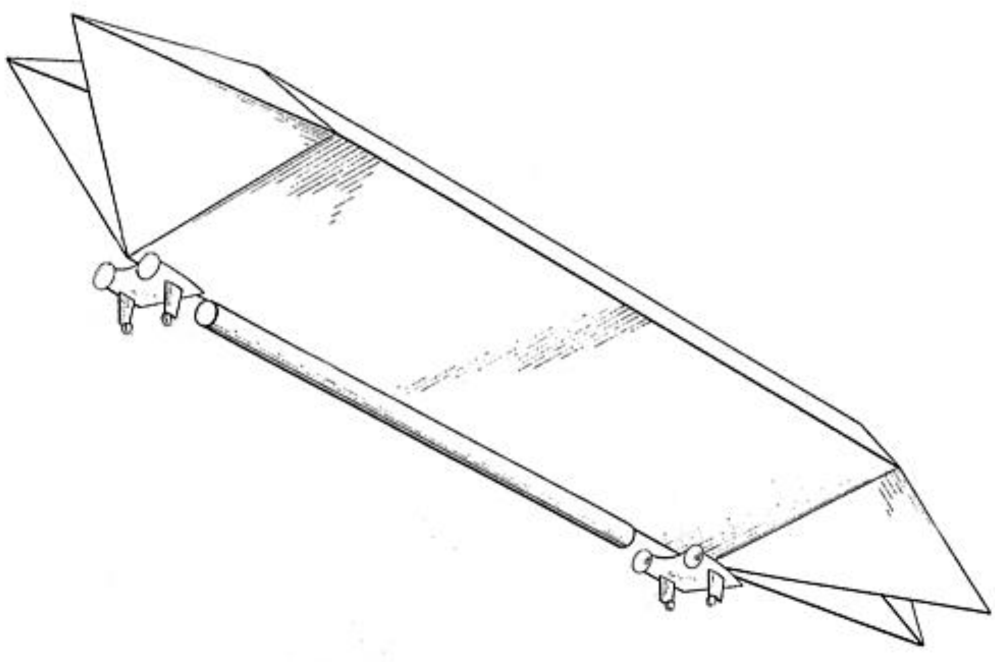
Dynapod variable volume, variable density airship

Peter Lobner, updated 10 March 2022

1. Introduction

Arthur Clyde (A.C.) Davenport invented the Dynapod and founded the firm Dynapods, Inc. in New Orleans, LA, in the mid-1970s. He defined a Dynapod as "an articulated, variable volume, variable geometry, zero differential pressure, constant surface area hull. It is a hull of square cross-section, the sides of which are hinge joined to allow the figure to vary its geometry and volume. Special pyramidal variable volume / geometry end sections complete the hull."



A Dynapod airship, stern quarter view from below (bow at right). Source: adapted from patent

He patented a design and process for operating a variable volume, variable density aircraft with a folded origami hull and a means for controlling its degree of inflation with a constant mass of working fluid that changes state between a lighter-than-air gas and a liquid to manage the average density of the working fluid and the overall buoyancy of the craft.

Davenport explained the merits of his Dynapod design over conventional, fixed volume airships:

- Always in buoyant equilibrium in flight. The airship never has to fly light or heavy and expend energy on generating negative or positive lift to maintain altitude.
- No ballast required. This significantly improves airship ton-mile efficiency.
- The displacement of the airship is always correct for its current pressure altitude. The airship is not propelling a lot of extra volume through the air when it is operating below its design pressure altitude.

In spite of these benefits, it appears that no Dynapod airships were ever built and flown.

2. The Dynapod patent

Davenport's patent is US4012016A, "Autonomous Variable Density Aircraft:"

- Filed: 15 September 1975
- Granted: 15 March 1977
- Assigned to: Dynapods, Inc.
- Available here: https://patents.google.com/patent/US4012016A/en

Patent Figure 1 is a perspective view of an autonomous variable density aircraft viewed from below the stern quarter. The bow of the airship is to the right. The airship is in the form of an articulated vessel (10) of variable configuration that is formed of relatively rigid panels joined along the edges by hinges. The hull consists of three sections: an intermediate (middle) section (12) constructed with rectangular panels, and two identical, folded bow and stern end sections (14) constructed with pyramidal panels. The long, cylindrical storage tank (26) running along the keel of the airship holds liquid used in the variable density control system. Two engine / landing gear modules (16) are located at the ends of the intermediate section.

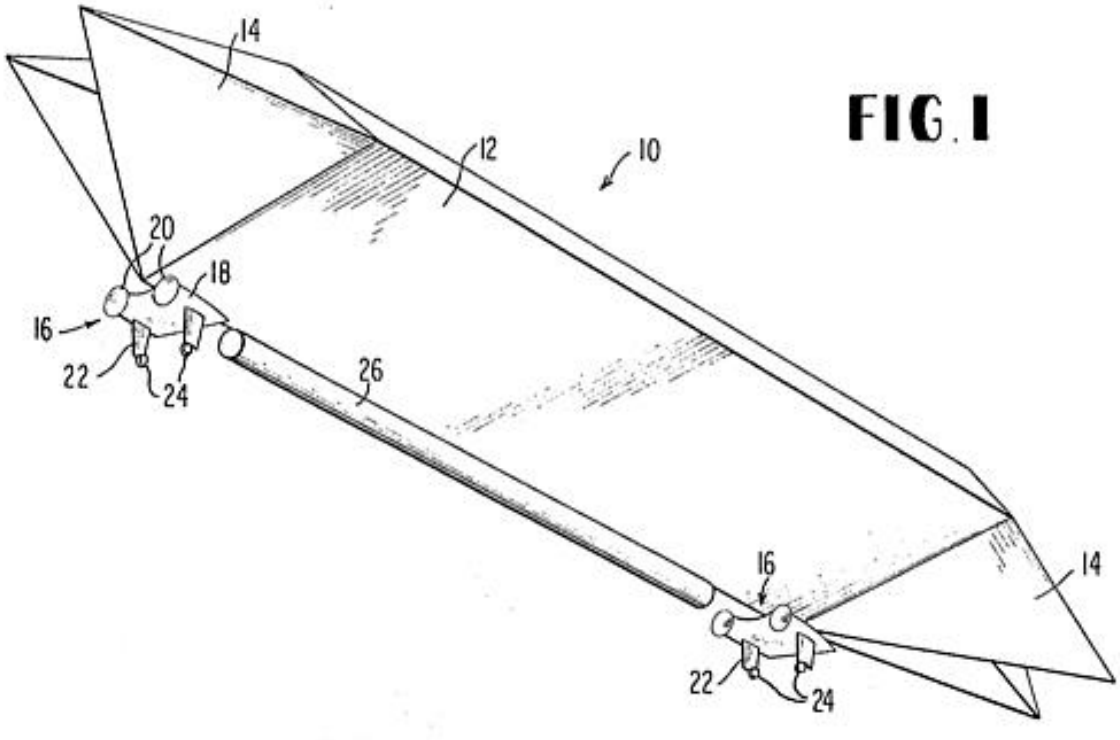
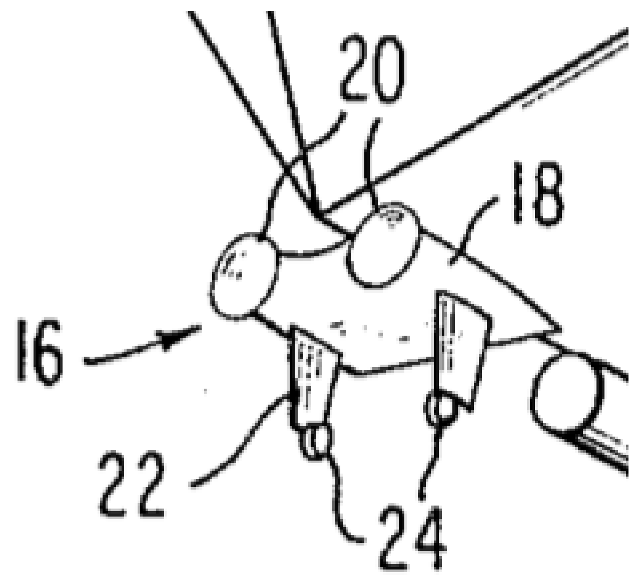


FIG. 1



The above close-up view of an engine / landing gear module (16) shows two engines (18) driving two propellers (20) on each module, which also is equipped with two landing gear (22, 24).

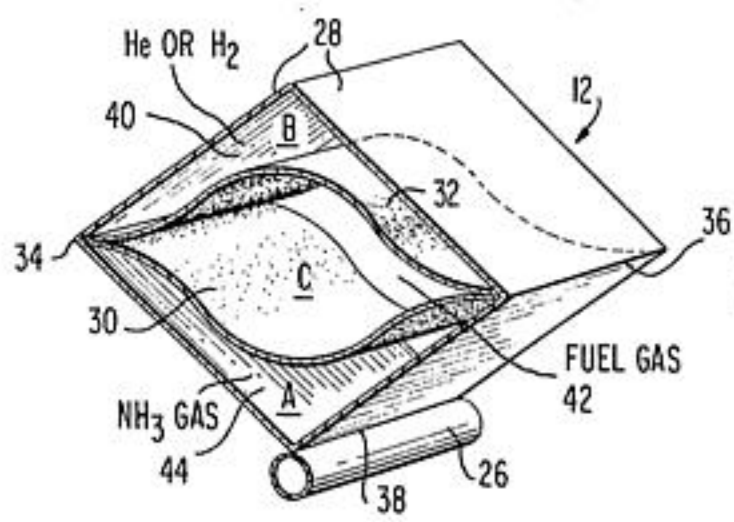
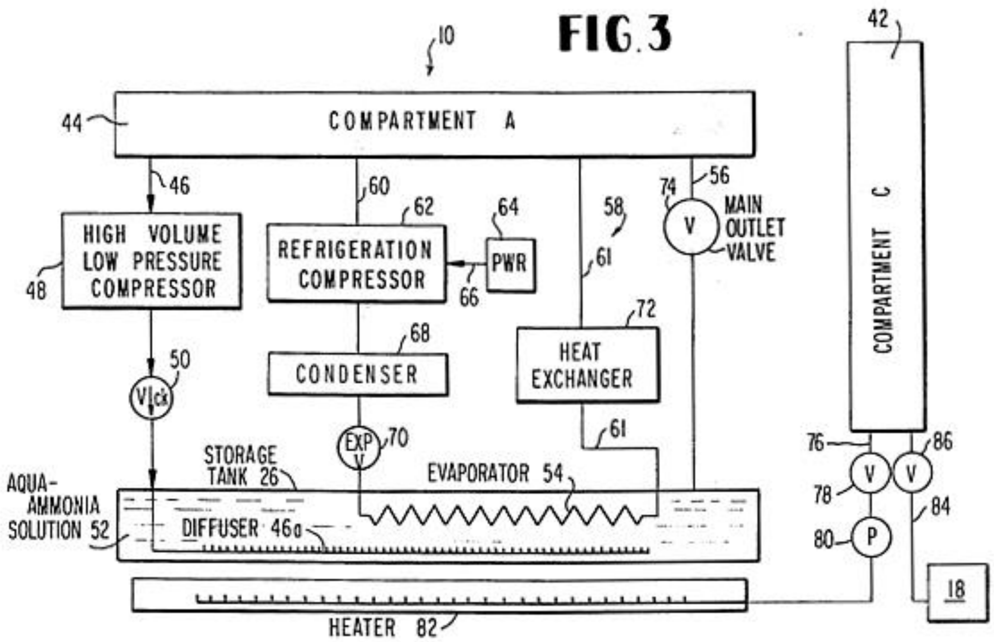


FIG 2

Patent Figure 2 shows a cross section of the intermediate (middle) section of the hull (12). The box-shaped hull is comprised of four external rigid, hinged panels (28) that can expand or contract. The interior of the hull is divided into three atmospheric pressure chambers, A, B and C by flexible, gas impervious sheets (30, 32).

- **Chamber A** carries ammonia gas, which is fed or extracted to change the density of the aircraft and its configuration, this being effected by a change in volume but without a change in mass. The increase or decrease of ammonia gas within Compartment A changes gross buoyancy of the airship, typically by enough to lift the full weight of the payload and effect the buoyancy control needed during a load exchange (pickup or drop off the payload).
- **Chamber B** carries a fixed amount of lifting gas (helium or hydrogen), typically enough to carry most of the weight of the airship, resulting in a slight negative buoyancy without any payload.
- **Chamber C** carries a hydrocarbon fuel gas having approximately the same density as air so that the weight of the vehicle will not change with fuel consumption by the propulsion engines and the heater for the variable density control system.



Patent Figure 3 shows the reversible, fluid expansion/contraction system. Gaseous ammonia exists in Compartment A. The aqua-ammonia solution in the storage tank (26) is ammonium hydroxide.

To increase volume (decrease density & increase buoyancy):

Fuel gas from Compartment C is burned by a heater (82) to heat the aqua-ammonia solution to drive out the ammonia gas, which is delivered to Compartment A via the main outlet valve (74) in line 56. Propulsion engine (18) exhaust heat can be used as the primary source of heat, with the heater (82) as a backup source.

To decrease volume (increase density & decrease buoyancy):

The high-volume, low pressure compressor (48) is started in line 46. Ammonia gas is drawn from Compartment A, delivered to the diffuser in storage tank (26) and rapidly condenses as it enters the aqua-ammonia solution and forms ammonium hydroxide.

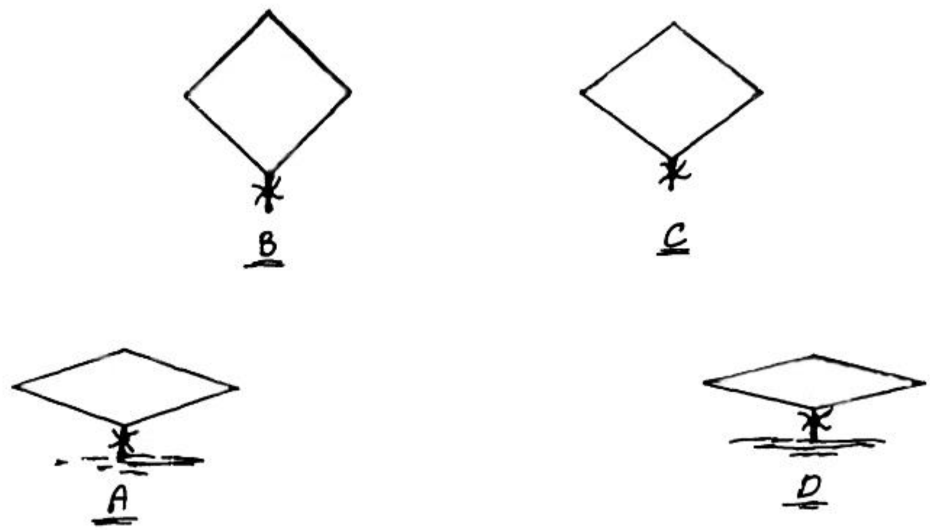
To manage the temperature of the aqua-ammonia solution:

The purpose of the closed loop ammonia refrigeration system (58) is to chill the aqua-ammonia solution within storage tank (26) to maintain a liquid temperature near 32° F, where it will absorb the maximum amount of ammonia gas possible and become ammonium hydroxide. The heat exchanger (72) is cooled by ambient air from outside the airship.

3. Operation of the Dynapod airship

The hull of the Dynapod is constructed of simple, lightweight, rigid panels that are completely articulated along the hinge lines between adjacent panels. The articulated design prevents the buildup of stress in any hull component.

A flight cycle of a Dynapod airship is shown in the following diagram and explained below, based on the patent.



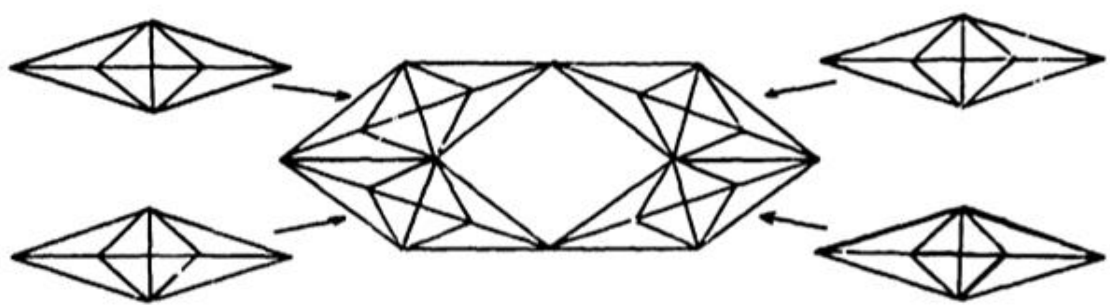
Source: adapted from A. C. Davenport, 1974

A: The vehicle is on the surface, partially inflated at slightly negative buoyancy.
B: Heat energy is added to the aqua-ammonia solution via the heater, producing ammonia gas and causing the hull to expand to its full extent. The hull displaces more air, increasing buoyancy and making the airship lighter-than-air.
C: As fuel gas is extracted from the interior of the Dynapod and consumed in flight, the hull volume contracts, thereby reducing its cross-sectional area. Since the fuel gas weight is equivalent to that of the ambient air, no change in airship density occurs. A proportional decrease in total volume and mass occurs.
D: Over the destination, the ammonia gas is discharged into the aqua-ammonia solution, rapidly condensing the ammonia and decreasing hull volume without a decrease in mass. This results in an increase in density, a decrease in buoyancy, and the vehicle settles to the surface.

In his paper, presented at the MIT Proceedings of the Interagency Workshop on Lighter than Air Vehicles in September 1974, Davenport describes the above process differently, based on just having two separate chambers inside the hull for a single-phase lifting gas (helium or hydrogen) and fuel gas, and a heating and cooling cycle. His later 1975 patent introduced the third chamber inside the hull and the use of the two-phase ammonia cycle, which provides greater volumetric expansion than just heating a single phase lifting gas.

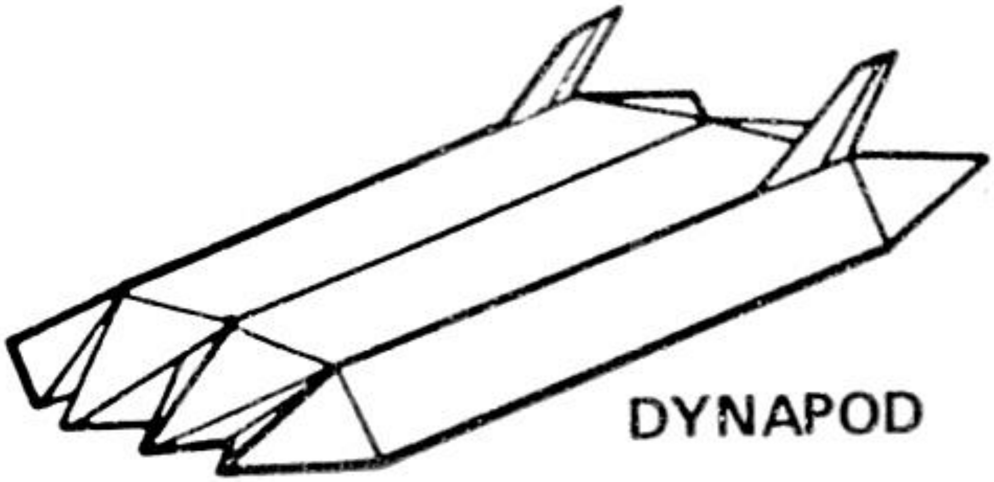
4. Dynapod clusters

A. C. Davenport proposed that individual Dynapods could be clustered to create a composite airship that could lift heavy loads.



Example of a Dynapod cluster. Source: Davenport, 1975

The 1975 NASA Feasibility of Modern Airships Phase I Study was one of the first large-scale US studies of modern airship technology, particularly for heavy lift cargo and passenger applications. The Dynapod was one of the airship concepts examined, but not selected for detailed analysis. However, the study contains the following graphic, which is a good representation of a Dynapod cluster airship.



A Dynapod cluster airship concept.
Source: NASA CR-137691, Volume 1 (1975)

5. For more information

- A. C. Davenport, "The Variable Density Aircraft Concept," conference paper from the MIT Proceedings of the Interagency Workshop on Lighter than Air Vehicles, September 1974, NASA-CR-137800, pp. 477 - 483, Doc ID 19760007968, published 31 December 1974: https://ntrs.nasa.gov/citations/19760007968
- "Feasibility Study of Modern Airships – Phase I, Volume I – Summary and Mission Analysis," NASA CR-137691, Volume I, Boeing Vertol Company, May 1975: NASA Technical Reports Server (NTRS) 19750024930: Feasibility study of modern airships, phase 1, volume 1. [structural design criteria/technology assessment

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