X. Balloon Performance Analysis–NCAR Scientific Balloon Facility

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Abstract

Flight history of NCAR-conducted flights are presented. Correlation of balloon vehicle performance versus size, material gauge and manufacture, free lift, gross load, ground conditions, etc., are presented. In addition, a thesis is presented which states that ascent failures best correlate with low temperatures and amount of excess material at the base of the balloon bubble.

Analyzed in this paper is the performance of balloons procured by NCAR for scientific flights and which, to the best of our knowledge, were launched under "normal" conditions. The balloons procured for scientific flight programs are standard in design and materials. They include taped and tapeless balloons, and fittings and appendages are of conventional, industry-practice design. Experimental balloons evaluated under NCAR's R & D program are not included in the analysis. For example, the Raven SVT design balloons flown by NCAR are not included in this flight analysis. Balloons constructed of other than unsupported polyethylene are not included.

A "normal" launch condition is not precise and it is, therefore, not unlikely that some undetected launch circumstances affected later performance. In general, "normal" includes launches with wind conditions of 10 knots or less, with launch within one half hour after completion of inflation, and gross lift and payload weight within manufacturer's recommendations. Equipment used in balloon handling was routine in design and usage and ground temperatures were within +25°F and +105°F.

The analysis is of balloon performance alone. Electronic or other types of malfunctions are not included in the record. Flights include those conducted by NCAR or under NCAR management and include launches from Palestine, Texas; Page, Arizona; the Panama Canal Zone; India; and Minnesota.

The flights were first classified according to the type of polyethylene resin that the balloon was made of. Figure 1 shows the flight performance by balloon volume for balloons constructed from Visqueen DFD 5500 film. The decrease in flight success with increasing balloon size is remarkably invariant. In the 1.5 to 3.0 million cubic foot group, most of the balloons were either 2.94 million cubic foot, taped balloons or 3.0 million cubic foot, tapeless balloons – both of which were widely used.

Figure 2 shows the same performance plot as Figure 1, except that the film used was either Winzen "StratoFilm" or Visqueen X124. In the first group, the success rate of 89 percent for 9 flights, compared to the old film record of 85 percent success for 54 flights, is not statistically significant. However, the second

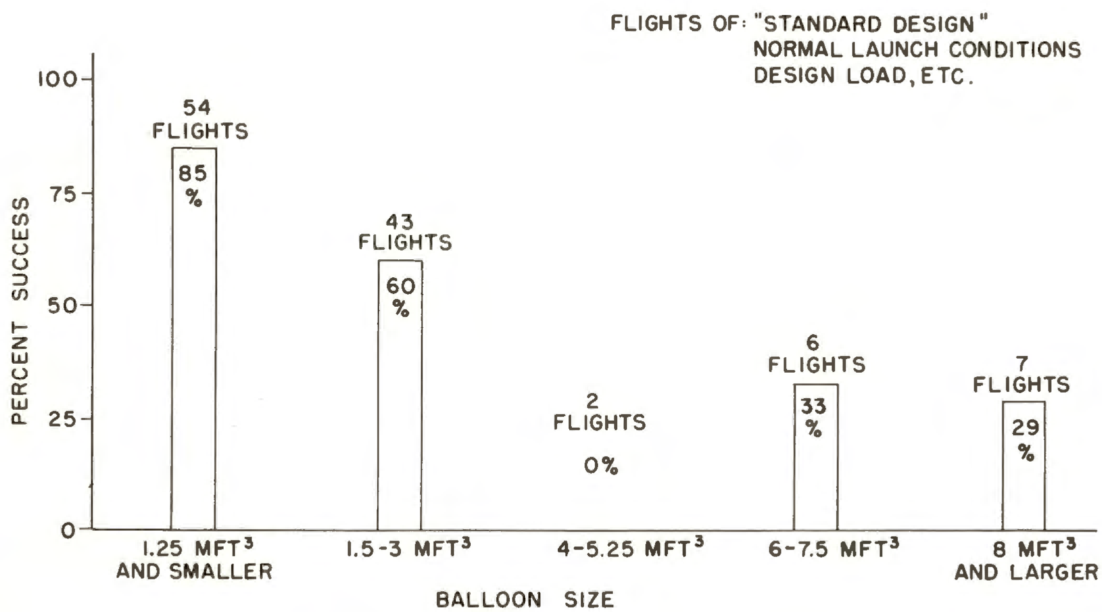

Figure 1. NCAR DFD 5500 Resin Performance – To August 1965

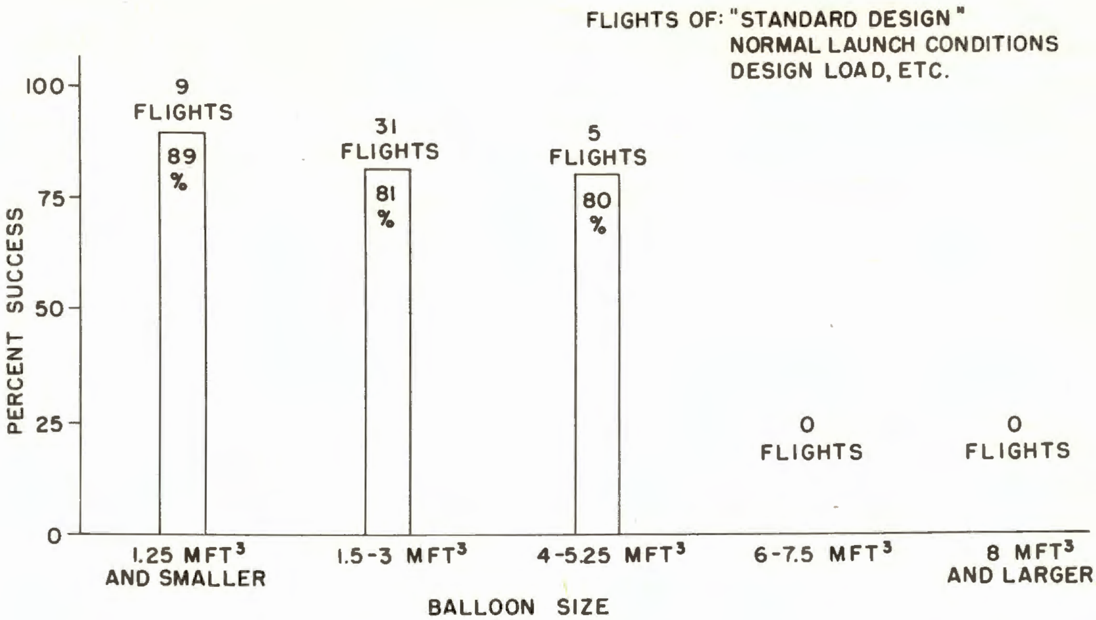

Figure 2. NCAR "StratoFilm" and X124 Resin – To August 1965

and even the third size groups are of considerable interest. With a reasonable sample (36), flight success is approximately 80 percent, compared to the record of 60 percent for the older films. In addition, 16 of the flights of these two groups were flown in India where tropopause temperatures were colder than those usually experienced within the continental United States.

As a result of our first years' experience with large balloons, we urged scientists to be conservative in their altitude requirements. As a result, at the time of this analysis, we have no experience with balloons larger than 5.25 million cubic feet constructed of the new films. R & D tests of large balloons have been made, but the designs were significantly different from standard.

Figure 3 shows a comparison of flight success and film gauge. So that a reasonable sample could be considered, no division into old and new film was made. It is interesting to note the consistency of performance regardless of gauge, except in the 0.6 to 0.8 mil range.

An important consideration in reviewing these data is the relationship of gauge to balloon volume. Considering that larger balloons are generally built of thinner gauge material, it is not surprising to see a decrease in flight performance with decreasing gauge at the approximately 0.75 mil level. It is surprising indeed to see that 0.55 mil film has nearly the same success as heavier gauges. It was noted in a study of quality control records that 0.55 mil film is more consistent in quality and has slightly higher tensile strength than heavier gauges.

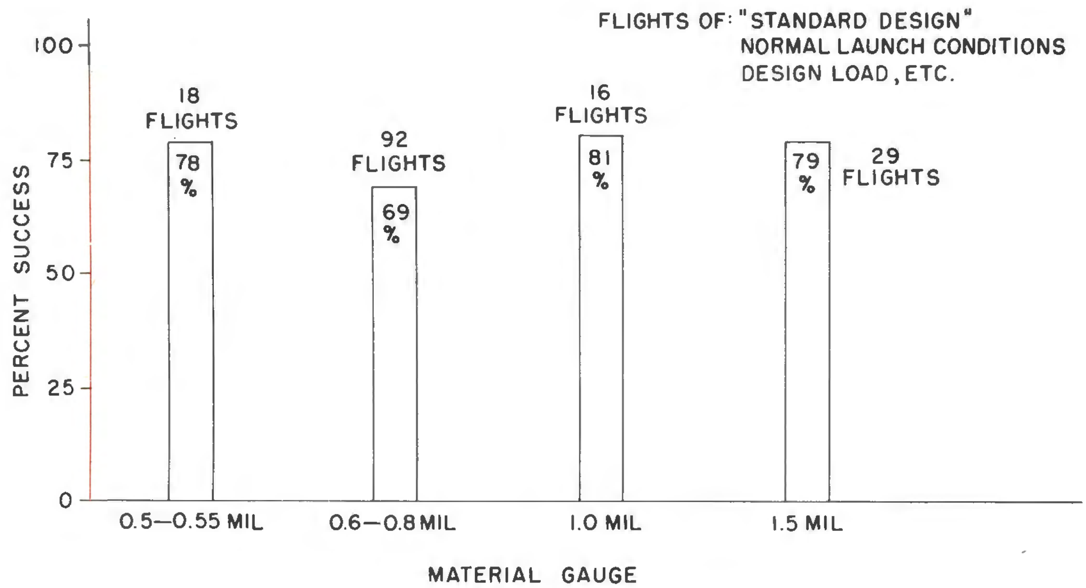

Figure 3. NCAR Polyethylene Material Gauge Performance – To August 1965

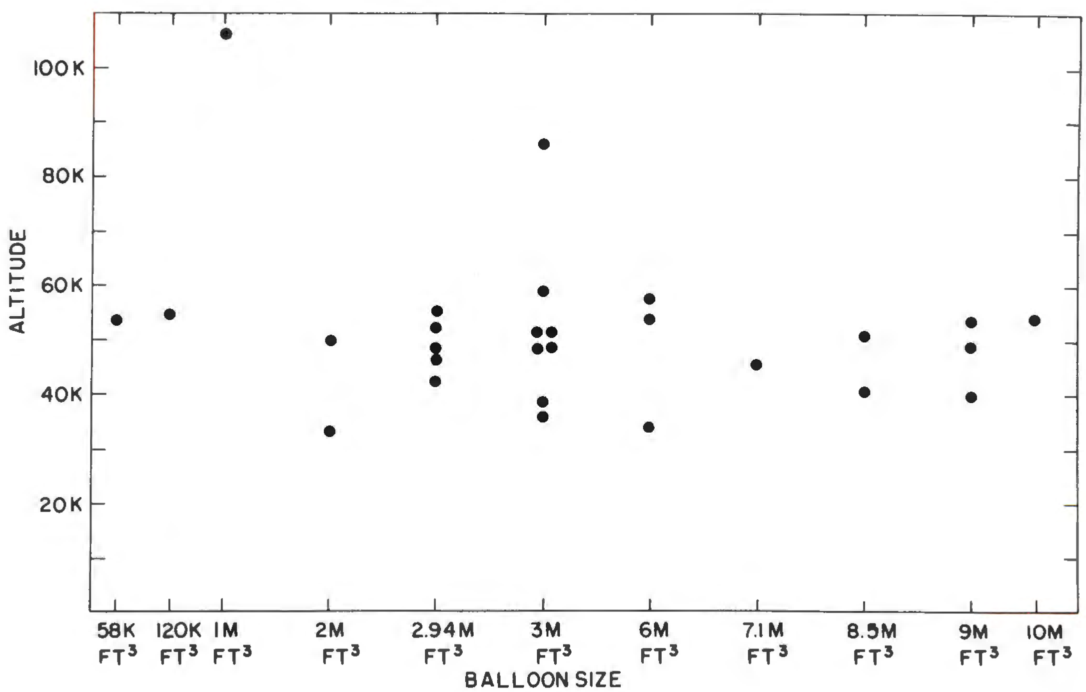

Figure 4. NCAR Ascent Failures – Altitude Versus Balloon Size – To August 1965

Most of NCAR's balloon failures occurred during ascent. Figure 4 shows a plot of failure altitude versus balloon size. Ninety percent of all failures after launch occurred within 33,000 and 58,000 feet altitude. No correlation is seen between balloon size and the altitude of failure. Few balloons failed at high altitudes during ascent, and even fewer broke at float altitude. The principal failure zone is obviously the zone of minimum temperature. Though not shown here, our results have shown no correlation of failure with rate of ascent.

In summary, our historical analysis points to a failure mechanism that occurs when the balloon is only a few (3 to 7) percent inflated. A specific percentage of inflation seems less important than the occurrence of low temperatures. Heavy film gauges appear to offer no improvement to flight success – even considering manufacturing and launch handleability. Indeed, the thinnest available gauge – 0.55 mil – seems to be the best performer. The failure mechanism works more severely on larger balloons, or else the greater statistical chance of imperfections on larger balloons explains their degraded performance. However, since the altitude of failure is within a narrow zone, regardless of balloon size, it seems unlikely that statistical imperfections explain the reliability decrease. Analysis of the 0.55 mil film quality control records and the quality control records of other gauges for a period of several years indicate an extreme performance sensitivity to material quality.