REVERSIBLE FLUID BALLOON ALTITUDE CONTROL CONCEPTS

Jack A. Jones
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California, 91109

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A number of novel balloon altitude control concepts have recently been developed at the NASA Jet Propulsion Laboratory (JPL), California Institute of Technology. These concepts allow balloon systems to use the temperature differences in an atmosphere to provide the power to greatly change balloon altitudes, and even to repeatedly land. Two concepts involve the reversible chemisorption of the lighter than air compounds of ammonia and hydrogen. At low, warmer altitudes, these compounds dissociate, thus releasing the buoyant gases and causing the balloon to rise. At higher, cooler altitudes, the compounds re-combine, thus deflating the balloon and causing the balloon to descend.

Another concept is to use a fluid that evaporates at lower, warm altitudes and condenses at cooler, high altitudes. In the earth's temperate atmosphere, all single fluids that have appropriate boiling points are heavier than air, and thus an additional, lighter-than-air balloon is required. In the first test of this concept, a primary helium balloon provided buoyancy for a secondary balloon containing a heavy Freon refrigerant 114 (R114). On the ground, the R114 was a gas, and displaced air, thus creating a slight positive net buoyancy of the two balloon systems. When the double balloon system reached an altitude of about 7 km (23,000 feet), the R114 began to condense, thus decreasing the volume of the R114 balloon and decreasing lift. At about 9 km (30,000 feet), the double balloon system attained a slight negative buoyancy and beganto fall, while still condensing more R114. Evaporation of the R114 began when the balloon system passed below 6 km (20,000 feet), and eventually reached 5 km (16,500 feet) before a slight positive buoyancy was again attained, causing the balloon system to rise. The earth's atmosphere was thus used as a giant heat engine to provide nearly five full cycles of climb and descent over a fourteen hour period, until communication was lost with the balloon at a distance of over 200 miles from the original launch site.

An alternate version of this reversible fluid altitude control technique can also be used to provide bobbing or repeated landings in a planet's atmosphere. Instead of a double balloon system, as was tested at JPL, a single balloon system could be used that contains two fluids, one that condenses andone that does not. For this system, the primary consideration is the <u>partial</u> pressure of the condensable fluid relative to its saturation (condensation) pressure at any given temperature.

There are also a number of altitude control techniques. For the JPL test, the altitude control was passive, or in effect, un-controlled. The condensed liquid would fall into a heat exchanger and would automatically be evaporated

when an appropriate lower, warmer altitude was reached. If the liquid is condensed and then trapped by shutting a valve, the balloon system would continue to descend and even land, until the valve is opened, allowing evaporation to occur and re-ascension of the balloon. An alternate buoyancy control technique is to have a wicking material on the sides of the condensing balloon. This eliminates the need for an enhanced heat exchanger to accelerate evaporation.

Possible applications of this novel balloon altitude control technique are for earth weather forecasting and environmental studies, as well as for surveillance and intelligence gathering. In regard to planetary studies, these concepts create an entirely new class of spacecraft that can provide long-life, multi-altitude atmospheric studies and even multiple planetary landings. Plans are presently underway to design a mission to Venus that will allow multiple daily landings on the hot Venus surface (460°C, 93 atm pressure) with subsequent swift climbs to higher, cooler altitudes of about 56 kmwhere the temperature is 18°C and the pressure is 0.44 atm. The higher altitudes then allow instrument cooling and data transmission to earth. Similar atmospheric bobbing scenarios are being considered using various condensing fluids for the outer giant gas planets of Jupiter, Saturn, Uranus and Neptune, and a multiple landing balloon system is being considered for Saturn's moon, Titan, which has a thick nitrogen atmosphere.