Development of large rubber balloons for high altitude weather studies

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The indigenous development of high-altitude rubber (latex) balloons was initiated in 1984 under a development contract with M/s. Pawan Rubber Products, Pune. During the period January 1985 and August 1989, five different developmental batches of 2000 g rubber balloons were manufactured at Pawan Rubber Products, Pune under close quality control by people from the Pawan Rubber and from the balloon group of the Tata Institute of Fundamental Research (TIFR). The first four batches were flight tested from Hyderabad; each balloon carrying IMD’s RS/RW payload weighing 1.8 kg. The fifth batch of balloons was tested from ISRO’s Sriharikota and Balasore station with light weight radar target as a payload. In this paper the flight test results of all the five developmental batches are presented. As the manufacturing parameters got optimized, the performance of balloons steadily improved from batch to batch up to the fourth developmental batch. About 70% balloons of the fourth batch reached 30 km and above. The manufacturing process parameters (mpp) were optimized to those used for the fourth batch, and the fifth batch was manufactured with these values of mpps. But only 55% balloons of the fifth batch reached 30 km and above, perhaps suggesting the need for better quality control and further optimization of the manufacturing parameters.

1 Introduction
A rubber (or latex) balloon, also known as weather balloon, is used to study the upper atmosphere, e.g. wind, temperature, humidity, etc. Normally, it is filled with appropriate quantity of a lift gas (hydrogen) and it is hand released with a light weight instrument (typically 1.5-1.8 kg) designed to measure atmospheric parameters, and a corner reflector to facilitate balloon tracking using a ground based radar. A rubber balloon with its light instrument, rises in altitude, typically at the rate of 300 m/min. From the tracking data, the wind speed and direction at various altitudes could be computed.

To sound the atmosphere (i.e. to measure wind speed, pressure, temperature, humidity) at various altitudes up to 25 km, the India Meteorological Department (IMD) conducts weather balloon flights from several stations spread all over the country. These flights are carried out daily at fixed time of the day and normally 875-g latex balloons (mainly from Pawan Rubber Products, Pune) are used for this purpose. There had been a long standing requirement to sound the atmosphere up to an altitude range 30-35 km, the TIFR Balloon group was entrusted to implement the project.

2 Programme of development of 2000-g rubber (latex) balloons
It was noted that M/s Pawan Rubber Products (PRP), Pune, a small scale industry, has been regularly manufacturing and supplying small (875-g) rubber balloons to the India Meteorological Department (IMD) for the regular upper wind scanning up to 20-22 km altitude. After reviewing the specification required for a balloon to take 1.8 kg IMD payload to the altitude range 30-35 km, it was estimated that 2000-g rubber balloon made out of latex (similar material is used for manufacturing 875-g balloon) could be a suitable candidate. As the PRP, Pune, is the only company in the country capable of manufacturing large size rubber balloons, it was identified for the 2000-g rubber balloon developmental programme; the PRP, Pune in turn indicated their willingness to undertake the programme of development of 2000-g rubber balloon in collaboration with TIFR, Bombay.

In August 1983, the TIFR, Bombay (operating/executive agency for the Balloon Board) and PRP,
Pune, entered into a contract for the development of 2000-g latex balloons with the seed money provided by the Balloon Board. Salient features of the development contract were: (i) PRP, Pune, will design and develop necessary machinery, and procure requisite equipment; (ii) PRP will experiment with various chemicals added to the latex for stabilization, protection against ozone etc.; (iii) TIFR in collaboration with IMD will carry out flight tests from IMD station, Hyderabad; (iv) Each PR-2000 rubber balloon developmental batches will consist of 60 balloons for which TIFR will bear the cost. A maximum of five developmental balloons were envisaged; (v) Based on flight results of a particular batch, PRP would make appropriate changes in the manufacturing parameters with a view to improving altitude performance and (vi) This project will be considered as a collaboration project and TIFR scientists will actively participate in all aspects of the quality control in development and manufacturing PR-2000 balloons.

The development project started in 1983. A new hydraulic controlled dipping machine was developed in 1984. All the manufacturing processes were carefully scrutinized and reviewed and specific procedures with a view for a good quality control were agreed upon. A trial ground burst test was also carried out in 1985. This test indicated that basically, 2000-g rubber balloon could reach altitudes up to 30-32 km range. The first development batch of 50 balloons was manufactured in 1984. Analyzing the flight results, appropriate changes were introduced in manufacturing process parameters and subsequent developmental batches were manufactured during 1985-88.

Following is a summary of the flight tests of all the five developmental batches. The flight tests for the first four batches were carried out from IMD's Hyderabad station, while the flight tests for the fifth batch was conducted from the ISRO's Shar and Balasore Center. Figures 1-3 depict the scenario of balloon filling and releasing from the test site. The weight distribution of the PR-2000 balloons for different developmental batches is shown in Fig. 4.

3 The 2000-g balloon flight tests

1st batch: A total of 32 balloons of the 1st developmental batch were supplied to the Balloon Facility (BF), Hyderabad. These were flight tested during the period 7 Jan. 1985-3 July 1985. Out of the 29 balloons which were tracked up to the burst altitude, 5 balloons crossed 28 km; 3 balloons reached 31 km and one balloon burst at 4.3 km. Some of the balloons out of the 1st batch were flight tested in New Delhi by the IMD, New Delhi.
2nd batch: The 2nd developmental batch of 50 balloons was manufactured in September 1985 and flight tests were conducted by the TNBF, Hyderabad, during the period 15 Nov. 1985-25 Apr. 1986. Out of the 47 balloons tracked up to the burst altitude, 12 balloons crossed 28 km; 7 balloons crossed 30 km and 2 balloons crossed 32 km. One balloon burst at 15.8 km (Fig. 5).

3rd batch: The 3rd developmental batch of 60 balloons was manufactured in November 1986. The balloons were flight tested by the TNBF, Hyderabad during the period 28 Jan. 1987-6 June 1987. Out of the 52 balloons tracked up to the burst altitude, all balloons crossed 18 km, 29 balloons crossed 28 km, 27 balloons crossed 30 km, 17 balloons crossed 32 km, 4 balloons crossed 34 km and 3 balloons crossed 35 km (Fig. 5).

4th batch: 60 balloons of the 4th developmental batch were manufactured during January 1988. These were flight tested by the TNBF, Hyderabad, during the period 18 Feb. 1988-24 July 1989. Out of the 50 balloons which were tracked up to a burst altitude, 37 balloons crossed 28 km, 35 balloons crossed 30 km, 17 balloons crossed 32 km and 4 balloons crossed 34 km (Fig. 5).

5th batch: 60 Balloons of 5th batch were manufactured during February 1989. Recognizing that the period for the flight tests of the balloons from
Hyderabad would take very long time (due to unavoidable reasons) it was decided to test the 5th developmental batch balloons (60 balloons) in a campaign mode from two range stations of the Indian Space Research Organisation (ISRO)—one at Balasore and another at Sriharikota. It was agreed that 30 balloons were to be flight tested from each range station. All the 60 balloons were launched at 1430 hrs in the afternoon with only a radar target payload (a payload of about 1.0 kg). Out of the 54 balloons which were tracked up to burst altitude, 42 balloons crossed 28 km, 30 balloons crossed 30 km, 14 balloons crossed 32 km and 3 balloons crossed 34 km (Fig. 5).

4 Discussion
It is observed that as the manufacturing process parameters and quality control procedures got optimized, there has been a steady improvement in the burst altitude performance (towards higher burst altitudes) with best results obtained in the 4th batch. The calculated thickness (in microns) of the skin of the balloon at the burst altitude has a narrower distribution for the 4th batch (Fig. 6) and this is also borne out in a better flight performance. The flight performance of PR-2000 balloons (batches 2-5) is compared with the Totex 2000 rubber balloon performance (Fig. 7). It is noticed that the performance of the 4th batch up to altitude of 30 km is comparable to the performance of Totex 2000 balloons. All this indicates that, in principle, it is possible to achieve the performance goals, but all manufacturing process parameters have to be optimized.

5 Conclusions
The performance of the balloons of the 4th developmental batch was encouraging and it was felt that one is approaching the goal of manufacturing balloons capable of reaching 30 km and above with IMD RS/RW payload. But the flight performance of the balloons of the 5th developmental batch did not measure up to these expectations. Apart from possible reasons related to the basic raw material and quality control in the manufacturing process, there...
could be some systematic errors or an error of judgement. The PRP, Pune, has analyzed the performance in reference to the manufacturing process parameters. There does not appear to be any correlation of poorer performance with the manufacturing process. One possible reason could be that the fifth batch balloons were tested in the afternoon at 1430 hrs rather than in the evening or in the early morning as was the case with the flight tests with earlier developmental batch balloons and also with the tests with the Totex rubber balloons. To understand this aspect, a sixth developmental batch with more tight control on the manufacturing parameters, and with balloon flight test planned in the evening, is under active consideration. There could be an ultimate limit due to the nature of material, namely, pure latex, which is used in the manufacture of the PR-2000 balloons. It may be recalled that, the US and the Japanese balloons are made out of a new material which is a combination of neoprene and latex; apparently this provides better mechanical strength for the balloon skin as it expands and becomes thinner while the balloon rises to higher altitudes. In view of this, future balloons with a mix of neoprene and latex are also planned. The overall performance has been good, considering that at least 60% balloons reach more than 30 km altitude. Considering cost differential (of the order of 400% in favour of indigenous balloons) between the present balloon and the imported balloon of the same size, it is quite an encouraging and cost effective answer for important substitution, although there is a scope to improve performance by using better materials and effecting a tighter quality control in manufacturing.

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