Department of Trade

ACCIDENTS INVESTIGATION BRANCH

Hot Air Balloon G-BCCG
Report on the accident at Saltley Trading Estate, Birmingham, on 8 October 1974

LONDON

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List of Aircraft Accident Reports issued by AIB in 1976

No.	*Short title*	*Date of Publication*
1/76	Sikorsky S–67 Blackhawk N671SA at Farnborough, Hampshire, England September 1974	April 1976
2/76	Hughes 269c Helicopter G–BABN at Beech Farm, near Barnby Moor, Nottinghamshire January 1975	April 1976

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Department of Trade
Accidents Investigation Branch
Shell Mex House
Strand
London WC2R 0DP

25 February 1976

The Rt Honourable Peter Shore MP
Secretary of State for Trade

Sir,

I have the honour to submit the report by Mr G C Wilkinson, an Inspector of Accidents, on the circumstances of the accident to Hot Air Balloon G–BCCG which occurred at Saltley Trading Estate, Birmingham, on 8 October 1974.

I have the honour to be
Sir
Your obedient Servant

W H Tench
Chief Inspector of Accidents

Accidents Investigation Branch
Aircraft Accident Report No. 3/76
(EW/C501)

Aircraft:	65,000 cu ft Hot Air Balloon G-BCCG
Owner and Operator:	Clark Equipment Ltd
Crew:	Commander — Killed
Passengers:	One — Killed
Place of Accident:	Saltley Trading Estate, Birmingham Latitude 52° 28′ 52″ North Longitude 01° 51′ 50″ West
Date and Time:	8 October 1974 at approximately 1400 hrs
	All times in this report are GMT

Summary

Shortly after take-off, as the balloon attained a height of approximately 800 feet, it collapsed completely and fell to the ground. The pilot and passenger were killed in the impact.

The report concludes that the accident was caused by the opening of the rip panel in flight allowing all buoyancy to be lost and the envelope to collapse. Although it was not possible to identify with certainty why this happened, it was established that the panel overlapped its aperture by no more than 2 inches. The stretching of the load tapes, which allowed the closure strip to be subjected to static and dynamic loading, is considered to be a contributory factor in the accident.

1. Investigation

1.1 History of the flight

The aircraft was carrying out a private demonstration flight from a car park in the Saltley Trading Estate, Birmingham. Before the accident the balloon and its crew had been operating in Ireland and last flew there on 5 October 1974 at which time nothing unusual was reported concerning its behaviour. Following the flights in Ireland, the envelope was packed into its valise in a wet state for conveyance to Birmingham by surface transport where it arrived at about midday on the day of the accident.

Preparation for the demonstration flight began at about 13.15 hrs when the balloon was unpacked and laid out at the site by the pilot who appeared to be in good health. The pilot contacted Birmingham Air Traffic Control (ATC) as required in Condition (d) of his Permission (see section 1.17) and according to witnesses, stated that he had obtained a weather forecast for the proposed ascent although no notes concerning weather information were found in his possession and there was no record of an enquiry having been made at the Birmingham Airport meteorological office. Witnesses also stated that the pilot appeared to be satisfied that the physical properties of the site, considered in conjunction with the actual weather conditions, were suitable for the proposed flight and declared his intention of making a high temperature lift-off to attain the desired height of 1,500 feet as soon as possible.

The pilot had expressed some anxiety over his ability to stay within the timing of the ATC clearance when a first attempt at inflation had to be abandoned because the balloon's rip panel became partially open. The trouble, which the pilot attributed to dampness, was apparently rectified by his opening the rip panel completely then re-sealing the 'Velcro' fastening. He also re-entered the envelope at this time to attend to the fastening. The re-sealing of the rip panel was completed and the second inflation started within about 10 minutes.

According to witnesses about five persons were holding the crown rope at one time and six were engaged in restraining the basket during the inflation. There is also photographic evidence that the burner was in unattended operation for part of the time. At take-off, a clear cut 'weighing off' procedure was not accomplished and some of the persons restraining the basket may have been momentarily lifted off the ground as it began to rise. When the balloon was finally free it was seen to rise initially very rapidly, with the burner being operated to approximately 100 feet. A witness, standing approximately 30 metres down wind of the launch point, said that he looked up into the balloon as it passed over his head and noticed what appeared to be a 'rugby football shaped' opening – about three feet long – in the top of the envelope through which the sky could be seen. The balloon continued its rapid ascent with the envelope pulsating slightly but, apparently, fully inflated. Witnesses away from the departure point remarked on an 'apple core' type of indentation which developed on its upper surface. It was also seen to commence an oscillating, semi-rotary motion during the climb with a period of approximately 10 seconds.

When the balloon had reached a height variously estimated as being from 800 feet to 1,500 feet, a red flare was discharged from the basket. At about the same time witnesses also noticed that the ascent had stopped and that the envelope was beginning to lose its shape with the throat and leading quarter of the balloon caving inwards. The collapse progressed rapidly, with an increasing rate of descent and another red flare was fired by the pilot. When last observed in the air, at a height of about 450 feet, the envelope had collapsed completely and was streamered out above the basket which was falling fast. The crew could be seen at this time, pushing at the rigging in an apparent attempt to re-deploy the canopy.

The balloon came down on a canal tow-path. The two occupants were killed by the impact and the basket and burner assembly were badly damaged; although damage to the canopy was slight. There was no fire.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1	1	–
Non fatal	–	–	–
None	–	–	–

1.3 Damage to aircraft

There was substantial damage to the basket and burner assembly with slight damage to the balloon envelope.

1.4 Other damage

None.

1.5 Crew information

Commander	Aged 26 years.		
Licence	Private Pilot's Balloons (Hot air filled).		
Last medical examination	18 December 1973. No restrictions.		
Flying hours on hot air balloons	Total –	P.1	191.51 hours.
		P.2	13.20 hours.
Flying hours on hot air balloons in last 28 days.		P.1	15.00 hours.

The commander had also had some experience as a glider pilot.

The commander had been the holder of a certificate, issued by the Civil Aviation Authority (CAA), exempting him from the provisions of Article 19 and Schedule 9 of the Air Navigation Order 1972 insofar as these provisions prohibited him from flying in command of a balloon for the purpose of aerial work. This exemption had lapsed on 30 August 1974.

Witnesses who were familiar with the commander's usual practice, commented upon his attention to detail when preparing for flight. It was his custom personally to carry out the closure of the rip panel and perform the 'tying-off' procedure on every occasion.

The passenger, aged 36 years, had also had considerable experience of balloon operating and was the holder of a current Student Pilot's Licence (Balloons).

1.6 Aircraft information

1.6.1 *General description (see Appendix 2)*

The type AX-7 – 65 balloon is a 65,000 cu ft balloon of bulbous gore design with 12 gores and a semi-circumferential type rip panel which extends for 180° around an upper circumference of the envelope, known as the 'two inch tape'.

The polyurethane coated nylon envelope, with a 'Nomex' fire resisting skirt, is contained by nylon horizontal and vertical load tapes, the latter carrying the load from the burner frame by stainless steel wires and Karabiner clips. In order to attach the round skirt of the envelope to the rectangular burner frame, the stainless steel wires are of dissimilar lengths and their correct orientation to the burner frame during 'laying out' is ensured by marking a 'long' length of the balloon skirt by a red tape. The gondola, which is made of basket ware, is attached to the burner frame by further stainless steel wires woven into the basket structure.

Control of the crown of the balloon during inflation is achieved by use of an external crown rope permanently attached to the crown ring on the same side as the red mark on the skirt. Two in-flight buoyancy control ropes are fitted inside the envelope, one to control an automatic closing dump valve in the side of the balloon and the second, coloured red, to operate the rip panel.

A warning device for the thermal protection of the envelope is secured internally near the top of the balloon. It consists of two strips of metal soldered together one of which is fastened to the envelope and the other is attached to a hanging streamer. When the internal air temperature exceeds 100°C the solder should melt and allow the streamer to fall as an indication to the pilot that the maximum permissable temperature has been reached.

1.6.2 *The load tapes and rip panel*

The load tape material has been adopted for use in balloons by reason of its strength and durability. The horizontal load tapes and the part of the 12 vertical load tapes below the 2 inch tape around the balloon at the bottom edge of the rip panel, are sewn to the envelope fabric down to the 'Nomex' skirt. Above the 'two inch tape' all load tapes are free lying, being brought together at the apex of the balloon by connection to a metal crown ring.

The rip panel is provided in order that residual buoyancy may be dumped from the envelope on landing. The panel consists of a semi-circular section of the top of the envelope, slightly larger than the opening which it fills, and closed along its circumferential edge by 2 inches wide Velcro pressure sealing tape, normally secured by the pilot prior to flight. As an added safety measure, tie-off rings, with corresponding rings on the envelope, are provided at three points on the panel itself and at one point on the lower pulley carrying the vertical part of the rip rope on the opposite side of the balloon. The tie-offs are normally secured by low breaking strain thread, nominally 10 lb at each rip panel tie-off and 30 lb at the rip rope.

The panel is operated in flight by the rip rope. One end of the rope is permanently attached to the panel; it then passes through two further pulley attachments on the rip panel and thence across to the other side of the balloon and down to the basket via an upper and lower pulley. To obviate its destruction by the burner, the lower part of the rope is made of steel wire covered with a red coloured, fireproof, fabric. The attachment of the rope is arranged in such a manner that pulling it will break the tie-offs if fitted, open the Velcro seal and collapse the rip panel inwards. To assist in initiating the rip opening, small triangular sections of plain tape are inserted in the Velcro at each rip rope connection to start the Velcro 'peeling'. As the full opening of the panel is irreversible in flight and the loss of buoyancy very rapid, it is not normally used at a height in excess of 50 feet.

1.6.3 *Airworthiness*

A Certificate of Airworthiness (C of A) is not required for a British registered hot air balloon if it is not being used for the public transport of passengers or for operations overseas. However, a C of A is required for participation in events requiring CAA permission. A C of A in respect of G-BCCG was issued on 28 June 1974 and was valid until 27 June 1975.

Since 1972 the CAA has accepted the Airworthiness Requirements drafted by the Flying and Technical Committee of the British Balloon and Airship Club (BBAC) for the certification of hot air balloons in the United Kingdom.

Few specific Standards are laid down in the Requirements for the envelope design and construction. Paragraph 1.1 (a) of the Requirements specifies the use of a design load factor of 'at least 10' and paragraph 2.7 (a) specifies that 'The general design of the envelope shall be such as to withstand the stresses encountered in normal ground handling and inflation as well as flight'.

The Requirements deal with the rip panel under 'Provision for Rapid Deflation' in paragraph 2.7 (b) which states (in part):

'(iv) The design of the means of rapid deflation and its controls shall be such as to render the possibility of accidental opening extremely remote.' and '(vii) The actuating control shall be designed so that it can be safely and easily operated by the pilot under all expected landing conditions, and so that the possibility of its becoming entangled with, or confused with, any other control or internal rigging is extremely remote.'

Paragraph 2.12 of the Requirements deals with equipment although it does not specify what equipment a balloon shall carry. In its entirety this paragraph reads:

'Each item of equipment on a balloon must be:

(a) Designed and installed to ensure that it will perform the intended function reliably under all reasonably foreseeable operating conditions.

(b) Designed to safeguard against hazards to the balloon if it malfunctions.

(c) Shown to function properly in the balloon.'

Paragraph 4 of the Requirements deals with the Operational Information which the manufacturer shall provide, which includes:

'4. (a) Written instructions on the operation of the balloon and its controls and emergency procedures, all operational limitations and all necessary maintenance and periodic inspections. Instructions shall also include a list of any instruments necessary for the safe operation of the balloon.

(b) Unless a temperature indicator is provided with instructions as to its installation and use, operational information must be provided to include a chart or graph showing envelope temperature in all permitted combinations of all up weight, ambient temperature and altitude'.

1.6.4 *Preparation for flight*

The laying out procedure for balloons and their preparation for flight are covered in the respective Pilot's Notes although manufacturers' instructions differ slightly. As no pilot's notes were found in the balloon after the accident and the pilot had flown G-BCCG for only approximately 26 hours of his total flying of 192 hours, the observations in this section are of a general nature, extracted from various sources.

There is some variation in the way the balloon skirt is marked to assist in orientating the envelope before connecting it to the burner frame. Some manufacturers place the red marker on the rip panel side whereas, on G-BCCG, in common with other balloons from the same manufacturer, the red mark indicates the opposite, dump valve, side of the envelope. When laying out, the red mark is usually put downwards. Although there is no 'right' or 'wrong' way for laying out, inflation is facilitated if the dump valve is kept downwards to prevent its hanging open and dissipating the heated air.

The manner of closure of the Velcro seal is also dealt with in various ways. Generally speaking the rip panel should be closed by firstly correctly positioning the ends of each straight section, stretching the section by pulling from each end, overlapping the Velcro seal fully and then closing it positively by hand.

Although the three tie-offs on the rip panel may be tied from outside by slightly opening the Velcro at the relevant points, they are normally secured from inside the envelope. The tie-off point on the lower rip rope pulley may only be reached from inside the envelope.

Mention is also made in the pilot's notes of the nature of restraint that should be exercised during inflation. A definite number of crew should be positioned on the crown rope by the pilot and they should be told by him to refuse any unsolicited help. The pilot should be advised of the degree of restraint being exercised and, when the lift in the balloon is approaching the weight of one man, the crown holder(s) should allow it to rise. It is important at this point that there should be plenty of helpers putting full weight on the basket as it is quite possible for the momentum of the rising balloon to lift the basket momentarily off the ground.

1.6.5 *History of G-BCCG*

Balloon G-BCCG, manufacturer's serial number 020, was manufactured by Thunder Balloons Ltd, of London and first flew on 1 June 1974. At the time of the accident it was owned by Clark Equipment Ltd.

According to entries in the relevant flight log, the balloon had made 33 ascents, its total flying time since new amounting to approximately 37 hours 10 minutes. During this time the balloon appears to have been properly maintained and no unusual occurrences or defects were noted in the records.

1.6.6 *Aircraft loading*

The all up weight (AUW) of the (dry) balloon and passengers was calculated as being 850 lb (385.55 kg) at lift-off, which was within the design loading limitations of the aircraft.

1.6.7 *Performance information*

1.6.7.1 Performance information available to the pilot

The performance data available in the pilot's notes are based on the balloon's lifting capacity with an envelope temperature of 100°C.

A chart is provided to cover variations from International Standard Atmosphere (ISA) so as to allow the gross lifting capacity of the balloon to be calculated for the planned operating altitude. The maximum permitted take-off lift is shown as 21.9 lb/1000 cu ft, at temperatures below – 15°C.

No data is available in the performance figures to indicate what the lifting capacity would be with envelope temperatures in excess of 100°C. Neither are there indications of what other limitations might apply if the balloon became airborne with excessive buoyancy.

1.6.7.2 Actual performance

An examination was made of the achieved performance of the balloon during the accident flight.

The total distance covered was approximately 900 metres on a track of 185°C (T) which, using a calculated average wind speed of 12 knots, results in a total flight time of 2½ minutes. Observations and calculations indicate that the balloon reached its maximum height of approximately 800 feet above ground level (AGL) 310 metres down wind from the point of take-off; an average rate of climb of 1,000 Ft/min. It crossed the first significant high tension cable down range at a height of approximately 700 feet AGL, clearing the wires by 540 feet.

1.7 Meteorological information

The actual weather recorded at Birmingham Airport, 5 nm WNW of the site, at the time of the accident was:

Surface wind	(Recording anemometer)	010° T 10 knots
Visibility		20 km
Cloud	4/8 Strato-cumulus	2,400 feet
Temperature		Ps 13°C
QNH		1010.1 mbs
Weather		Nil

No gust in excess of 14 knots was recorded during the period of inflation or the flight. Although there was no record of any forecast being obtained by the pilot, a general forecast for telephone enquirers had been issued to the Post Office by Birmingham Meterological Office at 11.15 hrs. This stated in part '...... The afternoon will be rather cloudy with scattered showers, but some sunny periods are also expected. The temperature will rise to 12°C this afternoon and tonight there will be isolated showers and clear intervals. Temperatures will fall to 5°C by dawn. The moderate Northerly wind will become light tonight.'

1.8 Navigational aids

Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome and ground facilities

The launching area was a private car park 70.1 metres x 57.91 metres, situated in the Saltley Industrial Estate, approximately 1 mile from Birmingham city centre.

Buildings and other structures of varying heights were adjacent to the launching site and flight path, including an electricity main transmission line mounted on towers up to a height of 200 feet AGL. In the case of the latter, the most critical dimensions within an angle of 45° either side of the actual flight path was a suspended cable, 140 feet AGL, at a distance of approximately 91.44 metres from the point of launch.

1.11 Flight Recorder

Not required and not fitted.

1.12 Wreckage

1.12.1 *Inspection at the accident site*

The balloon came to rest on a canal tow-path. Although the gondola had struck the ground with considerable force, it had remained the right way up and attached to the burner assembly and envelope.

Considerable damage had been caused to its flooring and basket weave structure by the force of the impact. There was a fracture near one corner of the burner frame assembly which had also been badly distorted by the impact; glass fibre and paint markings on the damaged frame corresponded with marks on the crew's protective headgear. The burner assembly was found hanging partially over one side of the basket.

The balloon envelope had initially fallen on top of, and completely enveloped, the basket. It was subsequently removed in order to remove the casualties. For examination at the site, the envelope was laid out alongside the rest of the wreckage. Some burn damage had occurred to the base fabric panels and there were also minor tears in the envelope, some of which may have been caused by ground handling after the accident. The rip panel was found fully open and the 'tie-offs' broken as was the lower rip rope tie-off. The Velcro sealing strip was found to be very wet – even in places where it had been protected from post-accident rain showers.

After the 'on-site' examination the balloon was re-packed and removed for detailed examination.

1.12.2 *Examination of the wreckage*

The complete assembly was delivered to a hangar on 11 October and when unpacked from its valise the envelope was still found to be wet. Preliminary inspection showed that the rip panel was partially closed and upon re-opening and closing it (from one end) the length of the Velcro on the main canopy appeared to be about 2 inches longer than the Velcro on the rip panel. However, upon re-opening and closing it gore by gore, the lengths of the rip and main canopy Velcro closure strips were found to be approximately equal. No 'shear' damage to the Velcro strip was found.

The balloon was then partially inflated using an air blower, and subsequent inspection of the canopy showed that it had suffered rather more damage than was observed at the scene of the accident.

Inspection of the interior of the balloon showed some wrinkling of the Velcro seal and the material of the main and rip panels adjacent to it. The length of the rip panel operating cord also appeared to be rather short. Furthermore, whilst some remains of tie-off thread was found on the lower rip pulley, no similar evidence was found at the two tie-off points on the rip panel. Finally, the appearance of the solder on the fusible link indicated that it had at some stage melted and cooled, – but it could not be determined when this occurred.

1.13 Medical and pathological information

Post mortem examination of the pilot and passenger revealed nothing which might have had a bearing on the accident. The cause of death in both cases was multiple injuries.

1.14 Fire

There was no fire.

1.15 Survival aspects

When the balloon was seen to be in trouble shortly after take-off, some of the onlookers called an ambulance while others set off towards the expected impact point. Men working near the accident site were first on the scene, arriving within 2 minutes of the impact, and one of them turned off the main gas supply to the burner which was still open. Police, rescue and fire-fighting services and ambulances also arrived within a few minutes and attended to the casualties. No other services were involved.

The accident was non-survivable.

1.16 Test and research

For the purposes of comparison tests of the load tapes they were numbered anti-clockwise looking upwards into the envelope. The load tape on the left hand side of the red marker being designated Number 1.

Prior to conducting the tests the following static dimensions were recorded under ambient temperature conditions with the envelope dry. In the rip aperture case the measurements were extrapolated to give the exact distance from the centre of the crown to the top edge of the Velcro, in inches.

	1	2	3	4	5	6	7	8	9	10	11	12
Rip panel load tape	158½	159	158¾	159¾	159	158¼	158¾	159⅜	158¾	158½	159¼	159¼
Rip panel fabric	161¾	162	161¾	161½	161	160½	161	161¼	161	161¼	161	161

Fabric crown ring diameter ..... 16.54 inches

Effective rip rope length ..... 78 feet 4 inches.

Apart from the crown fabric diameter (which was 1⅜ inches less than the 18 inches shown on the manufacturer's drawing), the rip panel measurements and the lengths of the gore tapes and free load tapes were found to be about the same as the measurements recorded under similar conditions at the time of manufacture.

After the 'as found' dimensions had been recorded the envelope was transported to Cardington where a serviceable gondola and burner assembly were attached and several indoor, tethered, test flights were carried out under varying, controlled conditions. During these flights no failure of the rip panel fastening occurred despite the overloading and buffeting to which the envelope was subjected. Nor did any undue propagation occur when sections of the Velcro were prevented from sealing by the insertion of lengths of plain tape. However it was noted that, under stressful conditions, strain marks appeared in the balloon fabric adjacent to the rip panel load tapes and the panel closure gave every appearance of carrying load. It was also noted that, under high load conditions, the position of a marker on a load tape moved approximately 5 inches relative to the adjacent rip panel closure seam, indicating a load tape stretch of this magnitude at that point. Although the amount of stretch decreased as the balloon cooled and the load was taken off, the full 5 inches was not recovered during the period of the observation which extended for at least 10 minutes.

Due to the possibility that further damage might have been caused to the envelope, the maximum crown temperature reached during the indoor flight was 107°C (within the 120°C band of the temperature sensitive crayon), and the maximum static loading applied in any test was 1,372 lb (622.328 kg). No data is available for conditions in excess of these figures. It should also be noted that the above observations were made under static conditions of buoyancy inside a closed hangar. Due to the difficulty in conducting tethered 'free' flights out of doors, no observations were possible of the loaded balloon's performance under the dynamic case and no data are available for such conditions.

In the light of the observations made at Cardington, overall measurements and tests were carried out on the vertical load tapes on the rip panel side of the balloon. The panel is positioned between load tapes numbered 6 to 11 and the total length of the five free-laying tapes over the panel were found to be as follows:

Load tape No.	6	7	8	9	10
Length	74 ft 10"	75 ft 1¾"	75 ft	75 ft 1½"	75 ft

No. 7 tape was selected for further dimensional checks as follows:

The balloon envelope and load tapes were all secured to a fixed position at the crown ring extremity and the rip panel was sealed as if for flight. A spring balance load was then progressively applied at the basket end of the selected load tape (No. 7) and the stretch and load measured at both the basket and rip panel points together with the change of load with the passage of time. For the purpose of the tests the tape was dry and the ambient temperature approximately 15°C.

The following pertinent figures were extracted from the results:

Load applied (lb)			*Elapsed time*	*Movement (stretch) inches*	
Start		*Finish*	*Minutes*	*At basket*	*At Velcro*
110	–	104	3	7½	3¾
190	–	178	2	14	4½
* 235	–	210	2	18¼	6

* The Velcro showed signs of opening at this stage.

284	–	266	3	21½	6¼
382	–	not noted (see below)		30	8¼

Note 1 The final stretch of 30 inches was maintained for a further 15 minutes during which time it was noted that, as the tape elongated, the applied load decreased. After 15 minutes the load was released and the, now slack, tape was measured and found still to have a residual stretch of 17½ inches beyond its original length. After a further 15 minutes in the unloaded state, although some recovery had taken place, the tape was still extended 12 inches. A recovery period in excess of 40 minutes was necessary before the tape returned to its original length. Loads re-applied to a tape before it had completed its recovery resulted in either an increase in the amount of stretch, or the same amount of stretch for a decreased load.

Note 2 During a repeat of the tests, when the Velcro was opened at a loading of approximately 200 lb, the two surfaces moved apart and could not be reclosed.

Additional tests were carried out on the load tape material under laboratory conditions at differing temperatures, loads and degrees of dampness. The results of these tests corroborated the tests made on the balloon envelope. It was not possible to measure what percentage of the lifting loads was carried by the load tapes and the material of the envelope respectively.

Appendix 3 of this report deals with other material tests and research and should be read in conjunction with this section.

1.17 Compliance with Regulations

Application to the Civil Aviation Authority for permission to carry out the flight was necessary. Article 67(1)(c) of the Air Navigation Order, 1974 was applicable, together with Rules 5(1)(a) and 5(1)(d)(i) of the Rules of the Air and Air Traffic Control Regulations, 1974.

The application, which should have been submitted at least 28 days before the event, was prepared by the Public Relations Officer of the sponsors and had been submitted to the CAA Directorate of Operations (Field), Northern Office, approximately 8 days before the projected flight. A map had been submitted with the application, as required by CAA, although this was subsequently found to be inaccurate and contained no reference to the location or height of the high tension cables or some significant obstructions adjacent to the take-off site. There was no requirement at the time for Divisional Officers of the CAA to visit the scene of proposed balloon flights and they did not do so in this case. Following discussions with Birmingham ATC and the applicant, the CAA Northern Office issued the required permission on 2 October 1974. Amongst other provisions the permission contained the following conditions pertinent to this report:

Condition (c) The forecast wind direction shall be such as to give a flight direction contained within the sector of airspace centred on the launch site and extending from 210°T clockwise through North to 070°T;

Condition (e) the balloon shall be flown in such a manner that a landing can be made without danger to persons or property on the ground;

Condition (f) unauthorised persons shall be excluded from the area within 20 metres radius of the balloon prior to taking-off and within 45° either side of a line on the ground vertically below the intended flight path of the balloon out to 60 metres from the take-off point;

Condition (g) the height of any fixed object within the sector 45° each side of a line vertically below the intended flight path of the balloon drawn from the launching point to a point one half nautical mile from the launching point shall not exceed 30% of the horizontal distance between the said fixed object and the launching point;

Condition (i) the pilot of the said balloon shall be in possession of a valid licence authorising him to fly for the purpose of Aerial Work or a valid exemption from the Aerial Work limitation of his private pilot's licence.

This permission shall have effect during the period 1200 to 1500 hrs GMT on 8 and 9 October 1974 unless previously revoked.

Under Article 60(3) of the Air Navigation Order 1974 the whole of the permission was invalid if any of its conditions were breached.

2. Analysis and Conclusions

2.1 Analysis

Photographs and observations made at the time indicate that the catastrophic descent of the balloon followed a loss of buoyancy caused by the opening of the rip panel in flight. This analysis is, therefore, principally concerned with the possible causes of the rip panel opening.

2.1.1 *Design and construction*

It was established during the tests that the nylon tubular material, with which the load tapes were made, tends to stretch with loading, heating and moistening and, once having done so, takes some time to revert to its original length. On the parts of the envelope where the tape is sewn to the envelope material, a laminate is formed which is capable of absorbing the effects of the stretching with little deformation and no effect on the integrity of the balloon. However, provision for the stretching of the unsupported load tapes across the top of the balloon and over the rip panel should be made by increasing the overlap of the loose rip panel, decreasing the length of the load tapes or a combination of both. The amount of rip panel overlap should be sufficient to compensate for any movement of the load tapes that might occur. If it is not, the Velcro seal of the panel will at times be subjected to load. In the case of G-BCCG insufficient margin existed and the 'no-load' measurements of the loose rip panel exceeded those of the load tapes by about 2 inches. Tests showed that this overlap was absorbed by the first 10-20 lb across the join and that any subsequent loading, from whatever source, must have been borne in part by the Velcro strip.

No serious shortcomings were found in the Velcro fitted to G-BCCG. The primary function of the Velcro strip is to provide an air seal around the periphery of the rip panel opening of the balloon. It is neither suitable nor intended to carry lifting loads. It has been established that the holding strength of Velcro can vary depending on the conditions under which the two surfaces are brought together. An incomplete overlap, ingress of foreign matter or the presence of heat or moisture can all reduce the strength of a Velcro seal. Tests have shown that, if closed under laboratory conditions when clean and dry, a 2 inch wide strip of Velcro, as fitted to G-BCCG, requires a load of 27-30 lb in shear in order to open. Once the seal has been broken, the separation propagates by means of a peeling action which requires only a load of 3-4 lb to continue the opening process. Under static conditions the rip panel is in shear. However, the inherent flexibility of the balloon envelope and the triangular peel points at the rip rope connections, tends to apply peel loads to the Velcro.

It was established that, under normal, static conditions, the ratio of basket load to load across the Velcro for a given tape is of the order of 10-1 and that, therefore, a load in excess of 270 lb at the basket end of the panel load tape may be sufficient to open, in shear, an ideally executed Velcro join. However, during practical tests carried out on G-BCCG under optimum conditions, the Velcro showed signs of giving way at between 210-235 lb, indicating that the basket load required to open the Velcro could be significantly less than 270 lb, particularly if the material was hot and/or wet, or the join had not been faultless.

The all up weight of the balloon has been calculated as being 850 lb, representing approximately 70 lb per load tape when evenly distributed, but this must be considered a minimum figure and in the static condition only. There is no way of establishing the additional weight of the balloon due to its wetness, nor is it possible to quantify the additional restraint being applied to the basket prior to lift-off although photographic evidence indicates that 650 lb would not be an unreasonable estimate. It is considered that the total attempted static lift would not have been less than 1,480 lb which, distributed equally among the 12 load tapes, would suggest an individual load of approximately 125 lb. However, it is unlikely that the load was evenly distributed. The basket is attached at four points and there are a number of reasons why individual tapes may carry more or less than an equal share of the total load. Differing load tape lengths, assymetric weight on the basket prior to lift-off, movement of the canopy during inflation, tilting of the basket, movement of the crew, use of gas, flight conditions etc, could all have had the effect of varying individual load tape static loads. In considering the degree of loading which may have been applied to particular tapes at any one time, due regard should be given to the orientation of the balloon during laying out. If the dump panel was kept downwards as recommended, then the rip panel would have been uppermost. The crown rope was fastened to the crown ring diametrically opposite to the centre of the rip panel, thus all the excessive restraint, which the evidence indicates was applied to the crown rope, would be borne by the load tapes overlying the panel.

The significance of the double inflation must not be overlooked. For a failure of the rip panel seal to have become apparent, there must have been a considerable degree of inflation of the envelope, and consequent stretching of the load tapes, during the first attempt. Once the tape has stretched, the tests indicate that it takes up to 40 minutes to return to its normal length and, as the second inflation at Birmingham followed within 20 minutes of the first, there would have been insufficient time for the load tapes to recover. Thus there may well have been residual elongation, with a corresponding reduction of the rip panel overlap, at the start of the second inflation. With the points discussed in this and the preceding paragraph in mind, the possibility must be considered that the rip panel was subjected to a substantially greater degree of strain immediately preceding the flight than a gentle, even lift of the basket would suggest.

If, due to any of the above conditions or a combination of them, any load tape had stretched sufficiently to apply an opening load to the Velcro then, once it had opened, it would have lost its initial holding strength as it began to peel. Furthermore, the movement of the load tapes would have meant that the two mating surfaces of the Velcro would no longer have overlapped, preventing any likelihood of their coming together again and resealing. Although such a separation was not induced in G-BCCG during the static tests, it was difficult to reproduce exactly the accident conditions in the tests, which were limited by maximum crown temperature considerations and the difficulty in carrying out a representative ascent. Nevertheless, there is sufficient evidence to suggest that an inadvertent opening of the panel may have occurred by reason of the stretching of the load tapes, or that their movement permitted the propagation of an inadvertent opening from another cause.

2.1.2 *Other causes*

Bearing in mind the constructional features referred to in section 2.1.1, a number of alternative hypotheses as to how the opening of the rip panel may have been initiated have also been considered. They are:

2.1.2.1 Incorrect sealing of the rip panel before flight

The pilot abandoned the first attempt at inflation when he noticed that the rip panel was improperly sealed. He then deflated the balloon and went to some trouble, both inside and outside the canopy, to re-seal the opening. Photographic and other evidence indicates that the second inflation proceeded well and the balloon lifted off cleanly. The pilot was experienced in balloon flying and usually careful in his preparation for flight and there is no evidence to suggest that, in this respect, the pre-flight procedure was incorrectly carried out.

2.1.2.2 Tying off

All the 'tie-offs' were either broken or missing when the balloon was examined after the accident. They were unlikely to have survived the 'in-flight' disruption of the rip panel, nevertheless, the pilot was not seen attaching them before the flight and no supply of suitable thread was found with the basket or in the pilot's clothing after the accident. The tie-off thread could have had considerable significance on a balloon with a 2 inch overlap such as G-BCCG, although this may not have been appreciated by the pilot. Had they not been in place, the restraint they provide against inadvertent initiation of a Velcro separation would have been missing, as would the additional support that the threads provide to contain loads across the Velcro. There was insufficient evidence to determine whether the tie-offs were in place, before the flight commenced.

2.1.2.3 Accidental opening of the panel by the rip rope

Although there were a number of inexperienced persons involved in handling the balloon during inflation, photographic and other evidence indicates that the visible part of the rip line, with its usual length of slack, was secured to the burner frame in the normal fashion when the balloon climbed away. Neither of the persons on board were seen handling it during the ascent and, bearing in mind their experience of ballooning, it is considered most unlikely that the rope could have been inadvertently pulled.

The fabric rope part of the rip line was measured and fitted to the balloon in a dry state. However, tests carried out on the rope indicate that its length tended to vary when it was wet, particularly after spending some time in a collapsed state such as when packed into a valise. There have been occasions when balloon rip ropes have been found to be unacceptably short and, although, once again, it was not possible to reproduce exactly the accident conditions, the possibility that there was insufficient length of rope at the commencement of the accident flight cannot be disregarded. Such a discrepancy could, in fact, have accounted for the failure of the rip panel to stay closed for the first inflation. When considering this hypothesis, the hysteresis of the rope must be borne in mind. As it hung suspended in the balloon, its tendency to become drier and resume its normal length would gradually take effect. It could well be that it had recovered sufficiently to permit the second inflation but was still of insufficient length for the ensuing flight. The 'Rugby football shaped' opening in the top of the balloon, seen by a witness at the launch point, is consistent with this theory.

The possibility must also be borne in mind that, with a rip rope of critical length, the deflection of the crown of the balloon, caused by the dynamic loading during the high initial rate of climb, may have fouled the rope and initiated an opening of the Velcro: or entanglement of the rope with one of its connections may have critically shortened its length.

2.1.2.4 Overloading, high rate of climb and envelope distortion

The evidence indicates that the balloon was subject to considerable overload conditions at the time of the flight and it is necessary to consider this factor in conjunction with both the preceding and succeeding sections of this analysis.

The static overload, which occurred before lift-off, resulted from too many people hanging on to the basket at 'weighing off' and the consequent excessive heating of the envelope in an attempt to obtain buoyancy. When those people who were hanging on to the basket were compelled to let go, the force already generated caused the balloon to shoot upwards and the static overload became a dynamic one. As the evidence indicates, the burner was being operated continuously up to a height of approximately 100 feet so it is unlikely that there was any reduction in the loading during the transition into flight, in fact probably the reverse was taking place. It may also be reasonably assumed that it took some time for the balloon to attain its 'generated' rate of climb and that there was, therefore, an accelerative factor in the stresses being applied to the envelope.

The tests indicate that, at some time prior to examination, the metal strips of the over temperature flag had been subjected to sufficient heat to melt the solder although the flag had not separated as it was designed to do. It is not possible to determine when this occurred but no previous occasion of overheating had been reported and the flag is normally examined before flight; whereas there is sufficient evidence to show that the balloon was very hot on the accident flight. Be that as it may as the canopy temperature sensitive link did not function, the pilot would have been under the impression that the crown temperature was within the operating range and would not have known that it had been exceeded. Photographs and statements indicate that the envelope was fully distended as seen from the point of departure and witnesses away from the scene remarked upon an 'apple-core' type of indentation which developed on its upper surface later in the climb. Although it is not possible to state with certainty what effects these phenomena would have had, they are unlikely to have decreased the stresses on the Velcro. Where the crown collapsed inwards, probably due to a high rate of climb, the construction of the balloon is such that the Velcro would have been subjected to a direct 'peel' loading across its width.

2.1.2.5 Surface wind

Consideration has been given to the effect of the surface wind on the flight. Although no proof of briefing, nor any record of meteorological information was found in either the basket or the pilot's possession after the accident, the pilot had expressed his satisfaction with the weather situation prior to inflation. An anemograph recording taken at Birmingham Airport at the time indicated a fairly steady wind blowing from the north at about 10 knots. No appreciable gusts above 12 knots were recorded during the period, no turbulence was reported and no undue buffetting of the envelope was observed. Although the wind direction was unsuitable for the proposed flight, the wind speed was greater than desirable and the launch was made from a built up area with possible local eddies, the conditions were within the balloon's safe operating range and have, therefore, been discounted as a causal factor in this accident.

2.1.2.6 Organisation of the launch and flight planning

The operation was a private flight which the pilot had agreed to conduct as a public demonstration on behalf of the sponsors of the event, who were also the owners of the balloon. Although there was no pressure upon him to make an ascent, it was an important occasion and, therefore, in the pilot's own interests, as well as the owner's, to ensure that the balloon flew if possible and that the maximum advantage was obtained from the event. Photographic evidence indicates that there was a large number of people gathered round the balloon as it prepared for flight, many of whom had no knowledge of ballooning but who, by reason of their connection with the occasion or their desire to assist, became involved with the flight. No doubt it was with the best of intentions that a number of these helped to hold the basket down when it looked like leaving the ground. Nevertheless, the fact remains that, had the 'weighing off' proceeded normally, the pilot may have had less difficulty in assessing the degree of buoyancy he required and calling for 'hands off' when it had been achieved.

There was little performance information available for use at the flight planning stage and only the over-temperature flag and pressure altimeter by way of instruments to measure the performance in flight. Even if the over-temperature flag had operated normally, the limited nature of its function, namely as an indication that the maximum temperature had been exceeded, was of minimal use as a performance aid. Similarly, the altimeter was too imprecise an instrument to indicate the performance being achieved. It is considered that, despite the pilot's considerable experience with balloons, his first indication that the balloon was over-buoyant and possibly unsafe to fly probably occurred after it had left the ground when it was too late for any remedial action to be taken.

2.1.3 *Compliance with regulations*

No representative of the CAA visited the proposed launching site after permission to conduct the flight had been sought by the sponsors. Consequently, the 'Permission' was granted on the basis of the inaccurate map and in the absence of information regarding the high tension cables nearby. However, the CAA had the right to expect the pilot to observe the restraining conditions in the permission. The decision as to whether the flight should be free-flying, tethered or abandoned altogether was left to the pilot's judgment, in the event he did not comply with the conditions in the following respects.

Condition (c) The general area forecast was for the wind to remain northerly. The actual track flown by the balloon was 185°(T) and the operation took place, therefore, outside the permitted sector.

Condition (e) Fortuitously no damage was caused to persons or property on the ground; however, in view of the circumstances, the flight cannot be considered to have been conducted within the terms of this condition.

Condition (f) There is strong photographic and other evidence that, at its early stages, the operation was in breach of this condition.

Condition (g) The undisclosed presence of high tension wires on towers and of other obstructions in the vicinity, precluded the possibility of compliance with this condition. (see Appendix 1)

Condition (i) As the exemption from the aerial work limitations of the pilot's private pilot's licence had lapsed on 30 August 1974, he was in breach of this condition.

2.1.4 *The launching site*

Investigation indicates that despite the general unsuitability of the site for balloon launching and the breaches of the 'Permission' that occurred, the actual flight intended was within the performance capabilities of the balloon and would probably have been successfully accomplished with a normal operation.

2.1.5 *General*

The investigation revealed that there was a remarkable dearth of factual information available to manufacturers and pilots of hot air balloons. It is desirable that information should be provided concerning operating limitations in terms of maximum buoyancy and maximum rate-of-climb permissible. The means of measuring these quantities to a sufficient degree of accuracy should be available to the pilot. In addition, guidance as to the dimensional limitations applicable to the canopy and rigging should be provided and devices to improve the security of the rip panel should be specified.

2.2 Conclusions

(a) *Findings*

(i) The balloon was wet when unpacked from its valise prior to flight.

(ii) The all up weight of the balloon was less than the maximum permitted for flight.

(iii) The commander was adequately experienced for the flight and was the holder of a valid private pilot's licence for balloons and airships. He did not possess either a valid licence authorising him to fly for the purpose of aerial work, or the appropriate exemption as required by the CAA in the permission granted.

(iv) The weather was not unsuitable for the proposed flight.

(v) The burner and associated controls functioned correctly.

(vi) Although the fusible link had melted, the temperature warning flag in the canopy failed to fall and, therefore, did not give the correct indication to the pilot that the maximum permissable air temperature had been exceeded.

(vii) The balloon lifted off with a high degree of buoyancy, causing a high initial rate of climb with consequent envelope distortion.

(viii) At a height of approximately 800 feet the rip panel opened in flight allowing all buoyancy to be lost and the envelope to collapse.

(ix) The balloon fell vertically to the ground from a height of approximately 450 feet.

(x) The load tapes stretch under load and stay elongated for some time after the load has been removed.

(xi) The static rip panel length exceeded that of the associated load tapes by approximately 2 inches.

(xii) Under normal operating conditions the slack in the rip panel was taken up by the initial load of 20 lb per tape.

(xiii) The rip panel Velcro sealing strip was carrying loads in flight for which it was not designed.

(xiv) There was no safety device on the rip panel to prevent its inadvertent opening in flight.

(xv) Insufficient performance information was available to the pilot either before or during flight.

(xvi) The pilot did not observe conditions (c) (e) (f) (g) and (i) of the permission granted for the flight.

(b) *Cause*

The accident was caused by the opening of the rip panel in flight allowing all buoyancy to be lost and the envelope to collapse. Although it was not possible to identify with certainty why this happened, it was established that the panel overlapped its aperture by no more than 2 inches. The stretching of the load tapes, which allowed the closure strip to be subjected to static and dynamic loading, is considered to be a contributory factor in the accident.

3. Recommendations

It is recommended that:

(1) An examination be made of the suitability of the nylon load tape material used in balloons.

(2) Hot air balloons should be so constructed that the Velcro sealing strip does not carry lifting loads and the rip panel overlap is adequate.

(3) Hot air balloons should be periodically examined to check load tape dimensions and stretch.

(4) An adequate length of rip rope for all conditions of service be fitted and maintained in all hot air balloons.

(5) Means of preventing an inadvertent opening of the rip panel be fitted to all hot air balloons.

(6) More performance information be provided for the operators of hot air balloons.

(7) A minimum standard of instrumentation in hot air balloons be introduced.

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Department of Trade

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