MRU Cardington Technical Note No. 3

Isles of Scilly field detachment September - November 1987

by

A.J.Lapworth

August 1993

Met. Office Research Unit
RAF Cardington
Shortstown
Beds, MK42 0TH

MRU CARDINGTON

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1 Introduction

This brief document has been compiled to give some record of what was undoubtedly the most remarkable flying detachment carried out from the Met Research Unit at Cardington. It involved flying a large (24,000 cu ft) capacity balloon from the island of St Agnes in the Scilly Islands during a period of strong winds in late autumn, which included the great storm of 16th October 1987. The island is only normally served by small ferry motor launches, and a special cargo ship had to be hired to transport the equipment.

The balloon then in use was the Airborne MB24 which was designed in 1984 and had been given some testing both at Cardington (where strong wind bedding trials had been carried out) and on a detachment in the Llanthony valley in Wales. The MB24 had two major design differences from its predecessor (the Bateman Mark 8) which were a longer conical section aft of the point of maximum width and modified fins which were shorter and more 'rocket' shaped than the Mark 8 fins, with reduced internal stiffening from diaphragms. Unfortunately only limited wind tunnel data was available to Airborne on this new shape. The MB24 was further modified at by the addition of a wind turbine ballonet and tail pressurization system incorporating a 'can' type air relief valve. These were shown to be effective at increasing the internal pressure of the balloon and reducing the tendancy of the nose to cave in in strong winds by comparative trials at Cardington. Further trials had shown that the balloon pitched up considerably more than its predecessor in strong winds and there was some doubt as to the tether cable tensions to be expected in strong winds. The stretched version of the MB24, known as the MB27 had shown a disasterous tendancy to pitch up uncontrollably in even moderate winds. A further problem with the MB24 that had become apparent over the previous year was an increasingly predominant waggle of the tail when flown in anything more than light winds.

The purpose of the detachment was to fly the balloon as a (hopefully weak) cold front passed over the Scilly Isles and thus make detailed frontal measurements in an area relatively unaffected by terrain - the Scilly islands are only a mile or so wide and less than 100 feet high. Measurements of turbulence in a maritime airstream were also to be made.

One of the major problems with the balloon was in determining the best way to anchor it overnight when flying had ceased. At first a pyramid system was used, but the shocks in the tether cables snapped half of the legs. Storm bedding was then used and although this was the safest technique, the envelope tore in a strong wind at a point where a small patch had been used on the balloon envelope. It should be noted that due to the problems of laying out a storm bed in only thin top soil, a 'sticky' bolt adhesive technique was used. Finally the balloon was flown on an extremely high breaking load strop at 300 feet with an extended rip cord clipped to the strop and tied off to the ground. This proved successful in the conditions on the Scillies where there is no significant topography or obstruction to the low level flow. However it was noted that the balloon distorted severely in strong winds, the lower nose flattening as the balloon pitched up and the thin conical tail section bending. The tail waggling became very intense and started tearing the seams joining it to the hull, at which point it was deflated. In total, three inflations were carried out on the island, which required extra supplies of gas to the transported by the 'Crazy Diamond'

The greatest cable tensions (47 cwt) were measured in a frontal wind of over 45 knots. This compares with a previous incident at Cardington when tensions of about 36 cwt were measured in winds of over 45 knots, and indicates that the worst fears of the pre-detachment performance assessment were realised. During 1988, a modified balloon, the MB24A was constructed which consisted of an MB24 hull with a Mark 8 tail. This had a better diaphragm structure and was never seen to suffer from tail waggle. It was tested in winds up to 37 knots and peak tensions of order 20 cwt were measured, which appears to indicate a reduced pitching up tendency. It seems that a possible cause of the marked pitching up by the MB24 is the reduced size of the fins which become ineffective in the turbulent wake of the hull.

The explosive cut-down device was used for the first time on the Scillies. Although none of the problems found in the 1988 Aldermaston detachment were experienced here, it is uncertain as to how useful it might have been were it ever needed as no method of checking continuity of the leads to the explosive was in use. These were found to be broken later on in the year but it is not known when this occurred. A hot wire method of cutting a hole in the balloon would have been more easily tested (by passing a low current through the wire) and would not have suffered the problems of premature triggering that occurred in 1988. Earthing problems were discovered on the receiver of the device and these were sorted out on the Scillies in 1987.

The following sections consist first of balloon operating notes written prior to the detachment, and which do not therefore incorporate experience gained on the detachment itself. The windspeed limits were decided from previous flights at windspeeds of around 40 knots and took the optimistic view that the balloon pitch would only increase linearly with windspeed at higher windspeeds or, more probably, would not increase even as much as linearly. In this we were influenced by the performance data of the Mark 8 which in retropect can be seen to be a very different design. In addition insufficient allowance was made for shock loads which can add 50% to the mean load on the flying tether. Unfortunately in the conditions of the passage of the front on November only limited data on the cable tensions was taken and it is difficult to say how much the

actual tensions exceeded the estimates.

The second section consists of extremely rough notes made in the form of an operating log at the time of the detachment. It was compiled mainly from accounts given by telephone to Cardington. As it contains the only technical record of the flying operations, it is reproduced in its entirety.

2 NOTES ON BALLOON OPERATIONS

2.1 Introduction

The balloon used for this detachment will be an Airborne MB24, with a volume of about 24,000 cu ft(680 cu m), a length of 75 ft(22·95 m), and a maximum diameter of 28 ft(8·45 m). It is manufactured from polyurethane coated nylon and can only be filled with Helium due to the static risk with Hydrogen.

2.2 General

For each flying period a forecast (0637-874032 (ex-directory) or 872201 ext. 225 (public)) must be obtained and ST. MARY'S ATC MUST BE INFORMED (0720-22109 (ex-directory) or 22677 (public)) both before starting flying and at the end of flying. An intermediate forecast should be obtained every 6 hours. Two types of flying are planned. In the first of these daytime measurements of the maritime boundary layer will be made. In this case the following limits are suggested as guidelines.

No flying should take place when the wind is over 45 knots at any level, if it is gusting 25-30 knots at the ground, or if the lightning risk is 1 or 2.

If no strong winds are forecast overnight, the balloon can be left on a pyramid mooring, but the rip must be tied off to a ground point (THIS IS A LEGAL REQUIREMENT). Otherwise the balloon must be bedded if possible. If the wind is strong enough to prevent either mooring to a pyramid or bedding, then it is preferable to attach navigation lights to the balloon cable and let the balloon up to 1000 feet. This should be high enough to clear surface turbulence and give enough cable to absorb shocks, while low enough to keep below the increased winds normally encountered at altitude. A watch must be kept on the balloon in this case.

If the balloon breaks away phone both St Mary's ATC (0720-22109 (ex-directory) or 22677 (public)) and West Drayton 0895-444077 or 0895-445566 Ext 6150 (distress and diversion) or Ext 6153 immediately. Our number is 0720-22272. The coastguard (22651 and 22873), police (22444) and St. Mary's harbourmaster (22768) should also be informed.

In the second type of flying - frontal flying - an initial assessment must be made of the likely strength of the front before launching the balloon. If the flying risks are judged to be acceptable, the balloon will be raised to altitude with a maximum of four

probes attached to the cable about 8 hours before the front is expected. As the winds at altitude increase, and the front approaches, the balloon should be lowered to a height of about 1500 feet. At this stage the winch should be evacuated and all personnel moved to a safe distance UPWIND of the cable. There are two main risks. Firstly, the wind-speed in the jet ahead of the front, or the updraught at the front, may cause the cable to break. Secondly, lightning from the frontal cumulonimbus may strike the balloon or cable. In the later case the balloon will probably be holed (either by the lightning strike or by the cutdown detonator having been triggered) and the balloon should sink to the sea, trailing probes and cable.

After the front has passed, there may be a clear period during which the balloon can be retrieved before the lightning risk increases in the unstable North Westerly airstream. After the flight, the cab recording tensiometer should be checked. If the cable tension is found to have exceeded 43 CWT, the cable should be changed before flying again.

2.3 Filling

The balloon should be filled to a net static lift of around 700 lbs. This assumes the following weights:

Skin + rigging wires + tail guy	=	592 lbs
Valve	=	6·5 lbs
Bell crank	=	8·5 lbs
Lightweight closehaul pennant complete	=	6 lbs
Handling guys	=	24·5 lbs
Air blower	=	6 lbs
Air relief valve	=	2 lbs
Two frames for air blower and relief valve	=	10 lbs
Cutdown device	=	14 lbs
Rudder surface roughners	=	5 lbs

This gives a total weight of 675 lbs (305 kilogrammes).

To fill the balloon 88 percent full at sea level requires about 49 bottles filled to 3000 psi, or about 58 bottles filled to 2500 psi or about 73 bottles filled to 2000 psi. Each bottle holds around 400 cu feet of gas at NTP when filled to 2700 psi.,which should give an increase in lift of around 26 lbs per bottle when pure.

The bottles are in four manifolded crates of 30 bottles per crate. Initial filling will thus use two crates. After this it is recommended to use bottles one at a time, opening each bottle onto the manifold in turn and CLOSING it after use, or using the next bottle will half refill the first one. Use in this way will reduce the effect of long term manifold leaks and makes accountancy of reserves easier. The alternative is to open all bottles onto the manifold. Used this way, the amount of gas used is proportional to the pressure drop. If all 30 bottles are opened onto the manifold then a drop in pressure of 100 psi is equivalent to about one bottle. One bottle filled to 3000 psi should give an increase in lift of about 26 lbs.

2.4 Flying

The balloon will be filled 88% full for this detachment, which will give it a pressure height (at which gas is valved) of 4000 feet above sea level. This gives a static lift of around 700 lbs assuming a purity of 98% and that handling guys and blower are attached.

A height of 4500 feet above sea level is theoretically attainable but this is inadvisable due to the large curvature in the cable giving a lieback of less than 30° to the horizontal at the pulley block in moderate winds when the purity gets low during the detachment (less than 95%). The large curvature will affect the accuracy of the balloon motion corrections. In strong winds the balloon can fly much higher than 4000 feet, but this is inadvisable due to the possibility of loosing dynamic lift when the wind drops, and the NOTAM limitation of 5000 feet.

The static lift is difficult to measure on detachment as even light winds increase the net lift (static + dynamic) by 50 to 100 lbs. If measuring the lift, check that the tail guy is free. It is best to overfill slightly and valve at pressure height. The static lift is constant with height provided that the internal temperature of the balloon is always the same as its surroundings and that pressure height is not reached.

Superheating by the sun can cause internal temperature excesses of 15° or more, increasing the lift by 50 lbs and also lowering the pressure height. This is a regular cause of helium loss and may require one or two bottles of helium a day to make good. The balloon has been shown to have a leakage rate when stored in the hangar giving rise to a loss of static lift of about 5 lbs per day. There is a loss of purity at the same time. This loss of lift and purity is mainly due to small leaks as diffussion through the fabric should only give a loss of 1 lb lift per day. Bedding trials over a few days showed that the background leakage rate was not significantly greater than in the hangar.

The balloon has a ballonet ceiling of 6500 feet above ground level. This should not affect operations, but if for any reason the balloon does exceed this height, the effect will only be noticable on the descent, near the ground.

The purity of the helium is extremely critical in obtaining a good performance. If the purity drops to 90% then even if the balloon was filled with helium on the ground to an adequate static lift, by the time the balloon reached 1000 feet it would have valved off some of the gas due to the increased volume per unit lift of low purity gas.

2.5 Windspeed Limits

The balloon should fly with a nose up pitch of 3 to 4° in low winds increasing to 16° at 40 knots. This means that dynamic lift and hence cable tensions increase as the cube of the windspeed. The tensions are maximum at the top of the cable, being reduced by

several cwt at the winch.

However, tests have shown that if the cable is stressed to over 50% of its minimum breaking load, there is a permanent weakening of the cable. In addition, if the cable is wound in or out, then it will start to break when the tension is around 65-70% of the minimum breaking load. This figure was determined from tests on KB65 cable using undercut 'U' groove capstans.

The windspeed limits are extremely critical. In order to obtain maximum performance an OPERATIONAL WINDSPEED MAXIMUM OF 45 KNOTS has been agreed. At this windspeed the cable tensions at the balloon are around 26 cwt which gives a safety factor of 2·2 on moving KB85 cable and 3·3 on static KB85 cable. This cable BREAKS AT 85 CWT WITH A STATIC LOAD, usually at the ferrule. Extrapolations of experimental results indicate that a cable tension of 85 cwt is achieved at a windspeed around 65 KNOTS, DECREASING TO 55 KNOTS IN A 10 KNOT UPDRAUGHT. There is an uncertainty due to the lack of data on movement of the centre of pressure. This range is only 20 knots above the operating maximum, and a single gust could break the cable, Two further points should be noted. Firstly, if the cable is wound in or out, the cable will start to break up at a cable tension in the region of 57 cwt. This tension should occur at a windspeed of around 59 knots. Secondly, the maximum windspeed that the balloon has been tested to is around 48 knots. Above this windspeed there may be unexpected drag increases due to either sharply increasing pitch or tail waggle. A CLOSE WATCH SHOULD BE KEPT ON THE TOP PROBE GILL READINGS WHEN OPERATING NEAR THE LIMITS. In addition the forecast winds at altitude should be regulary reviewed as, by the time the wind starts to increase it may be too late to make bedding possible. It should be noted that the highest tensions in the cable can be generated with the balloon near the ground if a gust catches the balloon sideways on. In this position the drag coefficient is around 10 times that in the nose on position and there is not sufficient cable to absorb shock loads.

2.6 Rates of Ascent and Descent

These are usually limited by the winch to around 200 feet/min. On ascent the speed should not exceed 150 feet/min in order to allow gas to escape from the valve restrictor plate when the balloon is above pressure altitude. This will also allow a reasonable profile to be taken. In high winds the descent rate should be restricted to 100 feet/min or less as the pitch angle of the balloon will be increased by the descent rate, increasing the cable tension (watch the cab tensiometer). Some approximate calculations suggest that the cable tension increases by around 6% for an updraught of 100 feet/minute.

2.7 Cold Frontal Conditions

During the approach of a cold front, the surface wind is often westerly to southwesterly, with a speed of 10 - 20 knots. Above the surface, a southerly wind preceeds the front. This wind (known as 'cold frontal jet', or 'warm conveyer belt') has a maximum windspeed of 50 to 70 knots at a height of 3000 feet immediately before the cold front

itself. In the region 3000 feet to 6000 feet the windspeed falls by about 10 knots, while below 2000 feet it decreases rapidly with decreasing height. The high winds in this 'cold frontal jet' extend to between 100 and 200 nautical miles ahead of the front. The front itself advances at a speed in the range 10 to 20 knots, so that to avoid the strongest winds, the balloon may have to be winched down to 1500 feet 10 or more hours before the front arrives. At the front itself there is an updraught of around 1000 feet per minute, with a horizontal width of about 1-2 nautical miles. The maximum updraught is at around 3000 feet. This will increase balloon pitch (it is equivalent to hauling the balloon down at this rate) and thus increase cable tension by around 60%. The balloon will then be subject to rain (or hail) and a high lightning risk for a few hours until the front passes. When the front passes there should be a clear period ('cold frontal clearance') before showers and lightning risk increase again in the unstable north westerly airstream behind.

2.8 Bedding

The balloon can be fairly easily handled near the ground in windspeeds of up to 15 knots. Above this it becomes progressively more difficult until at speeds gusting 25 to 30 knots it may become very difficult or impossible. If bedding the balloon is impossible, then provided winds above 50-55 knots are not forecast, it is best to leave it flying on about 1000 feet of cable which should be above the turbulent surface air. With this length of cable there should be sufficient absorption of shock loads due to gusts.

If the balloon is left like this overnight, someone must be left on watch to ring West Drayton should the balloon break away.

If the balloon cannot be bedded and a wind significantly higher than 50 knots or a high lightning risk is forecast, consideration should be given to ripping the balloon which is done by giving a pull of greater than 20 lbs to the RED NYLON CORD ON THE STARBOARD SIDE OF THE BALLOON. This is not too awful an action to contemplate as there is a spare balloon and the ripped one is easily repairable. Only the gas is lost, together with some flying time while the second balloon is inflated. It is far preferable to rip a balloon than to have that same balloon drifting in the airways or trailing cable across the countryside putting peoples lives at risk.

The bedding operation involves setting the pulley (snatch) blocks onto the bed so that the balloon is pulled down facing into wind, pulling the balloon down and transferring it to a central strop, removing the radar reflector, running the handling guys through the pulleys and clipping them to the spider, pulling the balloon down on the spider until the ballonet blower and air relief valve can be removed, removing and pulling out the rigging leg with topping up hose attached, putting padding over the main rigging and then tensioning down with the ballonet sleeve undone and exhaust tube inserted. Be careful to ensure that it is the ballonet sleeve and NOT the neighbouring gas inflation sleeve which is colour coded RED. Finally the tail exhaust sleeves are undone and the tail folded and lashed down, AND THE RIP CORD TIED SECURELY TO ONE OF THE STAKE PLATES.

If possible lines should run from the main rigging patches under the balloon to the bed wires to stop the balloon twisting in a wind. The tensioning should be set to about two tonnes of the main cable when it has been taken off the flying cable (which only has a limit of 2·25 tonnes) and transferred to the Tirfor. This should put a load of about 500 lbs on each of the patches, and may be increased from 2·0 tonnes to 2·5 tonnes in a high wind. The tension pressurises the balloon to withstand the wind, and should be in the range 10 to 20 mm water (i.e. 1 to 2 mb) The balloon can take up to around 60 mm water excess pressure although it will stretch greatly. However in the bedding position the main strain is on the patches, which stretch and eventually leave the fabric above them porous. As the balloon CANNOT VALVE GAS WHEN BEDDED (as the valve is not pressure but line operated) a check should be kept on the internal pressure and line tension, in particular when the sun falls on it first thing in the morning, causing the gas to expand.

Unbedding is the reverse of bedding (remembering to untie the rip line) except that the balloon must be inflated with air from a blower as it is raised. Otherwise in any wind the gas will surge around and the balloon will lie acrosswind rather than lining up with it. Another point to watch is the problems that arise if the wind is not in the same direction as when bedded. If the wind is greater than 15 knots it is probably best not to unbed in this latter case, but if unbedding is attempted the tail guy should be held on to until the handling guys have been unclipped and then released with care (there may be several hundred pounds force on it).

2.9 Air Blower and Exhaust Valve

The balloon is not pressurised by the helium gas except insofar as the static lift exerts a pressure of 8mm water near the top of the balloon dropping to zero at the bottom. The main pressure is due to ram air entering through non-return flaps at the nose and tail air scoops. This is augmented by an airbooster giving a superpressure of 1·5 to 2·0 times the ram air pressure which should stop the nose dimpling in a steady air flow. The booster is highly desirable but not essential to operations and can be removed provided its duct is tied up. As the balloon rises the ballonet diaphragm expands downwards and the air displaced must be allowed to escape or the balloon will burst. This is accomplished by means of a metal can exhaust valve facing into wind, and set to open if the internal pressure exceeds the ram pressure by about 14 mm water(1·4 mb). This valve is important. If it is not attached to the balloon, its ducting must NOT be tied up. However in this case the balloon will not be able to maintain a high internal pressure and will dimple in gusts and high winds.

For reference, there follows a table of ram air pressures expected for given windspeeds near the ground:

VELOCITY (Knots)	PRESSURE (mm water)
10	1·7
20	6·6
30	14·9
40	26·6
50	41·5
60	59·7

2.10 Weather Forecasts

The main factors affecting balloon flying are winds at all heights, turbulence near the ground, and lightning risk. The wind speed limits, which have already been noted, are 45 knots at altitude and 25 to 30 knots near the ground depending on turbulence. In strong turbulence lower limits should be considered. The other major risk to flying operations is that due to lightning strike. The balloon acts like a high level lightning conductor and can 'make its own strikes'. Many balloons have been lost due to this cause. In particular flying by night has the additional problem in that no local assessment of lightning risk by noting cloud thickness is possible.

Flying can take place in lightning risks of 4 or 5. With a lightning risk of three, convection above the freezing level is indicated and further advice may be sought from the forecaster. Usually flying is permitted below cloud base. There should be NO NORMAL FLYING IN LIGHTNING RISK VALUES OF 1 OR 2. If rain or dark clouds are noted during flying operations, the lightning risk should be queried. An important factor is thickness of convective cloud above the freezing level, a thickness of more than 5,000 to 10,000 feet giving a fair chance of lightning. Thus lightning is more likely in cold weather when the freezing level is lower. If flying in marginal conditions it is well worth while asking the forcaster to check weather radar for strong echoes every hour or two.

2.11 Navigation

St. Mary's ATC (0720-22109 (ex-directory) or 22677 (public)) should be informed at the start of flying operations and when they are finished at the end of the day.

By day drogues are flown at 500 foot intervals on the cable. By night, a pair of lights (white over red) are flown under the balloon and this pair is repeated every 1000 feet. At least one pair must be below cloud base. A triangle of flashing lights must be set out on the balloon bed.

The balloon should also carry a radar reflector in the rigging.

The area has been NOTAMed. The NOTAM gives a maximum height of 5000 ft AMSL. The local air traffic includes both fixed wing aircraft and helicopters.

If the balloon breaks away, first actuate the cutdown device. Then phone both St Mary's ATC (0720-22109 (ex-directory) or 22677 (public)) and RAF West Drayton (0895-444077 or 0895-445566 Ext 6150 (distress and diversion) or Ext 6153) and give details. The coastguard and police should also be informed.

If the cable breaks near the pulley block when the balloon is at altitude then it will probably trail cable a considerable distance over the countryside shorting power cables and causing damage. If the break is near the balloon it will rise (nose up) and may or may not burst (watch for this if possible) If it does not burst it will reach an equilibrium ceiling of 20,000 to 30,000 feet and drift downwind into the airways. If the cutdown device works, the balloon should sink to the surface in a few minutes.

2.12 Cutdown Device

In view of the possibility of loosing the balloon on the Scillies detachment, efforts have been made to equip both the main balloon and the spare with cutdown devices. These work by using a coded transmission from the ground to detonate a ring of explosive on top of the balloon, cutting a hole in the envelope. The explosive is Cordtex-related and detonates with a loud noise. Care has to be taken not to kink the charge, and a stiffening panel is provided to keep the charge flat during balloon inflation. The receiver and battery are located in the balloon rigging above the point of attachment. The battery should last for about 48 hours. The device operates on a frequency of about 153·63 MHz which is close to that of our walkie-talkies. To test the receiver, the transmitter can be switched to 'TEST' and the button pressed. A light on the receiver should then come on. To fire the charge, the transmitter is switched to 'ARM' before pressing the transmit button.

If there is some uncertainty as to whether the device has worked, the transmitter output power can temporarily be greatly enhanced by switching to the high power setting.

3 Log of Events

3.1 Monday September 21st

Transport left Cardington on Monday September 21st. Held up waiting for forklift and mid rising tides at Penzance. 'Crazy Diamond' and LC 'Mojo 3' landed first loads at noon Monday Sept 28th. 'Mojo 3' returned for constructor and landed this later in day. In all, approx 50 tons landed on East harbour of St Agnes. Site set up during rest of week (bed previously laid, apart from wires.)

3.2 Saturday October 3rd

Inflation on Saturday October 3rd. Wind got up from east during afternoon. Too turbulent at 100 ft (wind off Gugh) so put on 200 foot strop. By Monday, wind from NW, stable flow off sea. Put on pyramid on Monday p.m.(?) Pyramid is 4 legs of KB85 in corners of field 200 foot square, with central leg. Height about 60 feet (originally intended higher). Swivel at top with shackle above to 6 ton strop. Rip tied off to this shackle. Ballon let up on flying cable. Wind got up to 40 knot gusts on Tuesday night and backed to Southerly. In morning found that two windward legs and central leg had broken. Balloon appeared O.K. although twice seen to hit ground. Bulldog clips had been used to secure pyramid legs. These had slipped and the cables had broken at the kinks. Balloon was retrieved with wind reduced to WSW 15-20 knots at 6 metres. Pulled down with carpenters stops. Balloon let up to 200 metres in rain on 6 ton strop. Flying cable let slack and Rip tied off to top of strop. Ballonet exterior had small rip when dive bombed ground. At some stage a single probe was flown to 1000 ft and data collected from a short run.

3.3 Wednesday October 7th

On the afternoon of Wednesday October 7th, the wind dropped to 10 knots so balloon was bedded, facing into NW wind. Wind rose to gusting 50 knots during night. Balloon rising off bed nearly completely and shifting with greater than two tons tension in cable. Several bottles of gas put in which filled out balloon and left at 1.30 a.m.

3.4 Thursday October 8th

At 6 a.m. on October 8th, a small tag patch pulled and opened a hole. The tag patch was immediately above the bow deflation sleeve, and the tear extended a metre or so to starboard, and also downward on the port side of the tag patch itself and into the inflation sleeve cover. This patch had been tied off rather than weighted down, and was almost certainly bearing a non-tangential load. The rip was pulled but the balloon did not deflate more than a small amount and air was being rammed in through the bow hole and the open rip panel acted as a scoop. The balloon had survived most of the F7-F9 winds, even with side gusts during night. Balloon is repairable, but probably not on site. About 55 cylinders of gas have been used.

3.5 Monday October 12th - Monday October 19th

On Monday extra equipment including a 300 foot length of 16 ton cable, and the repaired cutdown device receiver is being sent down to the Penzance heliport. 60 Gas cylinders are being sent down to Penzance for shipment by the 'Crazy Diamond' which will also bring back the balloon for repair. Fresh gas shipped and 16 ton strops sent over, arriving St Agnes Wednesday October 14th. Second balloon inflated Saturday October 17th - the day after the exceptional winds struck SE England. Purity 99·5%. Put on 300 foot 16 ton strop with cutdown activated and rip tied to ground. Gale overnight - balloon watched till midnight. Wind Southerly gust 45 knots at 6 metres. Possibly 50 knots at 300 feet. Balloon seen to pitch continuously to very high pitch angle. Tail had thick ropes on rudder. Seen to flutter (not large amplitude waggle) in high winds, and next morning seen to waggle at 20 knots. Confirms idea that this is a resonance effect. Balloon seemed steady above island generated turbulence but lay over to only 100 feet up when struck sideways on by gusts associated with rain squalls. When this happened the cable did NOT go slack. Front two patches seen to be pulling in badly but balloon survived night. Pulled down on Monday 19th October for inspection and found to have maintained purity. Bolts in bellcrank believed to be weakest link now but test at Anglia Handling shows they only bend slightly with 30 seconds at 8 tonnes. Bellcrank itself elongates holes. Telephone down 18th - 19th October. Sometime around time Ivor first went out, winch cable slipped on capstans. Ivor seems to have fixed this, adjusting the winch clutch.

3.6 Tuesday October 20th - 21st

Tuesday October 20th, telephone repaired by Steve (cows had chewed cable) and balloon let up in low cloud to 1000 ft for run with single probe. As St Mary's airport wanted use of notamed area and LR1 forecast for p.m., balloon then put on 300 foot strop. Overnight the wind went round to NW and the flying cable having been let loose, caught round a drum. Tail waggling badly in 20 knot wind in morning. (October 21st) Cable slipping on winch yesterday. During afternoon, ropes on rudder removed as falling off due to waggle and they do not appear to do much good. It was noted that tail waggling was not as great with these ropes as seen at Cardington, but it should be noted that this was the No 2 balloon which had not been tried with ropes before and which had been considerably less used than the No. 1. Neither balloon showed much tail waggling when new.

3.7 Thursday October 22nd

October 22nd. Clear morning with LR3, tried flight to 4000 feet. Old balloon picked up from Penzance.

3.8 Monday October 26th

Monday October 26th (start GMT) Balloon put up to 3500 ft into first (extremely weak) cold front. Forecast for afternoon, LR3, max wind 30 knots at 2000 ft. Balloon static lift 750 lbs, purity 98·5First balloon now back at Cardington. Balloon flown in moderate winds till 1630 and then put on strop.

3.9 Tuesday October 27th

Tuesday October 27th started with Northerly force 6 (23 knots mean at 60 feet, many white caps) Balloon tail waggling slightly. Rain, LR3. Front appears to be passing overhead. At 1300hrs front had passed over and clearance. Some figures for the balloon were as follows:

BALLOON	3200 ft	
P2	3000 ft	16°
P3	2500 ft	22°
P4	1500 ft	30°
P5	1000 ft	37°

Ground temp 12°, pressure 1007mb, purity 98·5% two days ago. Lift 750 lbs two days ago. Balloon probably has water in it after rain, as ballonet and tail do not drain easily (few holes now) and tail blower duct does not drain at all. Windspeed 27 knots at 3000 ft, and 3750 ft of cable let out. Rustrak 7·8 cwt. Heavy rain previously found to alter static lift by 100lbs.

Calculated values of angles from these figures are:

P2	14°
P3	17°
P4	22°
P5	28°

Cable tension(rustrak) at bottom 6·5 cwt, cable let out 3500 ft. These figures imply that the cable has more drag than expected. Balloon will be let down at 1630. No 1 balloon inspected in hangar and will be sent to Airborne tomorrow.

3.10 Wednesday October 28th

Fine morning, 10 knots wind. Static lift 770lbs, purity 98·2%. Winds increasing later.

BALLOON	4000 ft		
P2	3812	4°	windspeed 12·5 knots
P3	2770	7°	
P4	1828	13°	
P5	870	21.5°	

Ground 1017·8 mb, 13° C, Rustrak 4·2 cwt. Let out 4200 feet cable. Calculated using 750 lbs static lift (calculated static 724 lbs max).

BALLOON	4000 ft
P2	4°
P3	6°
P4	10°
P5	17°

Cable tension(rustrak) at bottom 1cot9cwt, 4090 feet cable let out. As yesterday indicates excess drag on cable, also probably PIAB used for static lift is overreading or light winds are giving dynamic lift as PIAB is read. Rustrak is possibly overreading by 1-2cwt. 400 feet of cable then let out but angle at pulley block became so large (60-70° to vertical) that it was pulled back down again.

3.11 Thursday October 29th

Cloudy with rain forecast. Let out 2200 ft cable.

BALLOON	2200 ft	
P2	1723 ft	17°
P3	759 ft	25°

Windspeed 31 knots, Rustrak 15cwt, pressure 1010·5mb, 12·1° C. Tail waggling in bursts.

BALLOON	3000 ft		
P2	2823 ft	19°	29knots
P3	1881 ft	27°	35knots
P4	1074 ft	37°	31knots
P5	335 ft	48°	29knots

Rustrack tension 12 cwt. Tail waggling reduces as windspeed reaches 35 knots.

BALLOON	3340 ft		
P2	3144 ft	21°	34knots
P3	2222 ft	29°	37knots
P4	1426 ft	38°	
P5	681 ft	47°	

Some light rain. Rustrak reads 12cwt. Later windspeed reaches maximum of 40 knots at all levels and cab Rustrak reaches tension of 20cwt. Starboard Gill of top probe 2 lost during afternoon as came unscrewed at point where white body attaches to large Plessey plug that screws into tri-mount.

3.12 Friday October 30th

Balloon was in gusting 35 knots on 300ft strop overnight and NO tail waggling observed although tail waggling previously observed at 1000 ft. Is this associated with high ballonet position with reduced gas amount? Nose is not dimpling which implies a static lift of at least 590 lbs. Wind 15 knots at ground with rain and front expected this afternoon.

BALLOON	3110 ft		
P2	2910 ft	21°	30 knots
P3	1990 ft	27°	
P4	1190 ft	35°	
P5	420 ft	45°	

Surface pressure 1009·6mb, temp 10° C, tensiometer 10cwt. Raining. As on previous fay, the best fit to the above readings is a static lift of 450lbs, or a cable drag coefficient of 1·8. 1330. Raining.

BALLOON	3050 ft		
P2	2850 ft	16°	25·5 knots
P3	1890 ft	23°	
P4	1086 ft	34°	
P5	324 ft	48°	

Surface 1007·mb 12·5° C Rustrak reads 11cwt BUT CHECK IN CAB ITSELF SHOWS 8 CWT. Still raining.

BALLOON	3100 ft	
P2	2897 ft	11°
P3	1931 ft	20°
P4	1067 ft	34°
P5	306 ft	51(7?)°

Cab tensiometer 6·5cwt, rustrack 9 cwt.

Front finally cleared 1600hrs and balloon pulled down after a further hours flying. Static lift found to be around 750lbs using PIAB Implies either loss of lift from rain or greatly increased cable drag over that assumed in calculation.

3.13 Monday November 2nd

Calm day with 8 knots at 1000ft. Settled forecast for rest of week.

Some calibrations:

PIAB	4·5	7·75	8·0	10·75	14·0	22·5	24·0	25·75
CAB DIAL	5·0	5·0	5·0	10·0	10·0	20·0	20·0	20·0
CAB DIGIT	5·25	5·5	5·5	10·5	10·8	21·5	21·4	21·6
RUSTRACK	8·0	8·0	8·0	12·5	13·0	22·5	22·5	22·8
LCD SG	3·5	6·5		8·0			21·5	21·0

Calibration flight to 1000 ft.

BALLOON	3900 ft	15knots
P2	3700 ft	7°
P3	2750 ft	12°
P4	1980 ft	15°
P5	820 ft	24°

11° C surface, 1025mb, sun shining, 4·2cwt in cab(?? meaningless)

BALLOON	3380 ft		
P2	3180 ft	9°	18knots
P3	2250 ft	15°	20knots
P4	1490 ft	21°	16knots
P5	390 ft	32°	16knots

Surface pressure and temp as previously. Cab tensiometer 4cwt(?) PIAB checked with weights up to around 6cwt and found to be correct. Purity 98·2%

3.14 Tuesday November 3rd

Balloon in sunlight at 9 a.m. Some cloud but balloon probably dry as out of cloud.

BALLOON	3328 ft		
P5	3128 ft	16°	25knots
P2	2389 ft	21°	25knots
P3	1635 ft	29°	25knots
P4	1029 ft	38°	25knots
P6	410 ft	50°	25knots

Surface 1027·8mb, 11·2°C, 7·2cwt in cab tensiometer, 4200ft cable let out. During afternoon Hercules flew right over pulley block at 2000 ft with balloon at 3000 ft twice. Wind profile showed jet of 27 knots at 2000 ft. Getting gusty with convective showers.

3.15 Wednesday November 4th.

Late start to allow helicopter landing at 10.15 a.m. Balloon raised to 2500 ft, rudder waggling (rudder only) in sunlight with about 5 oktas cloud. Wind off Gugh (S.E.) Cutdown device batteries changed this morning.

BALLOON	2500 ft		
P3	2298 ft	17°	25·6knots
P4	1872 ft	22°	30·3knots
P5	1409 ft	25°	31·3knots
P6	941 ft	31°	30·9knots
P2	558 ft	34°	29·1knots

Surface 1029·3mb, 12° C, cab dial tensiometer 9· 9cwt, 2800 ft cable let out.

3.16 Thursday November 5th.

Balloon at 1800 ft:

PROBE	HEIGHT(FT)	CABLE TILT(°)	WINDSPEED	DIRN	THV
3	1500	9	19	145	13·4
4	1440	11	22	139	12·1
5	1291	13	24	129	10·9
6	774	17	22	115	9·0
2	353	20	24	115	8·8

Surface 1030·8mb, 11°C, 1950 ft cable let out, cab dial 6·5cwt Weather 5-7octas stcu, LR5. Balloon was OK overnight on 300ft strop although fresh winds off Gugh. Still no checks on balloon. Some comments from Paul. Measured pitch of balloon with protractor at 300ft as 6° in 20 knot wind but he notes wind tilted over land by around 5° which also confuses non plumb bob observations. He believes cable drag is very great as it was observed to curve 'backwards' in a LLJ situation. This confirms recent calculations on the cable curves previously measured which only make sense if a drag coefficient of around 1·8 is assumed for the cable. During afternoon inversion lowered and dry layer found, with minimum maintaining in velocity profile.

3.17 Friday November 6th.

Purity 98%, static lift 750lbs. Light wind with 14 knots at 1000 ft. Probe intercomparison flight.

3.18 Monday November 9th.

30 knot blow overnight, balloon OK but rip line tangled with cable. Also some signals recently have begun to appear on Magnetic tester, fan has seized up. After Helicopter landing this morning, cable to be cut. Fan has previously jammed and this time new bearings are needed. Flying cable is observed to be becoming ungalvanised. Also 16 ton strop is getting rusty.

3.19 Tuesday November 10th.

No flying, Lightning Risk. Three bottles of gas put in balloon.

3.20 Wednesday November 11th.

25 knots at 8am. Later wind gusting 40 knots, no flying. Some photos taken of balloon, probably angle of 30° pitch.

3.21 Thursday November 12th.

Kept watch over last night, gusting 55 knots in morning. Some photos taken, balloon lying back 80 ft from block on 300 ft strop. Wind moderating in p.m. Photos seen later show balloon cable lying back at 25° and 30° in gusts, with deformation at nose, giving undercut appearance below nose itself. Angles of pitch appeared from photos (taken on hill behind site) to be 20° in mean wind and 30° in gusts. Tail observed not to waggle in these 40 knot plus winds. No diving motions of balloon, wind from west. Rip line slightly wound round cable (webbing in future?) and flying cable tangled with fence in night.

3.22 Friday November 13th.

No flying. Lightning Risk.

3.23 Monday November 16th.

Wind 30 knots. Probe 2 magnetometer failed, cause is connector. Purity at weekend, about 97·8%

BALLOON	1028ft		
P3	828	22°	34 knots
P4	636	27°	33 knots
P5	406	28°	32 knots
P6	157	29°	31 knots

Surface 1010mb, 12·5° C, tension 20cwt. Later probe 2 top Gill went high, appears to have lost Gill again Found on descent that Gill had come unscrewed where one normally screws it onto probe trimount. Also probe 4 magnetometer u/s.

3.24 Tuesday November 17th.

Moderate wind, profile first and then put 5 probes on, with balloon at 1000 ft. Hercules flyby planned for midday. Gills all wired onto probes using holes in connectors. Probe 2 is now OK and probe 4 trouble has disappeared, so will have to wait for it to happen next time. Later in morning, low cloud and some drizzle. Hercules heard but not seen around midday - flying out beyond Bishops rock. Balloon let out to 3500 ft. Purity taken after final descent of 96%. Possible leak in purity tube.

3.25 Wednesday Nov 18th.

Checking balloon with leak detector while waiting for helicopter. Wind 15 knots. Balloon let up to 1000ft, pronounced shear with wind 25 knots at 200 ft. Three probes at 100 ft intervals noted to oscillate strongly IN ANTIPHASE Balloon tail waggling at this windspeed. Balloon pulled down at lunchtime and purity retaken after fix to purity

hose - found to give 97%. During afternoon, waited for 'Crazy Diamond' which is due later with balloon and cylinders. Ship too late for tide and did not arrive.

3.26 Thursday November 19th

Balloon up to 1000ft at 8 a.m. Wind 40 knots at 1000ft, 20 knots on surface. Weak front with waves lying east west off southern coast ireland, predicted to move southward to Scillies around midday. Alan Grant picked up by one of the handling guys this morning Cab tensiometer reading 20 cwt when 40 knots at balloon. 9.30am wind trace kicked at Cardington and 9 am chart shows a more well defined front lying along Bristol channel to Wash moving southwards. Dew points drop 5° across front and wind veers 90° and drops sharply.

BALLOON	1400 ft		
P7	1029 ft	25°	41 knots
P8	700 ft	29°	38 knots
P10	400 ft	30°	33 knots

Surface 1025mb, 12° C, cab tensiometer 19 - 23 cwt. Max gust at 1000 ft is 43 knots. Tail waggling was observed at 25 knots near surface, but not observable at 40 knots aloft. Balloon visible but in and out of low stratus. Probe 9 not working (transmitter?) and so not used. Balloon then let up to 2200ft with top probe at 1800 ft. windspeed rose to max of 45 knots at 1100ft falling to 35 knots at 1800 ft. Cab tensions rose from 20cwt to max of 36 cwt. Balloon then pulled down to 1170 ft, with cab tensiometer giving a max of 40 cwt on way down.

BALLOON	1150 ft			
P7	767 ft	32°	41·9	knots
P8	450 ft	34°	35·5	knots
P10	100 ft	33°	17	knots

surface pressure 1026mb. Note pressure sensors are very inaccurate, with zero errors of order 150 ft noted in this case. Planes (French and Hercules?) also dropping sondes etc. Jet continued until 1340 when dramatic passage of front after sudden increase in rain. Wind veered very sharply and dropped from 40 knots to 17-25 knots over a period of one minute. During the prefrontal period max tension of 47 cwt was seen on the cab tensiometer, while winds on the top probe were max of order 44 knots. There was no observable correlation between winds on probe and tensions, although max tensions did coincide with gusts on ground. Later, when balloon brought down, Probe 7 found to have its lower clamp slipped so that it was hanging from its top strop.

3.27 Friday November 20th.

Day for either unloading 'Crazy Diamond' if it arrives or for changing cable after yesterdays flight. At 11 a.m. balloon inspected and tapes around seam joining rudder to tail cone found to be coming adrift. Fins also appear to be coming detached. Close inspection shows that not only are T tapes along rudder seam becoming unstuck along

rearward end of the seam but that there is a tear running into the rudder. Fins also showing signs of wear. So balloon deflated 'Crazy Diamond' has not managed to get in with swell running. Will try later.

3.28 Monday November 23rd.

Arrived to find constructor broken down over weekend.

3.29 Tuesday November 24th.

Started cable change. Wind 25 knot. Showers

3.30 Wednesday Nov 25th.

Finished cable change. Mechanic arrived in evening. Wind 20 knot.

3.31 Thursday Nov 26th.

Constructor fixed (cutout disconnected) and mechanic left in morning.
Spent day laying out balloon in 10 knot wind.

3.32 Friday November 27th.

Inflated balloon on perfect calm day. Even Porton had stopped turning. Lift 820 lbs on PIAB, purity 99·3%. Used 77 cylinders. Any wind from east. Fitted receiver for cutdown (first failed) Took 3 hrs for main fill using 3 way filler. Put on 300 ft strop. NB Webbing must be used in any future rip line this long to prevent tangling with cable.

3.33 Monday November 30th.

First flight. Profile to 4000ft. Then flight with 10 probes with balloon finally at 3700 actual ft. Purity 99%. Winds 20 knots.

3.34 Tuesday December 1st.

Easterly wind with runs up to 3200ft.

3.35 Wednesday December 2nd.

Tail not waggling in 25 gust 35 easterly but started waggling at 2200ft Tension at 1000ft 13cwt max 17 cwt in wind 33 gust 37knots Balloon pitch 10 to 15° Later wind 30 gust 37 giving 12cwt max 23 cwt. Tail waggles as goes up. NB tail waggle period 0·9sec in 25 knot wind.

3.36 Thursday December 3rd.

No flying as cutdown receiver failed, as had other receiver after last frontal flight. Cause probably charging of balloon which burnt output chip after flying in Wednesdays iceing cloud. Same chip burnt out in other receiver after frontal flight. Receivers both fixed but too late for daytime flight. Surface winds in evening 31 gust 43 knots. Balloon probably in 35 to 40 knots. Pitch as seen from side 15 to 20°rees. Cable lay back 25°, max 29°.

3.37 Friday December 4th.

Last flight in low level jet peaking from 38 knots at 1600ft to 20 knots at 2500ft. Balloon would not rise above 2600 ft due to drag on cable (5 probes). Pulled down in pm as lightning risk increased.

3.38 Saturday December 5th.

Pulled down for helicopter after night with winds gusting 40 knots Too strong wind (25, gust 36) for deflation. Later in afternoon wind 20 gust 25 Tail oscillation period 0.85 seconds. Note added after return. Balloon 2 tail was in general in no worse condition than tail of Balloon 1. The Tape had come away giving an air leak at three points round the join to the hull but only over lengths of order 1-2 inches, apparently due to glue failure when stretched. At one of these points the fabric of the rudder (only the rudder fabric) had torn 8 inches vertically downwards. This looked as though it should have propagated under stresses of waggling and especially pressure in the tail, and it easily tore further. Later inspection showed that one of the diaphragms of the rudder had lost the rope around the inspection hole and that the diaphragm had started to split, the tear running down from the hole.