

# **Detroit Aircraft Corporation - ZMC-2 metalclad airship**

Peter Lobner, 31 July 2022

## **1. Introduction**

The ZMC-2 (Zeppelin Metal Clad) was the world's first successful metalclad airship. The ship's hull is a single structural unit (a monocoque) in which the metal skin is not only the lifting gas container but, in combination with the metal frame members, carries the static and dynamic loads. Although the size of the ZMC-2 was too small for operational military or commercial purposes, its performance and characteristics proved the feasibility of rigid, metalclad construction for larger airships.

The ZMC-2 also is notable because it was the first air vehicle constructed of Alclad, which is a corrosion-resistant composite material formed from high-purity aluminum surface layers that are metallurgically bonded (rolled onto) to a high strength aluminum alloy core material (i.e., duraluminum). While marginally thicker and heavier than sheet aluminum alloy, Alclad's corrosion-resistant properties were an important factor for the ZMC-2. Since its introduction on the ZMC-2, Alclad has been an important construction material for the worldwide aviation industry.



After receiving Congressional authorization, the ZMC-2 was constructed for the US Navy between March 1927 and August 1929 by the Detroit Aircraft Corporation (DAC) at the Naval Air Station Grosse Ile on the Northwestern end of Lake Erie, south of Detroit. DAC formed a new subsidiary, Aircraft Development Corporation, in July 1929 to take over and continue development of metalclad airships for military and civilian applications.

First flight occurred on 19 August 1929. The airship was accepted by the Navy about one month later and was transferred to Lakehurst, NJ in October 1929. It was operated by the US Navy at Lakehurst until being permanently grounded in 1939. Afterwards, the airship was used for tests and training on the ground until 1941 when it was disassembled and scrapped.

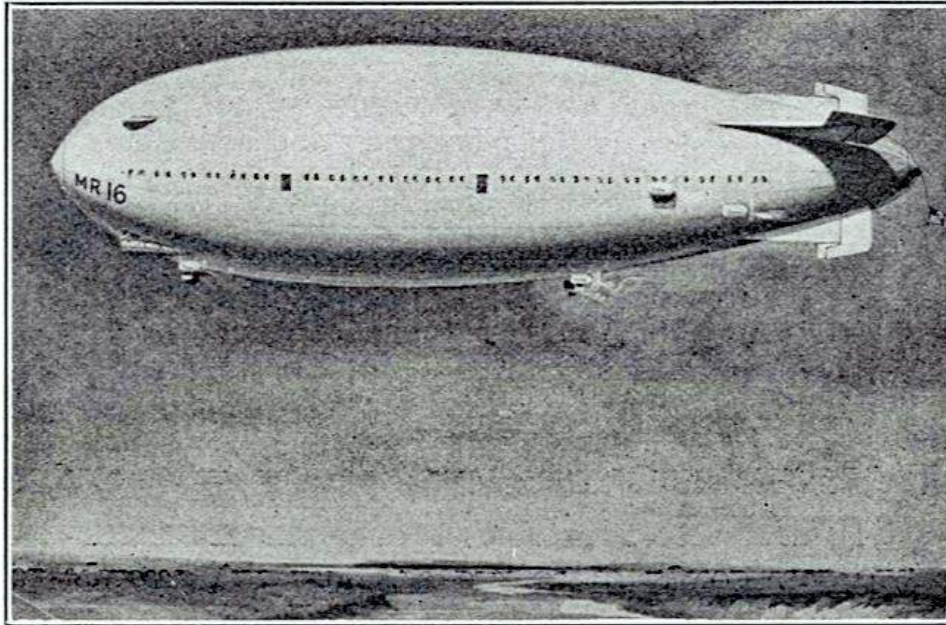
## 2. Design

Starting in about 1922, balloonist and engineer Ralph Upson was the driving force behind the effort to build a metalclad airship in the US in the 1920s. Upson teamed with Carl B. Fritsche of Detroit and together they formed the Detroit Aircraft Corporation, with backing from Henry Ford and Edsel Ford, as well as Charles Kettering of General Motors, Alex Dow, president of Detroit Edison, and William B. Stout, a local industrialist. Vladimir Pavlecka, a young Czech-American designer, was selected as the Chief of hull design.

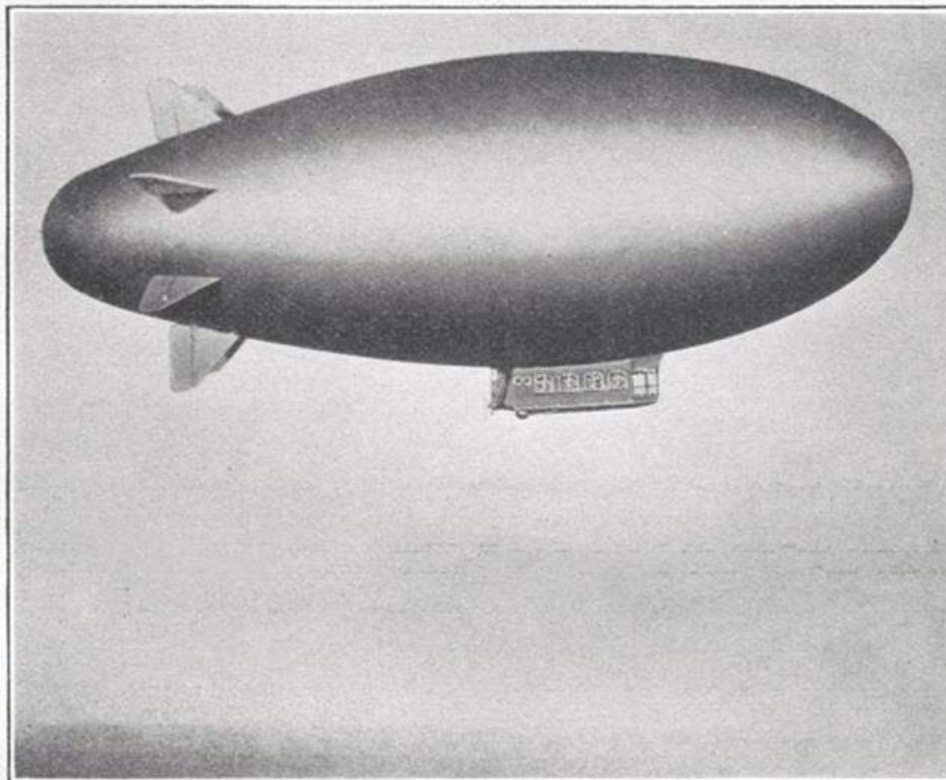
In 1926, Ralph Upson reported that, some years earlier, “prominent leaders in automotive industries cooperated to form a purely engineering group that had as its primary purpose developing a type of rigid-airship construction in which the public would have confidence. It was conceived that such an airship should be: (1) fireproof, (2) weatherproof, (3) durable and permanent in structure, (4) navigable in practically all kinds of weather, and (5) economical in the use of buoyant gas and ballast

To meet all of these requirements it was decided, after mature consideration, that a substantially all-metal construction was imperative. Development of the metalclad airship has now reached a point where the general soundness of the design seems fully assured...”

The first design developed in some detail by this group was a relatively large airship with a volume of 1,600,000 ft<sup>3</sup> ( 45,307 m<sup>3</sup>). This design exercise identified significant, and unexpected, weight savings from metalclad construction and created the opportunity to design a smaller airship for demonstration purposes. After making preliminary design and performance calculations for several metalclad airships with volumes from 80,000 to 5,000,000 ft<sup>3</sup> (2,265, to 141,584 m<sup>3</sup>), the 200,000 ft<sup>3</sup> (5,663 m<sup>3</sup>) model designated MC-2 was determined to be the best candidate for a demonstration airship and one that was ready for immediate construction.



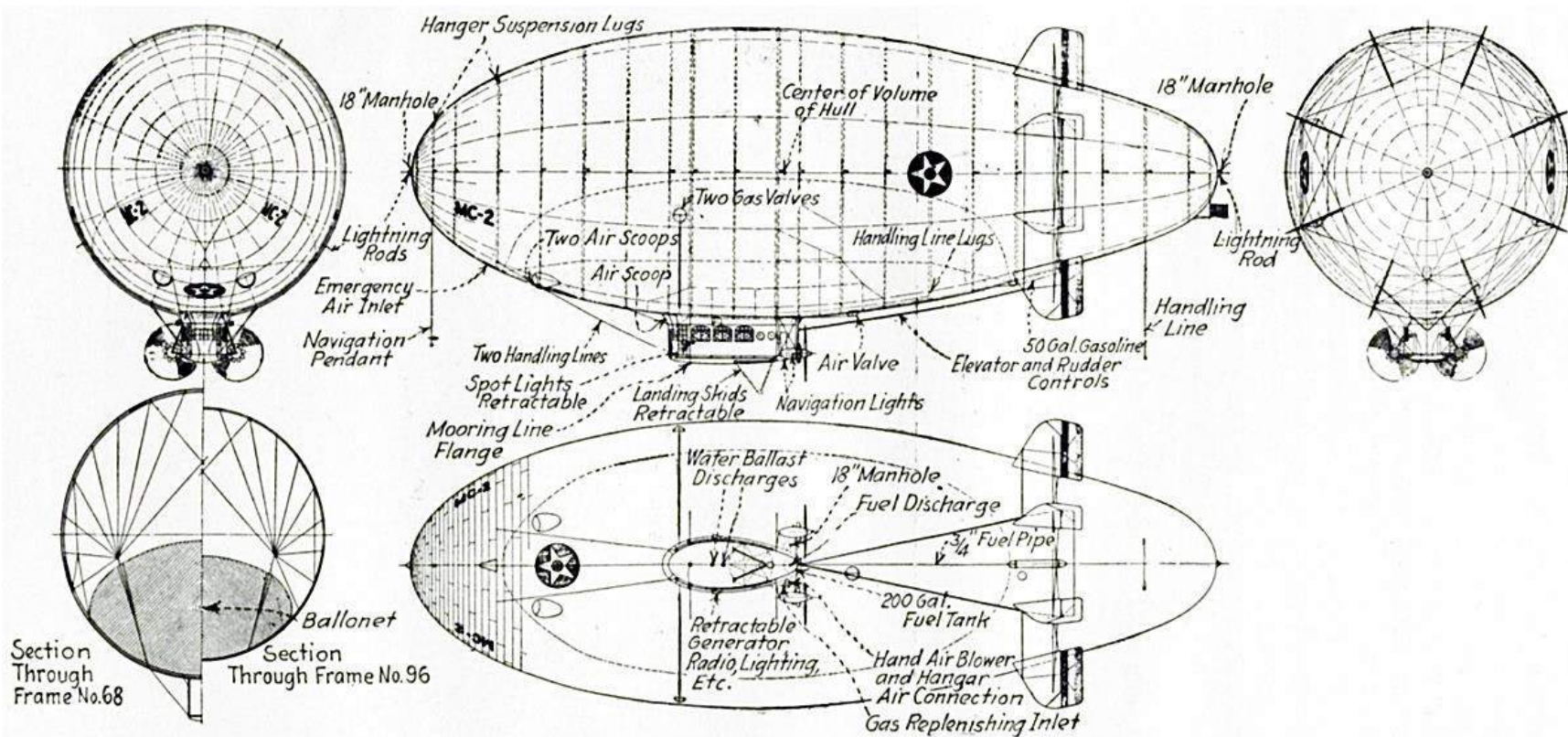
*First design of metalclad airship, MR-16, circa mid-1920s, designed to carry express freight & mail. It had a volume of 1,600,000 ft<sup>3</sup> (45,307 m<sup>3</sup>). Source: Upson (1926)*



*Preliminary design of metalclad airship MC-2, circa mid-1920s. It had a volume of 200,000 ft<sup>3</sup> (5,663 m<sup>3</sup>), about one-tenth that of the US Navy's Shenandoah (ZR-1) rigid airship. Source: Upson (1926)*

## General characteristics of the ZMC-2

Parameter	ZMC-2
Airship type	Rigid, metalclad
Length, overall	45.5 m (149.5 ft)
Diameter, max	16.1 m (52.7 ft)
Height, overall	19.7 m (64.5 ft)
Fineness ratio	2.83
Volume	5,720 m <sup>3</sup> (202,200 ft <sup>3</sup> ), forming a single lifting gas compartment
Ballonets	2 x rubberized fabric ballonets laced to the hull @ 25% of the total volume, used for helium pressure & trim control. <ul style="list-style-type: none"> <li>• 640 m<sup>3</sup> (22,600 ft<sup>3</sup>) front</li> <li>• 793 m<sup>3</sup> (28,000 ft<sup>3</sup>) rear</li> </ul>
Thickness of Alclad skin	0.241 mm (0.0095 in)
Lifting gas	Helium
Internal pressure	0 psig to slightly positive, 2 inches of water (about + 0.07 psig)
Lift, gross	5,557 kg (12,250 lb)
Weight, empty	4,134 kg (9,115 lb)
Useful load, comprised of: <ul style="list-style-type: none"> <li>• Crew (3)</li> <li>• Fuel (200 gal / 757 l)</li> <li>• Oil (25 gal / 94.6 l)</li> <li>• Ballast (50 gal / 189 l)</li> <li>• Passengers &amp; cargo</li> </ul>	1,418 kg (3,127 lb) <ul style="list-style-type: none"> <li>• 272.2 kg (600 lb)</li> <li>• 544.3 kg (1,200 lb)</li> <li>• 90.7 kg (200 lb)</li> <li>• 190.5 kg (420 lb)</li> <li>• 320.7 kg (707 lb)</li> </ul>
Propulsion	2 x Wright J-5 Whirlwind, 9-cylinder, air-cooled, radial piston engines rated @ 164 kW (220 hp) each @ 1,800 rpm
Propeller diameter	2.8 m (9.2 ft)
Speed, max @ 328 kW (440 hp)	100 kph (62 mph)
Speed, cruise @ 149 kW (200 hp)	80.5 kph (50 mph)
Ceiling, static	2,743 m (9,000 ft)
Range, cruise, 250 gal (946 l) of fuel	1,094 km (680 miles)
Range, max possible, still air	1,609 km (1,000 miles)
Endurance, cruise	11 hours
Fins	8 x all metal fins <ul style="list-style-type: none"> <li>• four acting as rudders, four as elevators</li> <li>• 41 m<sup>2</sup> (440 ft<sup>2</sup>) total fin area</li> </ul>
Control car length	7.3 m (24 ft)
Control car width	2 m (6.5 ft)
Accommodations	3 crew + up to 4 passengers



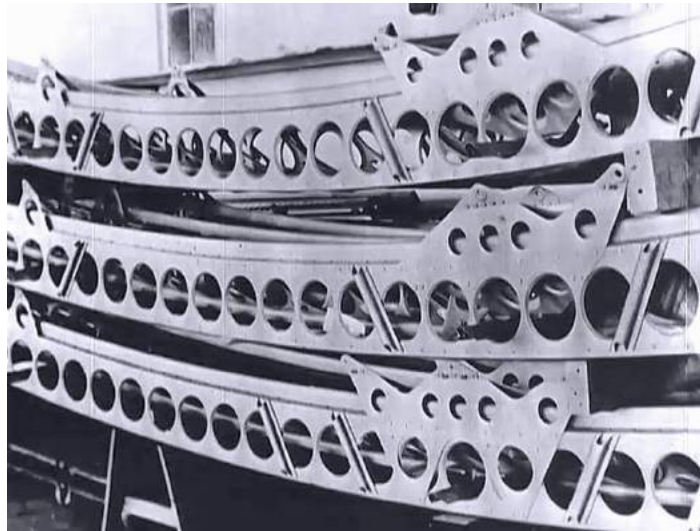
General Arrangement of the ZMC-2 Metalclad Airship  
Source: Upson (1929)



### 3. Manufacturing

Construction began on 7 March 1927. With construction complete, it was inflated with helium for the first time and float tested on 7 August 1929. The first flight occurred on 19 August 1929. The airship was delivered to the US Navy 127 lb (57.6 kg) under its contracted weight.

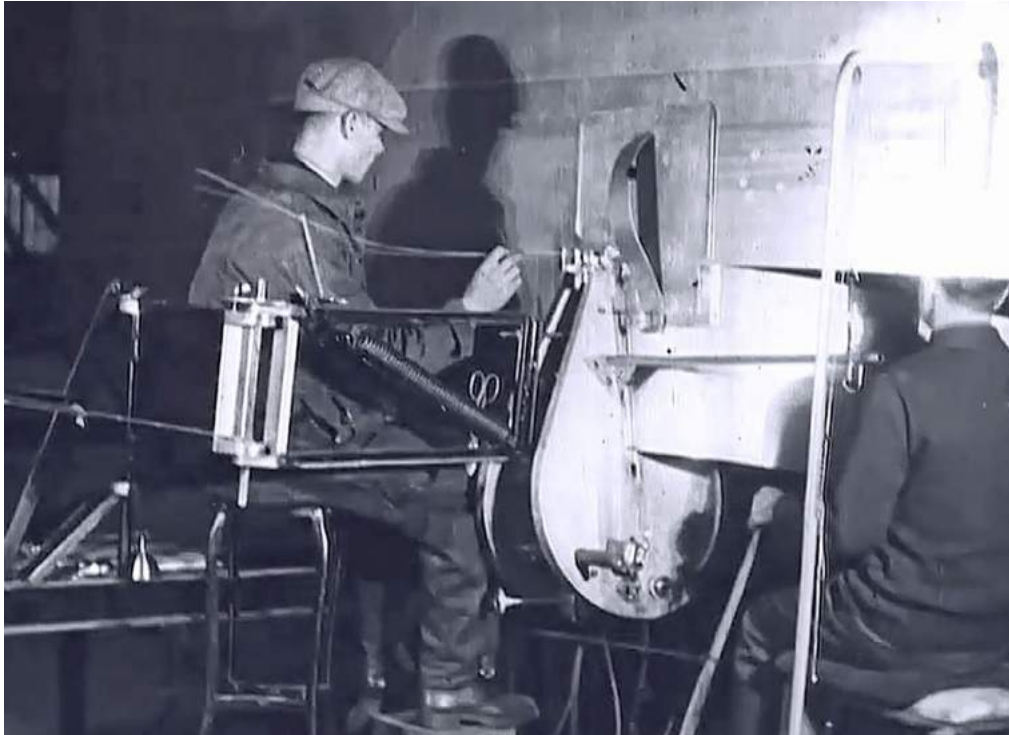
Unless otherwise noted, the following photos in this section are screenshots from a 1929 Dailymotion video on ZMC-2 construction.



*A stack of triangular section aluminum alloy ribs for the airship's lightweight structural frame.*

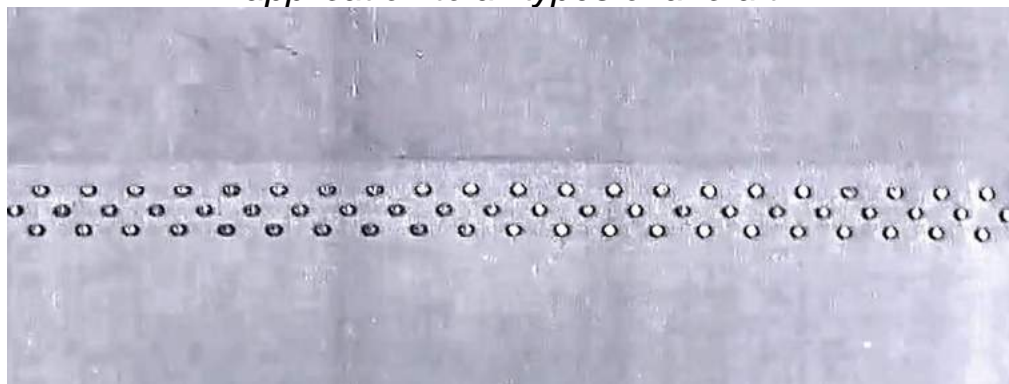


*The airship was erected vertically in two halves. More than 20 ft (6 m) of the bow had been completed with sheet duraluminum by the time the decision was made to switch to Alclad for the skin material.*

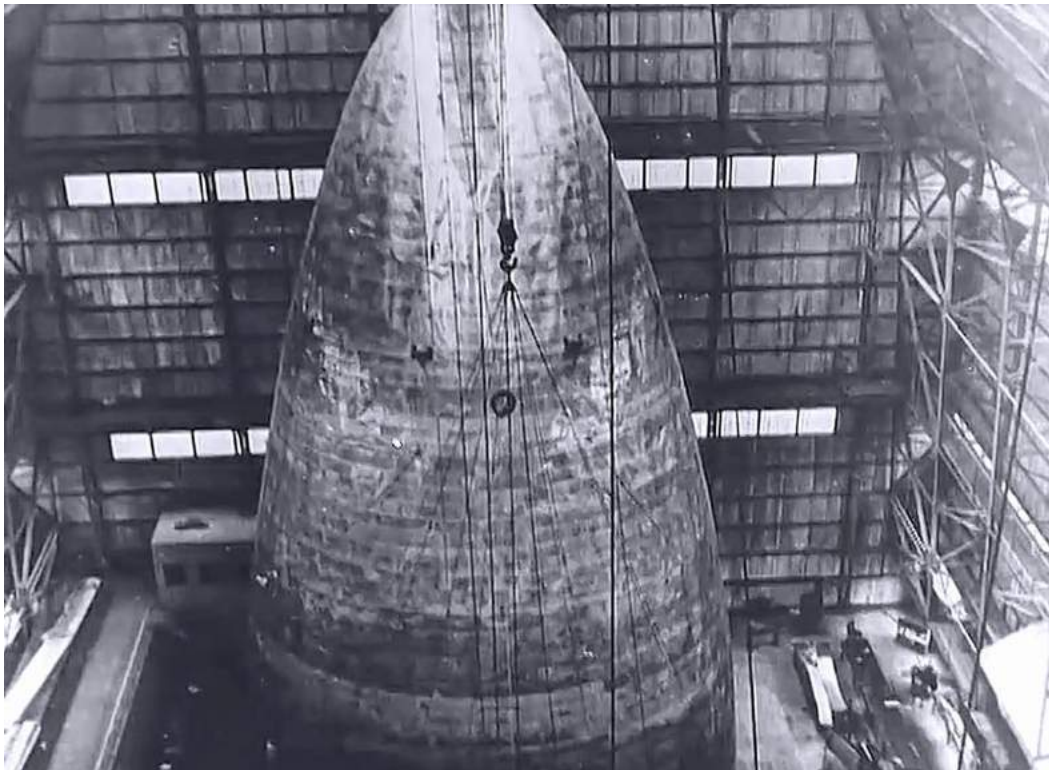


*Automatic riveting machines developed by the Detroit Aircraft Corporation joined adjacent rings of 18 inch (46 cm) wide sheet metal to form the skin of the airship over the lightweight aluminum hull framework, which established the curvature of the hull.*

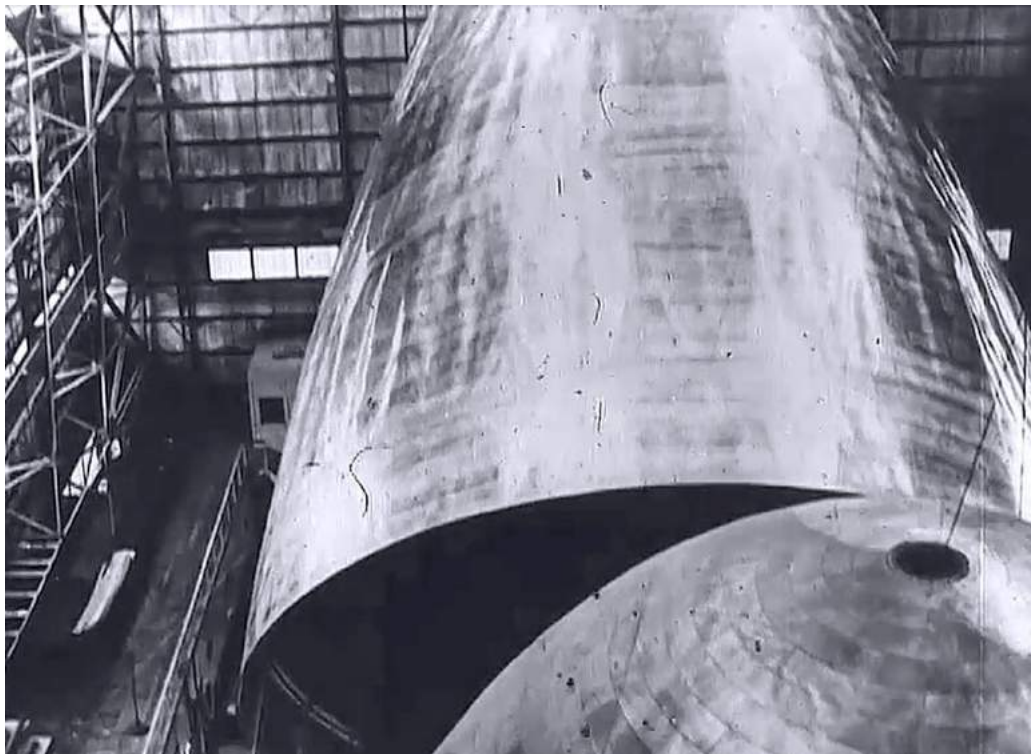
*There were 142 rings of riveted sheet metal from bow to stern. In June 1929, DAC formed Aviation Tool Company to take over and continue the development of automatic riveting machines and their application to all types of aircraft*



*Closeup of a finished riveted lap seam between two rings of Alclad skin. Since the skin contains the lifting gas (helium), the seams and riveting had to be gasproof. This was accomplished by treating the lap seam with a special bituminous material after riveting. The automatic riveting machine could place more than 5,000 rivets per hour. About 3,500,000 rivets were used in the skin of the hull.*



*Finished half section of the hull.*

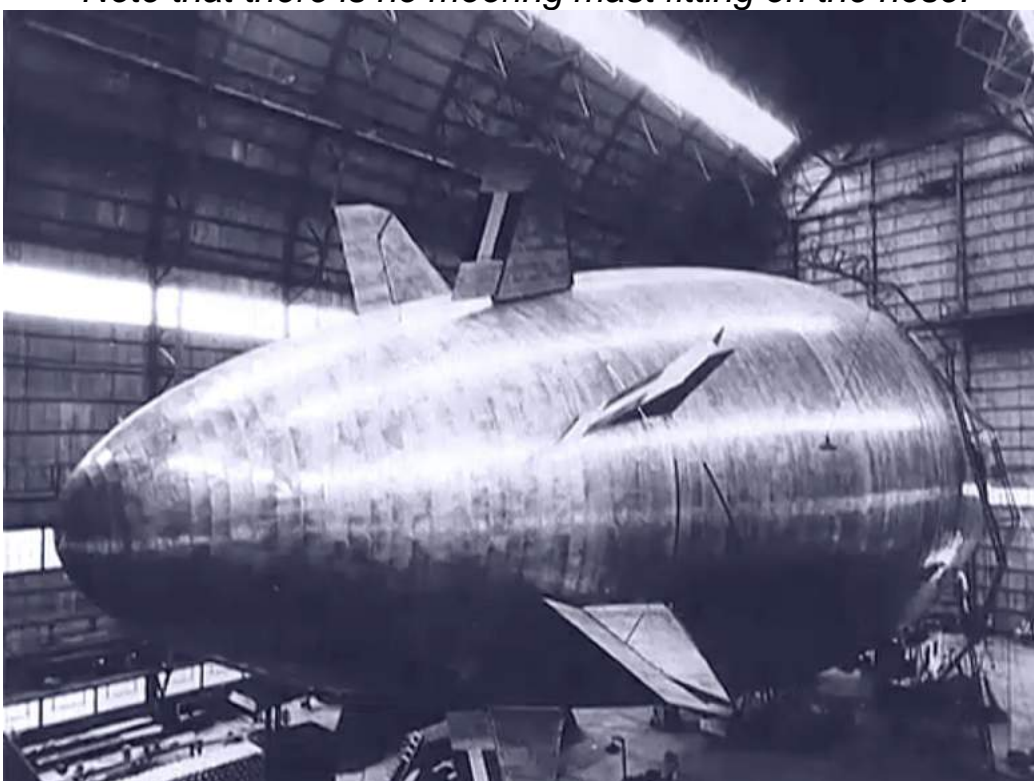


*The two halves were rotated horizontally and riveted together.*

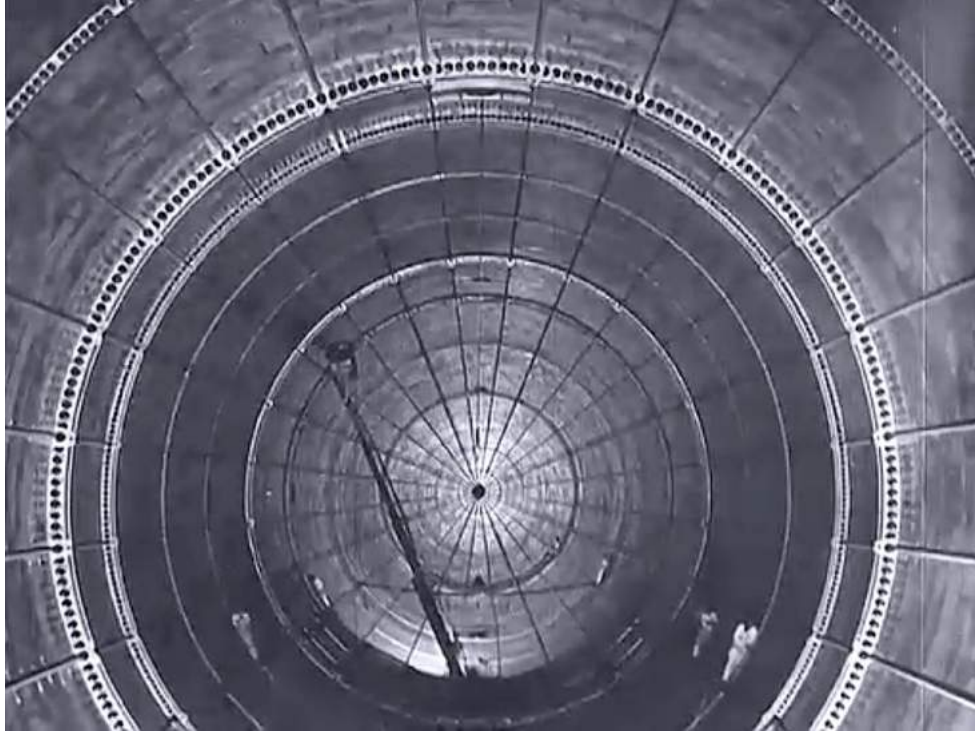




*Front view of the assembled hull, February 1929.  
Note that there is no mooring mast fitting on the nose.*



*Stern view of the assembled hull, showing multiple fins,  
all with movable control surfaces, February 1929.*



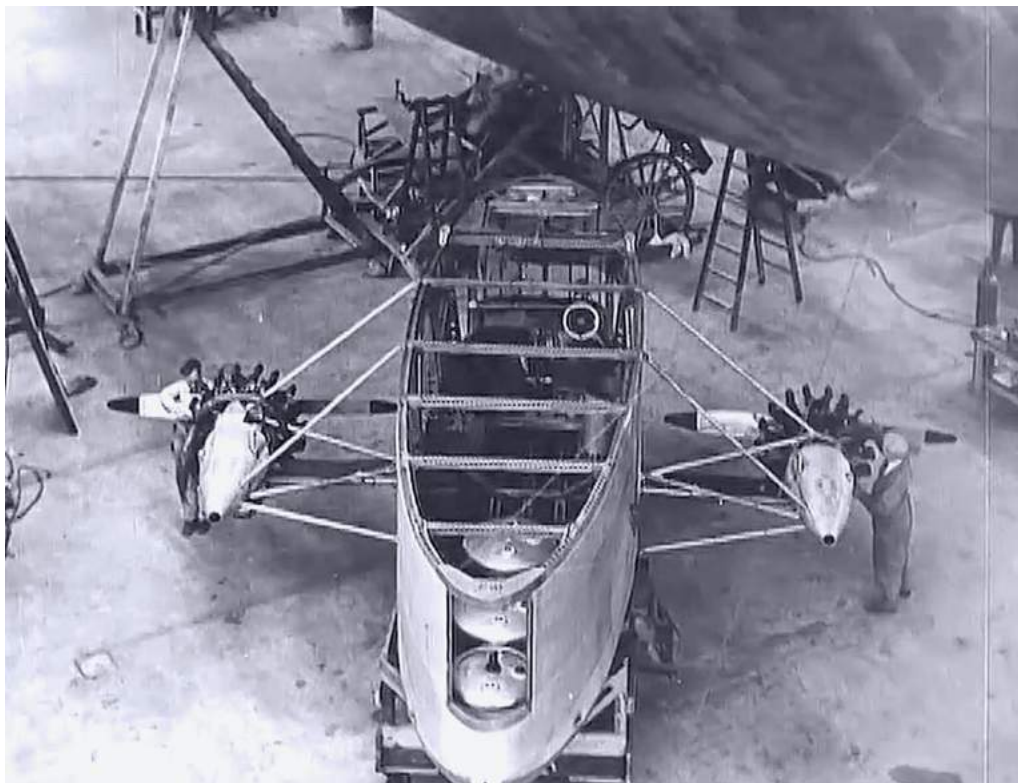
*Details of the framework inside the forward hull section.  
Note that there is no radial wiring.*



*View of the interior of the hull showing transverse hull frames,  
longitudinal longerons and strips of Alclad that are riveted together  
and fastened to the framework to form airship's monocoque  
structure and the pressure-retaining, low-leakage skin.*

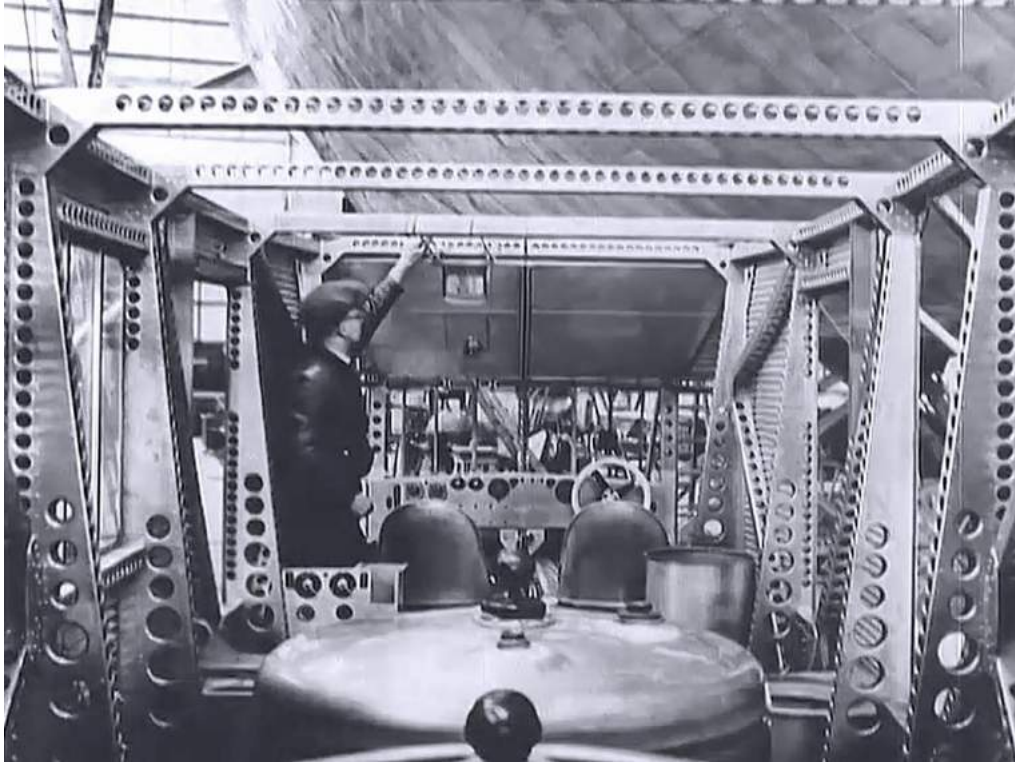


*Control car side view before installation.*

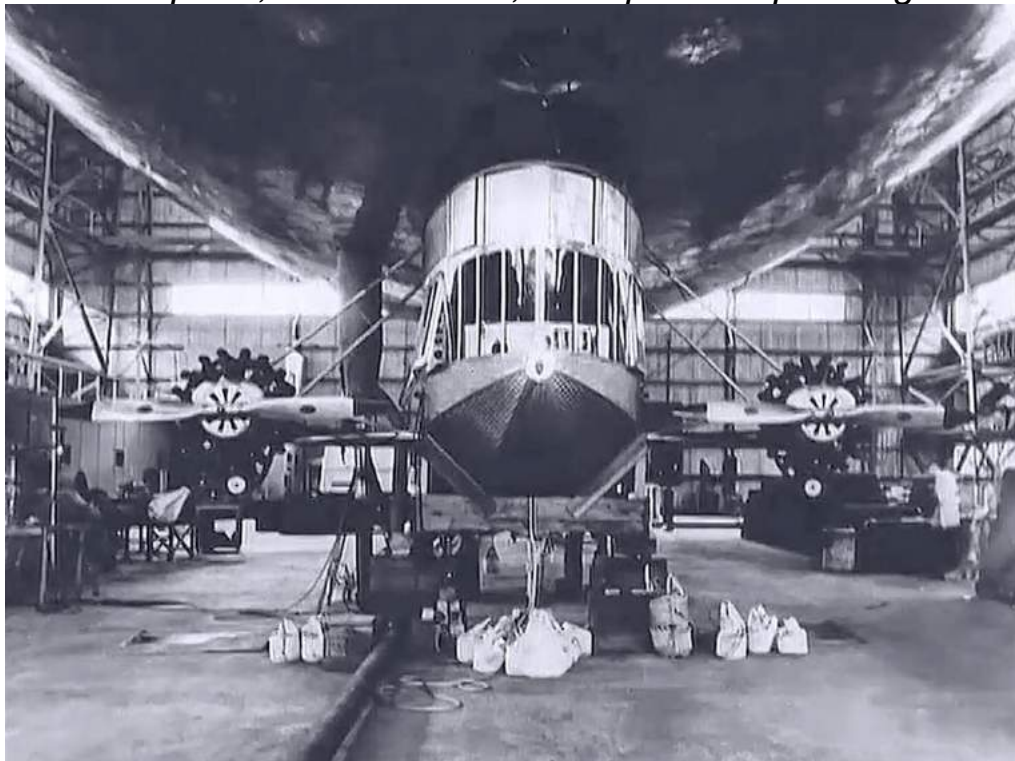


*Control car overhead view before installation.  
Note the tubular outriggers for the Wright J-5 Whirlwind engines.*



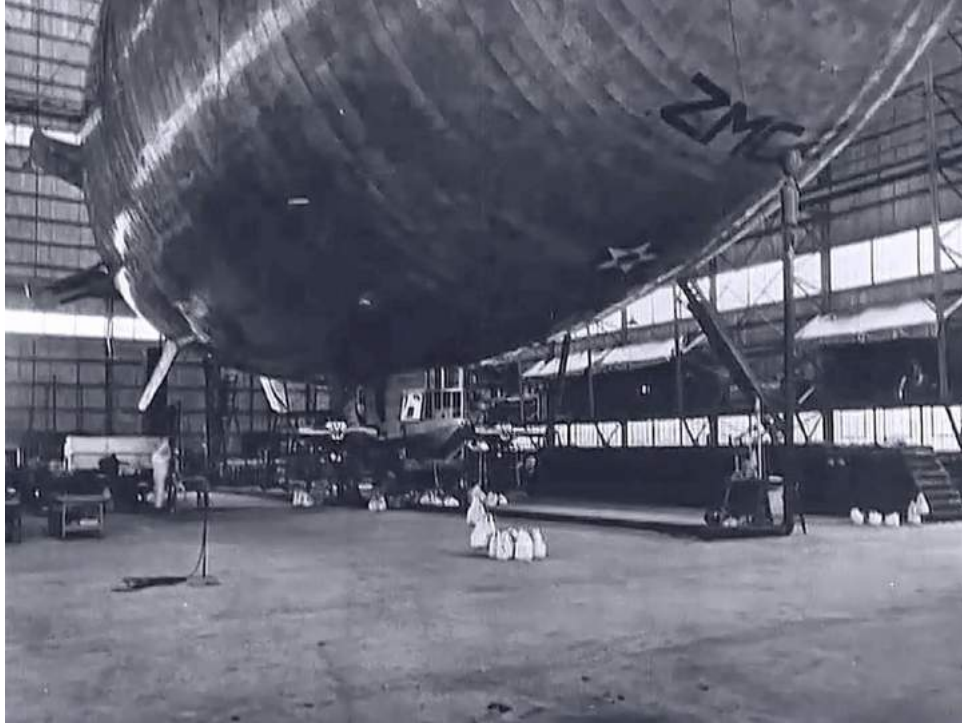


*Control car interior view. The car contains fuel tanks, control instruments, radio, blower, and chart table, and has places for two pilots, one mechanic, and up to four passengers.*



*Control car bow view, installed under the hull.*





*The completed airship was filled with helium in August 1929 by first displacing air with heavier carbon dioxide (CO<sub>2</sub>), which is easier to separate from helium than air. Once filled with CO<sub>2</sub>, the helium was pumped in through valves at the top of the hull, forcing the CO<sub>2</sub> out through valves at the bottom, and then recovering any helium that mixed with the CO<sub>2</sub>.*



*Leaving the construction hangar at Naval Air Station (NAS) Grosse Ile. Source: <http://nasgi.net/zmc2.htm>*

## 4. Operation

The airship made its first flight on 19 August 1929 and passed its final tests at Lakehurst about a month later. It logged 752 flights and 2,265 flight hours before making its last flight 10 years later on 19 August 1939.

During its service life the ZMC-2 was found to have good performance. The metalclad hull had a much lower helium diffusion rate than contemporary fabric-hulled blimps, meaning that a much longer time would pass before additional helium needed to be added to the ZMC-2. No seam leakage was recorded in 12 years.

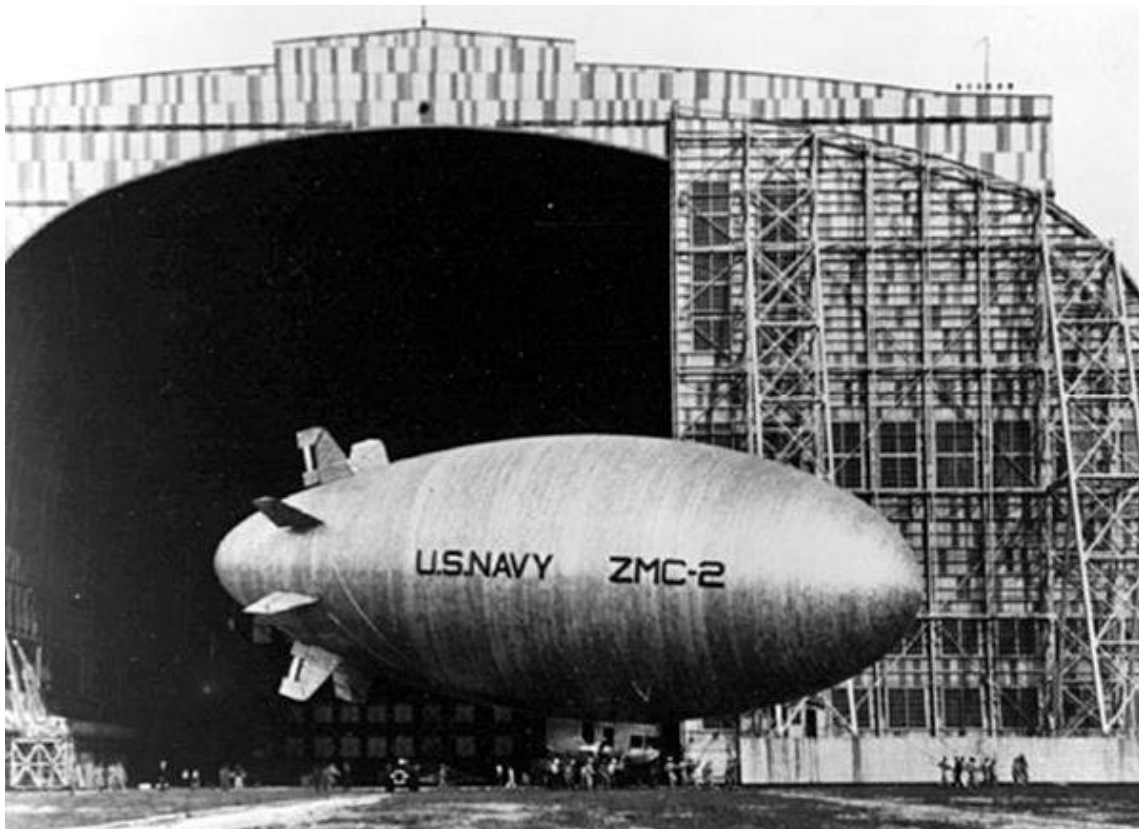
After use as a non-flying training platform, it was disassembled and scrapped in 1941. The control car, complete with engines, instruments and appurtenances were salvaged and assigned to the Lighter-Than-Air Ground School at Lakehurst.



*The ZMC-2 at Lakehurst, New Jersey with ground handling crew.*

*The ZMC-2 did not use a mooring mast.*

*Source: Ryan Crierie via blimpinfo.com*



*ZMC-2 at NAS Lakehurst.  
Source: US Navy via Encyclopedia Britannica*



*U. S. NAVY METAL-CLAD AIRSHIP, NAVAL AIR STATION, LAKEHURST, N. J.  
Source: US Navy via blimpinfo.com*



*ZMC-2 flying over Washington D.C.  
Source: US Navy via blimpinfo.com*

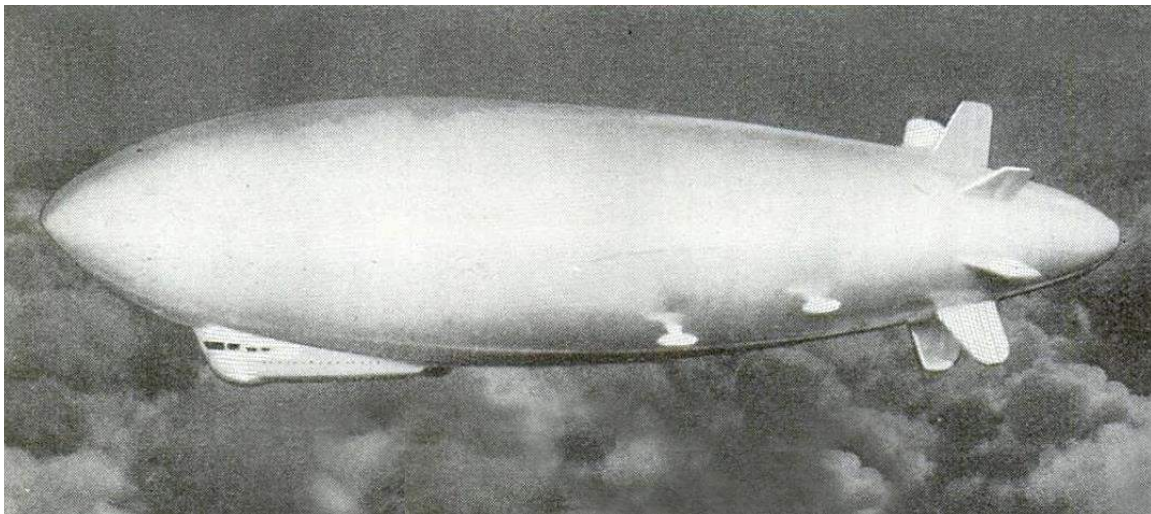


*Source: Naval History & Heritage Command*

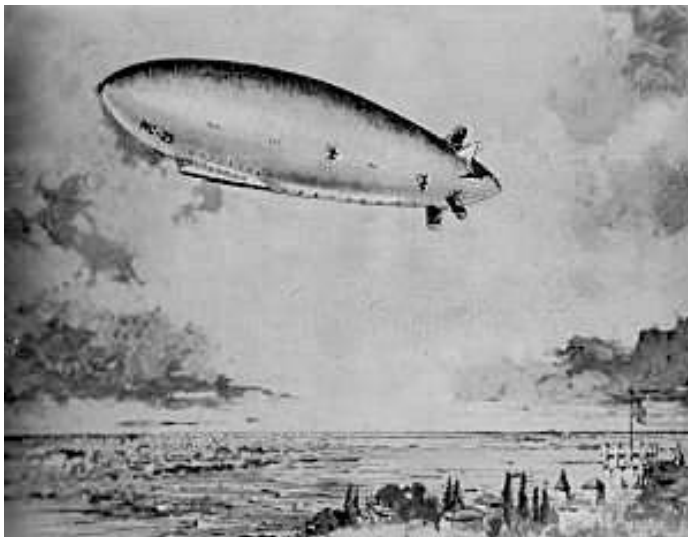


## 5. A concept for a scaled-up metalclad for the Army with a 20-ton useful load

In the year before the Great Depression, the US Army sought funding for a large metalclad airship based on the ZMC-2. It would have been larger than the German Graf Zeppelin and capable of carrying a useful load of 40,000 lb (18,144 kg). Powered by eight engines of 600 to 800 hp (450 to 600 kW), the airship would have a maximum speed of 100 mph (121 kph) when fully loaded. The airship would have a volume 40 times greater than the ZMC-2, or about 8,000,000 ft<sup>3</sup> (226,535 m<sup>3</sup>).



*Rendering of a large metalclad airship design concept based on the ZMC-2. Source: Popular Mechanics (April 1931)*



The US Army planned to use this large airship as a tender for air-launched aircraft, similar to plans the U.S. Navy had for future dirigibles (i.e., the ZRCV-class). The \$4.5 million need to construct the first Army metalclad airship was never allocated by Congress.

*MC-25 concept. Source: ZMC-2 Prospectus (1929)*

## **6. Detroit Aircraft Corporation's design for an airship terminal**

While not related to the ZMC-2, Detroit Aircraft Corporation's patent US1753592, "Airship Terminal," which was filed on 9 May 1927 and granted on 8 April 1930, illustrates that the firm had plans to play a major role in what it saw, at the time, as a growing airship industry.

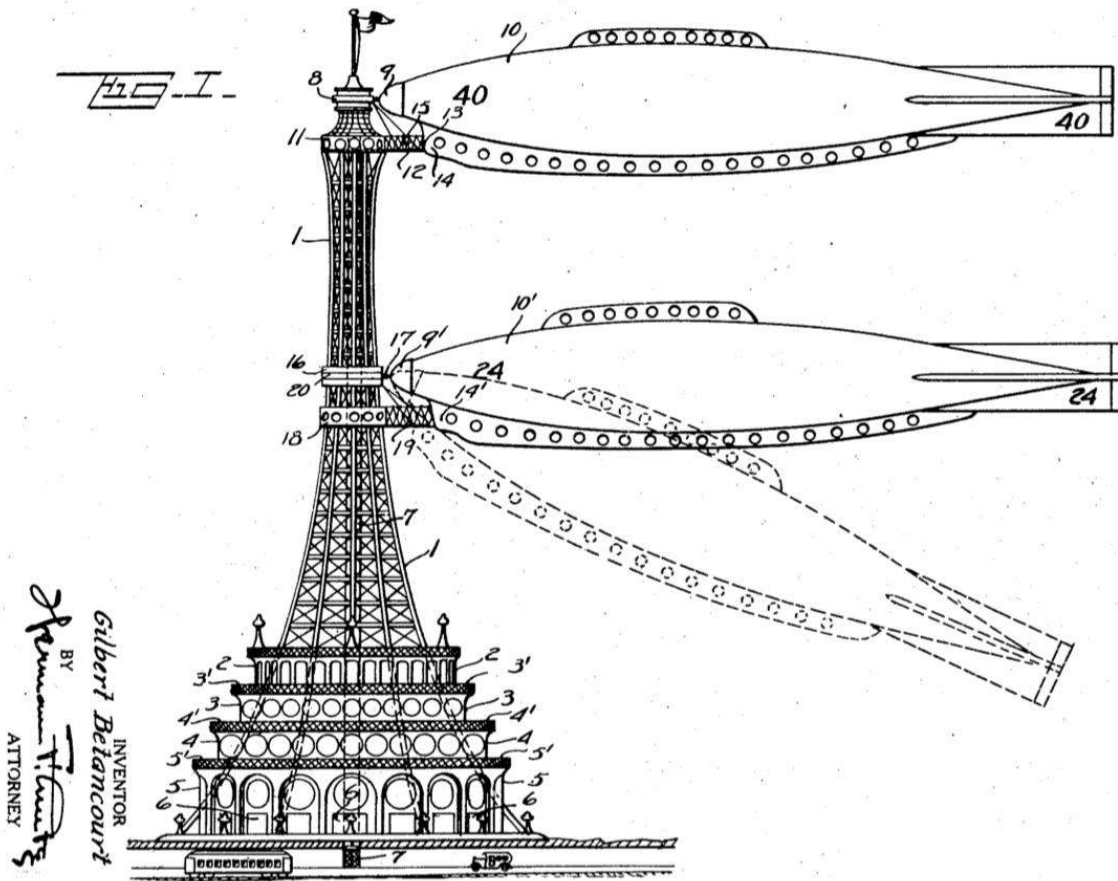
As described in the patent (in a remarkable run-on sentence), "This invention relates to an airship terminal, and among its objects are:

the provision of suitable tower to which one or more airships may be temporarily moored by the bow and permitted to swing by-the-wind,

to provide coordinated facilities to handle passengers to and from airships so moored in conjunction with land traffic bringing the passengers to the terminal, and

to provide all of the facilities necessary or desirable for the accommodation at the terminal associated with the mooring tower for passengers and terminal organization, for the most convenient handling of passengers and goods as may be required for a depot or terminal."

One embodiment is shown in patent Figure 1, which is an elevation drawing of a complete terminal and mooring tower (a monumental artistic architectural edifice) showing two moored airships. The drawing shows how one ship that may be out of trim, shown by dotted lines, is accommodated at the mooring tower.



Source: US1753592\_Fig 1

The top mooring ring structure (8) is secured and rotatable around a section of the tower and has means for permitting vertical adjustment. The ship nose mooring (9) connects the airship (10) with the rotatable and vertically adjustable mooring ring (8).

A second mooring point lower on the tower includes the rotatable mooring ring (16) with the ship nose mooring coupling (17) connecting the airships nose (9) to the mooring ring.

Connections to public transit are located at the lowest level of the airship terminal.

## 7. Epilog

The Great Depression put an end any plans the US Navy and Army had to procure additional large metalclad airships. Detroit Aircraft Corporation went into receivership in October 1931. The heavier-than-air divisions of the company were amalgamated under Lockheed, while the lighter-than-air divisions were formed into a new unit called the Metalclad Airship Corporation.

Nonetheless, the ZMC-2 is notable for establishing the following aviation milestones:

- First air vehicle to use Alclad, which remains an important material in aviation manufacturing today.
- World's first successful metalclad airship.



*US Navy ZMC-2 airship stamp,  
2017 Sierra Leone  
Source: <https://picclick.co.uk/>*

An unsuccessful contemporaneous metalclad airship was Thomas B. Slate's *City of Glendale* airship, which was built by Slate Aircraft Corporation starting in 1924. This airship was constructed with a framework of thin-wall (0.018 inch / 0.46 mm) duraluminum tubing and an outer skin of ultra-thin (0.012 inch / 0.30 mm) duraluminum sheets formed into gores with a longitudinal corrugated pattern. The airship, without a powerplant, conducted an outdoor "float test" in January 1929. With a revised powerplant, a "maiden flight" may have occurred in December 1929. Slate filed for bankruptcy in 1931 and some time that year the airship was purposely destroyed and its hangar was dismantled and recycled. You'll find a very detailed article on this metalclad airship here:

<https://welweb.org/ThenandNow/City%20of%20Glendale.html>



The ZMC-2 served as a model for the Airships International Inc. MC-7 (also designed by Vladimir Pavlecka), the Airship Industries R40/R130 and R150, and the Wren Skyships Ltd. R.30 and RS.1 metalclad airship designs in the late 1970s and early 1980s. None of these modern metalclad rigid airships were built.

## 7. For more information

- Ralph Upson, "Metalclad Rigid Airship Development," Society of Automotive Engineers (SAE) Transactions, Vol. 21, Part 1, pp. 604-670, 1926:  
[https://www.jstor.org/stable/44729851#metadata\\_info\\_tab\\_contents](https://www.jstor.org/stable/44729851#metadata_info_tab_contents)
- "The Metalclad Airship ZMC-2 [Prospectus for Investors in Dirigible Airships]," Detroit Aircraft Corp., 1929
- "Metal Covered Airship to Carry Twenty Tons," Popular Mechanics, p. 552, April 1931:  
<https://books.google.com/books?id=Y-IDAAAAMBAJ&dq=popular+mechanics+1932&pg=PA552&hl=en#v=onepage&q=popular%20mechanics%201932&f=false>
- J. Gordon Vaeth, "The Blimp Business," Flying & Popular Aviation Magazine, Vol. XXVII, No. 2, August 1940:  
[https://books.google.com/books?id=FXXkd3-oWuQC&printsec=frontcover&source=gbs\\_ge\\_summary\\_r&cad=0#v=onepage&q&f=false](https://books.google.com/books?id=FXXkd3-oWuQC&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false)
- Vladimir Pavlecka & J. Roda, "State of the art of metalclad airships," Turbomachines, Inc. paper, MIT Proc. of the Interagency Workshop on Lighter than Air Vehicles, 1 January 1975: <https://ntrs.nasa.gov/citations/19760007957>
- Walker Morrow & Carl Fritsche, "The Metalclad Airship: ZMC 2," self-published by Walker Morrow, ASIN: B009MJDHWS, 1 January 1987
- "Detroit ZMC-2," Wikipedia:  
[https://en.turkcewiki.org/wiki/Detroit\\_ZMC-2](https://en.turkcewiki.org/wiki/Detroit_ZMC-2)
- "ZMC-2: The Metal Clad Airship," BlimpInfo:  
<https://www.blimpinfo.com/wp-content/uploads/2012/08/ZMC-2-The-Metal-clad-Airship.pdf>
- "NAS Grosse Ile – Metalclad ZMC-2," 2010:  
<http://nasgi.net/zmc2.htm>

## **Videos**

- “First All Metal Airship (1929),” (1:29 min), British Pathé, 13 April 2014: <https://www.youtube.com/watch?v=hyslql7TPDE>
- “The Metalclad Airship [ZMC-2] Build by Detroit Aircraft Corporation (1929),” (16:00 min), Dailymotion via PVT.Snafu: <https://www.dailymotion.com/video/x8006yy>

## **Patents**

- DE555688C, “Riveting machine with automatic supply of the riveting material,” Filed 16 April 1926, Granted 30 July 1932, Assigned to Aircraft Development Corporation: <https://patents.google.com/patent/DE555688C/en>
- US1753592A, “Airship Terminal,” Inventor Gilbert Betancourt, Filed 9 May 1927, Granted 8 April 1930, Assigned to Aircraft Development Corporation of Detroit: <https://patents.google.com/patent/US1753592A/en>

## **Other *Modern Airships* articles**

- *Modern Airships - Part 1*: <https://lynceans.org/all-posts/modern-airships-part-1/>
  - Airship Industries - R40 / R130, R150 metalclad airships
  - Airships International Inc. - MC-7 metalclad airship
  - Wren Skyships Ltd. - R.30 & RS.1 metalclad airships
- *Modern Airships - Part 2*: <https://lynceans.org/all-posts/modern-airships-part-2/>
  - Varialift Airships Plc. - ARH-PT, ARH 50 & ARH 250 metalclad variable buoyancy airship
- *Modern Airships - Part 3*: <https://lynceans.org/all-posts/modern-airships-part-3/>