N76-15056

THE VARIABLE DENSITY AIRCRAFT CONCEPT

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ABSTRACT: In the variable density aircraft concept the aircraft's density is varied by varying its volume. This is accomplished by combining a variable volume hull, which I call a dynapod, with intrinsic means for the controlled variation of a mass of working fluid or substance within the aircraft. The dynapod is a hinged structure and follows the volumetric variations of the working fluid. The result is a variable density hull, which with the attachment of power plants, etc., becomes a variable density aircraft.

THE AIRSHIP'S DILEMMA

Its fixed mass concept is the airship's dilemma. Part of the concept of airships is fixed geometry and weight maintenance through the use of ballast. This fixed mass concept is illustrated by: 1) U.S. airships using the water recovered from engine exhaust gases to replace the weight of consumed fuel; and 2) German airships using gaseous fuel whose consumption had little effect on the weight of the airship as its own weight was very near that of the air by which it was replaced. These systems were developed in an effort to provide a means of maintaining a selected density altitude. Let us review the operational penalties of the fixed mass concept.

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Operational Penalties of the Fixed Mass Concept

Inertial - The greater the mass accelerated the greater the energy required. In the above examples energy is wasted in the acceleration, positive and negative, of ballast. Ballast is weight carried only for the sake of its own weight. The magnitude of this penalty is indicated by the realization that an airship developing 5,000 hp and having a specific fuel consumption of .6 lbs/hp/hr will consume 72,000 lbs of fuel in 24 hours. The replacement of the weight of this consumed fuel, whether by air or water, means that the airship, in a 24 hour flight, will carry an average excess load of 36,000 lbs. At any reasonable speed this translates into a lot of ton miles of useless effort. Fixed mass airships do not, as do other aircraft, benefit from reduced load operations.

Dynamic - Floating objects are in buoyant equilibrium. They float only when they are displacing that amount of the surrounding fluid exactly equal to their own weight. Floating objects require substantially less power to propel horizontally than do super- or subbuoyant objects because no energy is wasted in the production of positive or negative lift. Fixed mass airships, because of the difficulty of maintaining buoyant equilibrium, routinely fly "heavy" or "light" thereby wasting energy in aerodynamic lift production.

Volumetric - The amount of energy required to propel a floating object through the air is largely due to its size and shape. The size and shape of the object govern its displacement. Heavy floating objects require more energy to propel them, not only because of their inertia, but also because they displace more of the surrounding air than do lighter floating objects.

The displacement of airships is also affected by the geography of the earth which requires that long range aircraft be capable of rising above mountain ranges or rising above most of their area and circumnavigating the rest. This practical requirement means that an airship has to be designed to operate at reasonable altitudes. If an airship's "pressure" altitude is 10,000 feet, for example, the LTA gas which it contained at sea level will have expanded 35% when the airship reaches its pressure altitude under standard temperature and pressure lapse rates. Airships are designed and built oversized to accommodate for this expansion. Airships normally fly at much lower levels, 3,000 feet or below, where the expansion of the LTA gas is 9% or less, and routinely pay a 26 to 32% excess volume tribute to the fixed mass concept.

In the operational modes the fixed mass concept wastes energy as it requires the lifting, acceleration and steady state propulsion of hulls whose weights and displacements are excessive because they carry such large amounts of ballast. The fixed mass concept is in diametric opposition to the purpose for which the airship was conceived.

THE VARIABLE DENSITY AIRCRAFT'S SOLUTION

The variable density aircraft solves the airship's dilemma by combining a dynapod with an intrinsic means for its expansion and contraction.

What is a Dynapod?

A dynapod is 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 pyramidic variable volume/geometry end sections complete the hull.

Since the dynapod can follow the volumetric variations of a working fluid the density of the assembly, that is the dynapod and the equipment attached thereto, can be controlled by varying the volume of the contained working fluid. By attaching the apparatus of propelled flight such a variable density hull becomes a variable density aircraft.

Expansion and Contraction

The volume of the contained working fluid is controlled by the addition and subtraction of the "wasted energy", heat, of the exhaust gases of the power plants. The expansion rate provided by this basic system can be augmented by auxiliary burners or other means when desirable. The addition and subtraction of heat in the basic system is through a heat exchanger of conventional design.

A single power plant, such as a UAC PT-6 developing 900 shp, has a mass air flow of 6.5 lbs/second. This air becomes part of the combustion products when burned with the fuel. These combustion products, as gases and vapors, are exhausted at a temperature of 613 degrees C. By transferring this heat into the working fluid via a heat exchange system it can be made to perform a useful service in the variable density aircraft by providing a substantial part of the energy needed to lift and carry loads. When heat extraction from the working fluid is desired the exhaust gases are diverted to the atmosphere and ambient air is channeled through the heat exchanger.

Intrinsic Expansion - The intrinsic expansion of the working fluid results in an 100% gain of the weight of the displaced air as useful lift. Father Francesco de Lana, in the 17th century, conceived the idea of using evacuated metal spheres to produce aerostatic lift. Only a weightless sphere containing a perfect vacuum could match the performance of intrinsic expansion as employed in the variable density aircraft concept.

DESIGN CONSIDERATIONS

Since the heat input required to expand the variable density aircraft from a semi-buoyant to a buoyant state depends upon the density differential of the two states, it is best to design the aircraft so that it is only slightly heavier than air in its minimum operational configuration. A slight increase in the temperature of the working fluid over ambient temperature will then result in positive buoyancy.

Effective control of the heat level of the working fluid requires control of the heat transfer from the hull. The use of low heat transfer materials and lightweight insulation in the construction of the hull establishes this control.

Major cost factors in the transportation of an object are the initial fabrication and routine maintenance costs of the carrier. These factors are elevated by design complexity. The design simplicity of the dynapod allows minimum facility, engineering, fabrication, and maintenance costs. No oversized, unorthodox buildings are required in their fabrication. Production in meaningful quantities can be economically achieved. The zero differential pressure feature of the dynapod allows the use of lightweight materials without substructure as the contents of the hull support the panels used in its construction. Since the dynapod is completely articulated, stresses are dissipated through out the hull as soon as they are applied.

A SIMULATED FLIGHT

Figure 1 on page 5 shows a cross section of the dynapod hull, the four panels of which are indicated by p. The flexible diaphragm, d, in the interior of the hull separates the fuel, f, from the LTA gas, g. The fuel gas, following the German system of using Blau gas, has a density equivalent to that of the surrounding air. The temperature of the LTA gas, g, is controlled by channeling either exhaust gases from the power plant, P, or air through the heat exchanger, h.

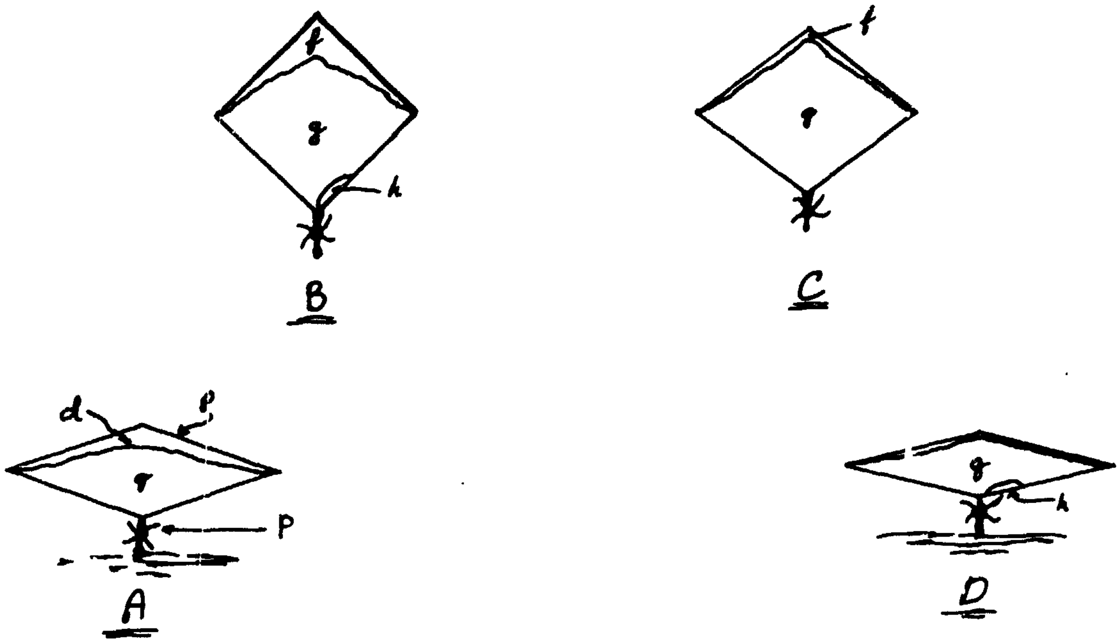

Figure 1
Cycle of Operation

A - The vehicle is on the surface in neutral buoyancy.
B - Heat energy has been added, via the heat exchanger, h, to the LTA gas, g, causing it to expand. As the dynapod expanded concurrently it displaced more air and the vehicle became LTA.
C - As fuel is consumed in flight the extraction of the fuel from the interior of the dynapod causes it to contract thereby reducing its volume and frontal area. As the fuel weight is equivalent to that of the air no change in density occurs. A proportional change in total volume and mass occurs.
D - Over destination heat energy is extracted from the LTA gas, g, by channeling ambient air through the heat exchanger, h. This decrease in volume without a decrease in mass results in an increase in the density of the vehicle and it settles to the surface.

VERSATILITY

Vehicle vs Load Size - A major factor in determining the cost of transporting an object is how well the carrier is matched to the load. Dynapods are clusterable and can be matched to exceptionally large or heavy loads without paying the penalty of exceptional load capability when carrying routine loads. Two different ways to cluster four dynapods are shown in Figure 2. More dynapods can be added to these.

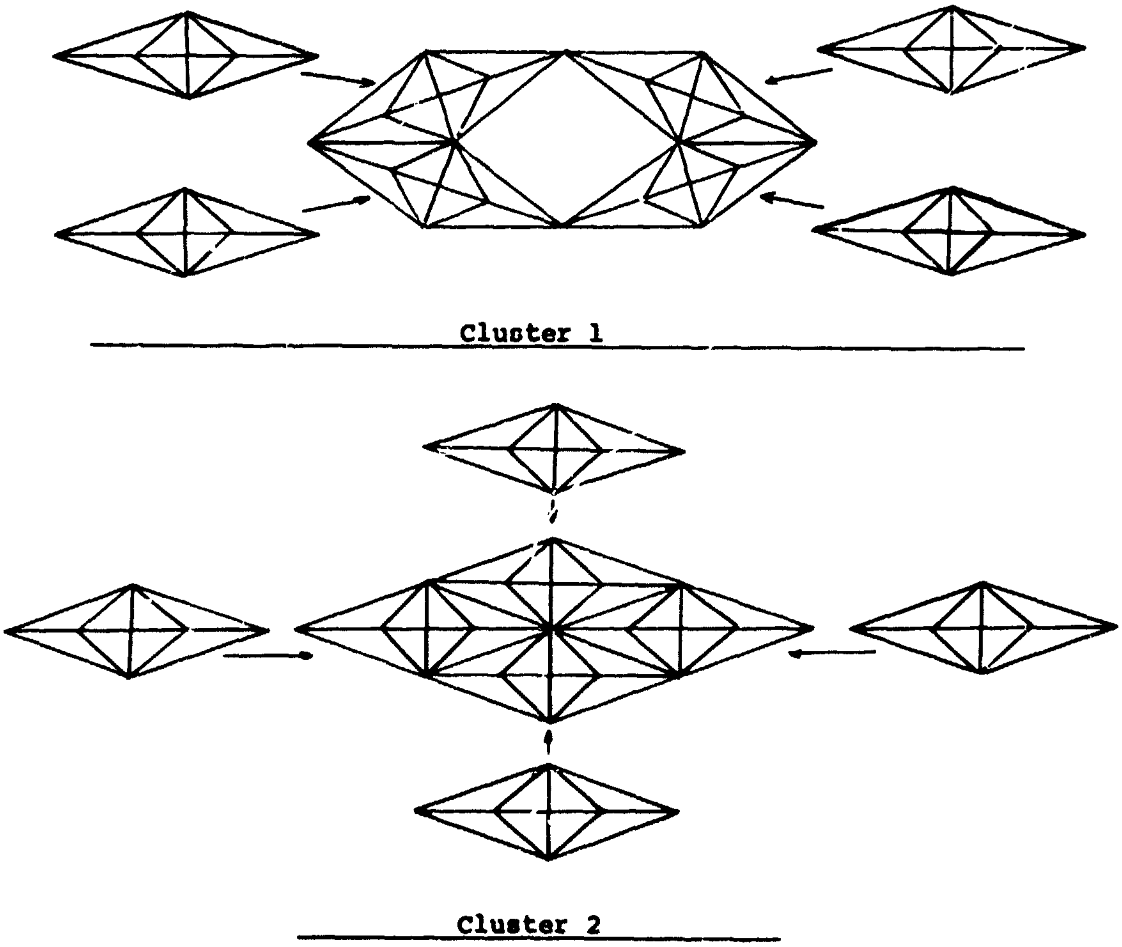

Figure 2
Clusterability

Low Profile - In the semi-buoyant configuration dynapods are relatively low in profile and are therefore less affected by gusts and wind changes. This assures easier ground movement and handling operations. When not in use dynapods are collapsible providing near perfect compact storage.

WHY A VARIABLE DENSITY AIRCRAFT?

Because it is a simplified, energy conserving transportation system. Practically all of mankind lives within that narrow band of air between sea level and 10,000 feet. The key factor in man's success as a species has been his ability to transport himself and his goods within that limited space. Transportation is movement, movement requires energy, and man today, because of his dependence on depletable energy sources, is suffering from an energy crisis. Stagnation is not the answer. It is not even an acceptable intermediate solution. We must develop energy conserving transportation systems to use until science can introduce non-depletable energy sources.

It is axiomatic that the more complex the system the more energy required in its operation. Complexity is introduced into surface transportation systems by the size and weight restrictions imposed by tunnels, bridges, transfer steps between terrain and water systems, etc. The use of our air ocean removes all of these restrictions provided that the same vehicle used to pick up a load at point of origin can also deliver it non-stop to its final destination. This implies a vehicle that can hold position over a load and pick it up or take off and land vertically with a load and carry that load long distances. The vehicle that can do these things economically and with minimal adverse ecological effect will serve man well. That vehicle is the variable density aircraft.