pierce, Floating Hangar  
<http://www.digitalvaults.org/#/detail/2892/?record=2892>  
<http://digitalvaults.org/record/2892.html>

[PopSci] “‘Walking Beam’ Docks Giant Airship,” Pop. Sci. 33 (April 1932).  
<https://books.google.com/books?id=QSgDAAAAMBAJ&pg=PA33&lpg=PA33&dq=bolster+beam+airship&source=bl&ots=As3iMHPYNm&sig=tUqtz7vTE9II9dvRD7BQuDQFFGM&hl=en&sa=X&ved=0ahUKEwjmpdyRqYDOAhULVT4KHVBNCVUQ6AEIjAB#v=onepage&q=bolster%20beam%20airship&f=false>

RBF Consulting, ‘The Tustin Hangars: Titans of History (2008).

Rodrigues, Our Airship Landings Were Always Exciting  
<http://battleblimps.com/landing.html>

Rosie, The Flight of the Titan: The Story of the R34 (2012).

Roshko, Experiments on the flow past a circular cylinder at very high Reynolds number, *Fluid Mechanics*, 10 (3). pp. 345-356 (1961)  
<https://pdfs.semanticscholar.org/2b0e/17ef8b142cd1100ec608956c75aa5c2ce24c.pdf>

<http://c8.alamy.com/comp/C45MKN/wreck-of-the-zeppelin-airship-germany-ii-lz-8-in-dusseldorf-1911-C45MKN.jpg>  
“SciAmSuppl”, “Rotating Airship Shed”, *Sci. Am. Suppl.* 77 (No. 1987): 77 (Jan. 21, 1914).

Sforza, Manned Spacecraft Design Principles (2015).

Silverstein, Ground-Handling Forces on a 1/40th-Scale Model of the U.S. Airship ‘Akron’, *NACA Rept.* 566 (1936).

“Slide”, post on The Old Hangar re visit to Aeronauticum  
<http://mainescenery.proboards.com/thread/11076>

Slindon, WWI Airship Station, The Military History of Slindon  
<https://slindonatwarmyblog.wordpress.com/ww1-airship-station/>

Solheim, A new 4-lane Mjoesbridge built in timber?, *Intl. Timber Bridge Conf.*, Lillehammer, Norway, Sept. 12-15, 2010.

Stephenson, “Helium Is a Busy Bachelor,” *Pop. Mech.* 84(5): 50 (Nov. 1945).

Støttrup-Andersen, “Masts and Towers”

Taylor, Development of Longer Span Wood Bridges, in Bakht, et al., *Developments in short and medium span bridge engineering '90:Proceedings of the 3d International conference on short and medium span bridges*; 1990 August 7-10; Canadian Society for Civil Engineering; 1990: 2: 391-402.

Tinker, The Whys and Wherefores of Airships, *US Naval Institute Proceedings*, 48: 691 (1922).

Underwood, *Structural Design: A Practical Guide for Architects* (2011).

Walker, Jr. Mooring and Ground Handling Rigid Airships, in *Proceedings of the Interagency Workshop on LTA Vehicles.*, pp. 297-310 (1975)  
<https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19760007954.pdf>

Whale, The Mooring and Handling of Airships on the Ground, *U.S. Air Service*, 5: 14 (May 1921).



WWA, Wonders of World Aviation (May 17, 1938)  
[http://www.wondersofworldaviation.com/mooring\\_airships.html](http://www.wondersofworldaviation.com/mooring_airships.html)  
(includes picture of the floating mast)

Wood Database  
“Eastern White Pine”  
<http://www.wood-database.com/eastern-white-pine/>  
“Scots Pine”  
<http://www.wood-database.com/scots-pine/>

Images of Floating Hangar at Lake Constance

<http://static.thisdayinaviation.com/wp-content/uploads/tdia/2012/08/Airship-LZ4-over-the-Bodensee-0605-4-August-1908.jpg?>

[https://upload.wikimedia.org/wikipedia/commons/4/45/Zeppelin\\_inside\\_floating\\_hangar.jpg?](https://upload.wikimedia.org/wikipedia/commons/4/45/Zeppelin_inside_floating_hangar.jpg?)

<http://c8.alamy.com/comp/BJWCA4/zeppelin-lz1-in-a-floating-hanger-at-manzell-friedrichshafen-germany-BJWCA4.jpg?>

Image of Berthing DN-1 at Pensacola  
<https://www.floridamemory.com/items/show/40219>

Videos

USS Los Angeles Moors To Mast, Lakehurst, NJ (full)

<https://www.youtube.com/watch?v=inTJue5kRBI>  
(this shows the experimental stub mast and stern car)

Moving Mechanical Mooring Mast (1930)  
<https://www.youtube.com/watch?v=4sdm3C9YQFA>  
(the crawler mast)

LZ-127 Graf Zeppelin in flight and LZ-126 ZR-3 airship being positioned..  
[https://www.youtube.com/watch?v=C2j\\_Lo\\_evwI](https://www.youtube.com/watch?v=C2j_Lo_evwI)  
(railway mast sterncar on RR track)

Zeppelin Hindenburg moored by ground crew at Lakehurst Naval Air Station, New Jersey after landing.

[http://www.criticalpast.com/video/65675052077\\_airship-LZ-129-Hindenburg\\_Naval-Air-Station\\_mooring\\_tower\\_loudspeaker\\_Charles-Rosendahl](http://www.criticalpast.com/video/65675052077_airship-LZ-129-Hindenburg_Naval-Air-Station_mooring_tower_loudspeaker_Charles-Rosendahl)  
(good closeup of mooring cup engagement)

Lighter Than Air Operations, NAS, Lakehurst, N.J, 12/14/1943  
<https://archive.org/details/NPC-1831>

USS Los Angeles (ZR-3) Is Towed From Hangar & Hooks On To Mast, Lakehurst, N.J, 1928  
[https://archive.org/details/NPC-1991\\_201505](https://archive.org/details/NPC-1991_201505)

Rigid Airship Ground Operations USS Macon (ZRS-5), Sunnyvale, California, 1934 – 1935  
<https://archive.org/details/NPC-1995>

[https://www.youtube.com/watch?v=pK89NgDJx\\_w](https://www.youtube.com/watch?v=pK89NgDJx_w)  
(ground handling theory)

piling up spill and turbulence

Ground crew move the airship USS Akron on mooring masts out of its large hanger, ...HD Stock Footage  
<https://www.youtube.com/watch?v=F4Bex6EMX4g>  
(rail mast)

[http://www.criticalpast.com/video/65675029800\\_docking-airship\\_airship-in-hangar\\_utility-vehicle\\_ground-handling-officer](http://www.criticalpast.com/video/65675029800_docking-airship_airship-in-hangar_utility-vehicle_ground-handling-officer)

AT-10 airship / BLIMP GROUND HANDLING AT CARDINGTON stabilised  
<https://www.youtube.com/watch?v=F8xvbUrY5U4>

Patterson, “How to ‘lasso’ a Goodyear ‘blimp’ “  
<http://www.cnn.com/2015/11/04/us/goodyear-blimp-wingfoot-one-cockpit-mast-truck/>

[LAFD History – The Hayes Aerial Ladder Truck](#)

Getty Images, Akron  
<http://www.gettyimages.com/detail/video/navy-airship-akron-taking-off-crashing-rudder-into-ground-news-footage/145881601>

Brown, Airship Hangars Around the World (2014)  
<http://googlesightseeing.com/2014/04/airship-hangars-around-the-world/>

Landing operations of LZ-127 Graf Zeppelin airship at Friedrichshafen, Germany  
[http://www.criticalpast.com/video/65675052180\\_LZ-127-Graf-Zeppelin-airship\\_landing-operations\\_radio-room\\_airship-floats-in-air](http://www.criticalpast.com/video/65675052180_LZ-127-Graf-Zeppelin-airship_landing-operations_radio-room_airship-floats-in-air)

first mooring of the Macon, 1933  
[http://www.criticalpast.com/video/65675070498\\_USS-Macon\\_hangar\\_attached-to-mooring-mast\\_passengers-come-ashore](http://www.criticalpast.com/video/65675070498_USS-Macon_hangar_attached-to-mooring-mast_passengers-come-ashore)

the largest building in the world with no internal supports—365 meters long, 200 meters wide, 100 meters tall.  
<http://www.forbes.com/global/2002/0429/034.html>

Human performance

<http://msis.jsc.nasa.gov/sections/section04.htm>

Bregenz wind data

[https://www.meteoblue.com/en/weather/forecast/modelclimate/bregenz\\_austria\\_2781503](https://www.meteoblue.com/en/weather/forecast/modelclimate/bregenz_austria_2781503)

For Cooper's Standard Loading see American Civil Engineers' Handbook edited by Mansfield Merriman 848ff

Artists rep of Nordholz

<http://elric888.deviantart.com/art/Dawn-Over-Nordholz-193773252>

Behrens, Published aeronautical patent (Brit)

27,731, Transportable shed for airships

published april 22, 1909, applied for in 1908

French paddle frigates

<http://www.shipscribe.com/marvap/220b.html>