Eversphere™ Glass Balloons for Scientific, Military, and Commercial Applications

Entry for “Strength in Glass Contest”

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INTRODUCTION

The need for faster communication, faster travel, and better understanding of the whole Earth environment has driven scientists upward through the atmosphere in search of data to meet these needs. Low Earth orbit satellites and suborbital flights provide data on the Earth’s atmosphere beyond 200 km. Lower than this height the majority of the data collected comes from weather balloons, which have been in use for almost 80 years. These balloons are made of a highly flexible latex material to allow for expansion as the balloon rises. These polymer-based materials however suffer from UV degradation, ozone attack, and overexpansion at high altitudes that leads to a limited useful life. A balloon made of UV/ozone resistant material that retains its shape at all altitudes would allow for semi-permanent “flight”. High-strength glass has sufficient strength-to-weight ratio and chemical inertness to manufacture permanent balloons. This type of balloon would allow for placement of scientific monitoring apparatus at permanent levels in the atmosphere. Continuous data collection of atmospheric conditions would be valuable in hypersonic flight design, greenhouse gas (i.e. CO_2/CH_4) and ozone depleting chemical (i.e. CFC) concentration measurement. Also permanent balloons could serve as receiver/transmitter stations for communications purposes and would be significantly less costly compared to satellite build and placement by rocket launch.

BACKGROUND AND PURPOSE

High-altitude balloons are normally filled with hydrogen or helium gas. The ascent rate is controlled by the amount of gas filling the balloon prior to launch. High-altitude balloons may reach altitudes of 40 km (25 miles) or more, limited by diminishing pressures causing the balloon to expand to such a degree (typically by a 100:1 factor) that it disintegrates, upon which the instrument package it carries is usually lost or dropped[1]. Polymer based balloons cannot be placed at permanent levels because they expand and contract with temperature and pressure in the atmosphere. A land-based tether is required to locate them in permanent positions, which is impractical above a few hundred feet. One current idea proposes the use of cell phone balloons in remote areas which are less costly than permanent relay towers. The balloons must be permanently refreshed however because as they rise and expand they eventually burst.

Balloons made with high-strength glass can be made in permanent spherical shape which does not change with atmospheric temperature or pressure. Glass balloons are evacuated instead of filling with hydrogen or helium. Where latex balloons suffer from expansion as they rise due to less external pressure allowing the internal hydrogen increase in volume, glass balloons contain an internal vacuum which is not expansion susceptible to external pressure changes. Glass balloons are under constant compressive force, which is highest at sea level, thus are less susceptible to forces from atmospheric pressure as they rise. With an engineered volume and weight, glass balloons can be designed to rise to a specific altitude whereby they float in permanent position.

Another advantage of glass balloons is their chemical inertness. Polymer based balloons decompose from UV radiation, ozone attack, and cold temperature embrittlement. All of these factors increase with altitude. Multicomponent silicate based glass however is nearly inert to UV or ozone corrosion, and the mechanical properties are unaffected by temperatures experienced through the mesosphere.

The uses for permanent glass balloons fall into multiple categories.

- Scientific: Glass balloons stationed at permanent altitudes to collect atmospheric chemical composition and temperature for monitoring of greenhouse gases, ozone depleting chemicals, and components that affect hypersonic plane design. Also equipment could be placed to collect non-terrestrial subatomic particles (i.e. neutrinos) that are filtered by our atmosphere.
- Military: Small receiver/transmitter devices could be floated into place for deployment of localized communications control. Remote sites that offer difficulty for satellite base communications (i.e. valleys) could be connected to the communications network through localized floating stations. In addition due to the optical transparency of glass these stations could be made for stealth use.
- Commercial: The primary commercial application would be permanent communications stations. These stations could be placed at much higher altitudes than steel towers, thus provide a much wider range of operation at a significantly lower cost. Commercial stations for weather monitoring would also possible. A novelty use for glass balloons would be floating Christmas ornaments. Whereby standard thin glass ornaments decorate Christmas trees by hanging from the branches, glass balloons could be made to float from the tree branches (using helium gas). Floating glass ornaments are puncture resistant from the tree needles and leak resistant from helium gas, thus could be stored for annual use.

PROPOSED IDEA

The advent of high-strength glass allows for the manufacture of vacuum-based thin-wall glass spheres that could serve as permanent balloons. In comparison to titanium, a normal aerospace manufacturing material, high-strength silicate based glass has 40-50% less density with a higher failure stress (3.5 GPa). The strength-to-weight ratio of new high-strength glass is advantageous to manufacture thin-wall spheres, that when evacuated can obtain neutral buoyancy.

The glass balloon size can be calculated based on the atmospheric pressure and glass properties. Figure 1 shows the variation in atmospheric pressure with altitude up to 100 km[2]. The maximum differential pressure (atmospheric pressure – balloon internal pressure) occurs at sea level. At sea level ΔP is approximately 1 atm (101325 kPa), which decreases by five orders of magnitude to 0.00001 atm (1.0 Pa) at 100 km altitude.

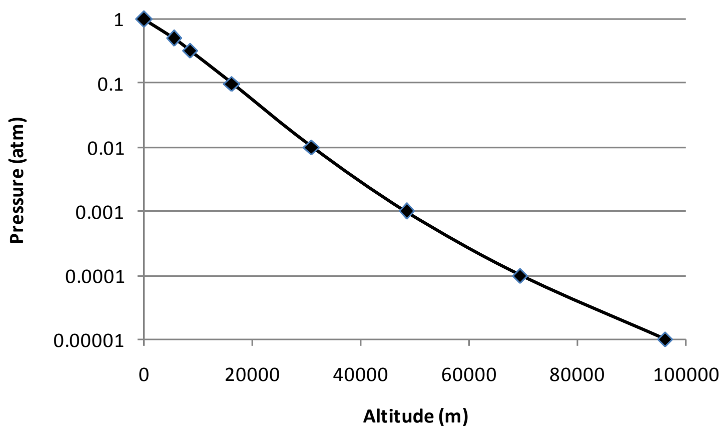

Figure 1. Atmospheric pressure variation with altitude.

The glass is estimated to have a compressive strength of 3.5 GPa and density of 2650 kg/m³. The wall thickness for a sphere under vacuum can be calculated from pressure vessel mechanics[3]. The sphere volume can be calculated from the diameter and the total weight from the wall thickness and material density (assume 99% effective vacuum). Based on these calculations a 1 meter sphere with ~1mm wall thickness could achieve neutral density or a 30cm sphere with ~0.2mm wall thickness could achieve the same. Smaller spheres could be clustered to provide more overall system robustness and simpler handling. The spheres can be coated (internal or external) with an atmospheric chemical resistant polymer (i.e. PTFE) to provide enhanced toughness for handling or use.

CONCLUSIONS

This proposal aims to provide the initial feasibility of the use of glass balloons as permanent vessels for use in atmospheric study and commercial use. These balloons would retain permanent spherical shape (hence the trade name Eversphere™) thus provide significant advantage over polymer balloons which expand upon rising into the atmosphere and are degraded by the high-altitude environment. It is possible that these balloons could be manufactured at the end use site to minimize the handling cost. Several applications have been identified that show glass balloons would serve as a valuable tool in scientific, military, and commercial use.

REFERENCES

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