ACCIDENT

Aircraft Type and Registration:	Cameron O-120 hot air balloon, G-BVXF
Year of Manufacture:	1994
Date & Time (UTC):	1 January 2011 at 0947 hrs
Location:	Midsomer Norton, Somerset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Fatal) Passengers - 1 (Fatal)
Nature of Damage:	Balloon destroyed
Commander's Licence:	Private Pilot's Licence (Balloons and Airships)
Commander's Age:	42 years
Commander's Flying Experience:	194 hours on balloons Last 90 days - 2 hours Last 28 days - 0 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot was attempting to climb to an altitude of 6,000 m (approximately 19,700 ft). Having reached an altitude of 21,500 ft the balloon descended for about 80 seconds at approximately 1,500 ft/min. It then entered a rapid descent of approximately 5,500 ft/min from which it did not recover. In the latter stages of the descent the envelope was seen in a collapsed, 'streamered' state. There was a post-impact fire, which damaged much of the balloon basket and envelope.

The British Balloon and Airship Club (BBAC) and the balloon manufacturer actively assisted in the AAIB investigation. As a result of the accident the BBAC will be issuing guidance information for operation of hot air balloons at high altitudes.

Background information

One of the elements for award of the BBAC Gold Badge is to achieve a flight to an altitude of over 6,000 m amsl. The pilot was attempting this element. There have been 23 successful Gold Badge flights over 6,000 m altitude in the UK, and additionally there have been numerous flights over 4,000 m made by British balloon pilots in the Alps.

Members of the ground crew recalled that the pilot started planning for the attempt in October 2010. During the following months the pilot spoke to other balloonists experienced in high altitude flights, seeking advice from them. They all commented that, from the pilot's questions, they considered his preparation was thorough. The pilot acquired the Cameron O-120 from a leasing company on 19 December 2010; this was his first flight with a Cameron O-120 with a 'lock top' fitted. To reduce mass a smaller basket from another balloon was used. The pilot and passenger had flown together in this basket several times before.

The pilot obtained written approval for this altitude attempt in the form of an Airspace Co-ordination Notice from the CAA on 21 December 2010. This stated a 'launch window' from 27 December 2010 to 4 January 2011, with an estimated flight duration of 90 minutes, and '*vertical limits from the surface to FL210'*. The pilot was required to phone Bristol ATC 24 hours before the launch and on the morning of the flight, to discuss anticipated rates of climb and descent; this he did.

Aircraft description

The envelope was a Cameron O-120 which has a volume of 120,000 cubic feet (Figure 1). This type of envelope has a 'parachute valve' which allows the controlled release of hot air (venting) and, for landing, the complete deflation of the envelope. It takes the form of a circular parachute-style panel that seals on a circular opening in the top of the envelope (Figure 2). The parachute valve is held in place by a combination of the internal pressure of the hot air and a set of centralising lines inside the balloon (12 for this design of balloon). For venting, a red line is pulled in the basket and the valve is held open for a few seconds, whereas for deflation it is pulled further and held open until the envelope deflates.

This balloon envelope was fitted from new with a 'lock top' landing deflation system. This is a modified parachute valve, fitted to larger envelopes. The centralising lines are longer and allow the red vent line, and thus the parachute valve, to be pulled down further for faster final deflation. At the top of the envelope there is a large metal ring called the 'crown ring' and to

Figure 1
Envelope, G-BVXF

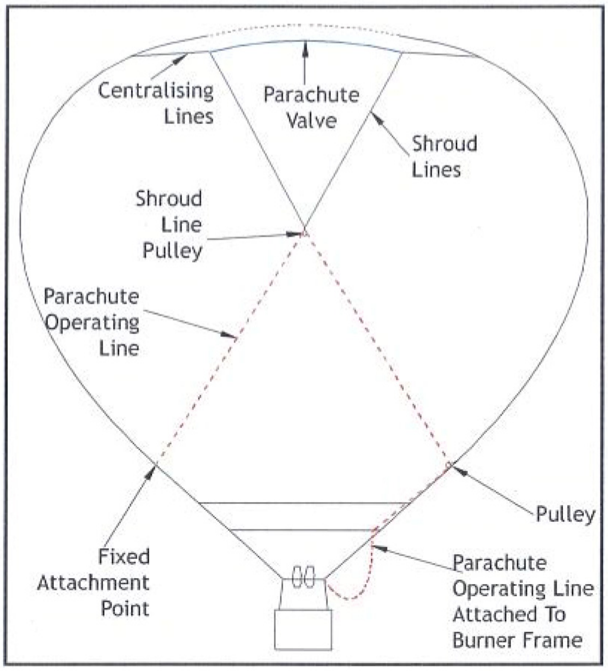

Figure 2
Parachute valve

which the 'crown line' is attached; the other end of the crown line is free and is used for ground handling. The centre of the parachute valve is attached, on a lock top system, to the crown ring by a snap shackle (Figure 3). With the connection rings from the crown ring and the parachute valve secured inside the snap shackle the parachute valve can only be partially opened; this is to prevent the deflation mechanism operating without an additional control decision to arm the system.

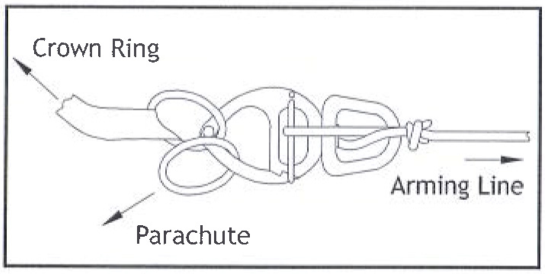

Figure 3

Release shackle assembly

On the final approach to land a yellow and black 'arming line' is pulled to release the snap shackle and a flag marker appears inside the envelope to indicate visually that the system is armed. With the system armed, the red vent line can then be pulled down to a position where the hot air will vent rapidly. Shortly after this point, re-inflation of the envelope will not be possible.

In preparation for launch the yellow and black arming line, and the red parachute valve operating line, are normally stowed by attaching their free ends to the burner frame.

This balloon was fitted with two burners. Each burner had a pilot light, a main burner and a 'whisper' burner. For this flight four gas cylinders were carried, with two connected to the burners at any time. The system featured a cross-flow valve, allowing both burners to be fed from one cylinder. Each cylinder had a pressure relief valve, which would activate in the event of elevated pressure, from exposure to a fire for example. Vertical control of the balloon in flight is achieved by a combination of use of the burners, natural cooling and by venting hot air through the parachute valve.

Two temperature sensors were fitted to the balloon. A 'temperature streamer' was fitted insider the top of the envelope and was held in place by a solder designed to melt at 127°C; if the temperature exceeds this value the solder melts and the streamer falls down through the mouth of the envelope alerting the crew. There was also a 'tempilabel' indicator, which is mounted in the top of the envelope and which has temperature-sensitive areas that change colour at different temperatures between 90°C and 150°C, thus providing a permanent record of the maximum temperature that the fabric has reached.

Two radios were carried, one for communication with ATC and one for use with the ground crew. A variometer/altimeter, which measures altitude and rate of climb and which belonged to the pilot, was fitted to the burner support frame. A transponder was also used which informed ATC of their altitude, and a barograph was carried to ratify the attempt.

This balloon type has been certificated to EASA.BA.013 which includes requirements for the ability to control the balloon safely during all phases of the flight.

History of the flight

The pilot, passenger and ground crew arrived at the launch site at Chelwood, 7 nm east-south-east of Bristol International Airport at approximately 0800 hrs on 1 January 2011. A BBAC observer was also present to ratify the flight.

The rigging of the basket and the envelope proceeded under the supervision of the pilot. Just before cold inflation of the envelope it was noticed that the crown line was tangled around some of the crown webbing lines. This was untangled before cold inflation commenced. At about the same time, one of the ground crew, who was manning the line attached to the crown ring and who was also a trainee balloon pilot, noticed the lock top. Not knowing what it was he asked the pilot, who explained its usage, adding it was only to be used on the ground; he was heard doing so "in a confident manner". The same member of the ground crew also witnessed the pilot clip the lock top snap-shackle closed with at least one, and possibly two, of the rings required. Cold inflation was then completed without further event.

The pilot and passenger were both seen to don their supplementary oxygen system and test it (see the 'Personal equipment' section below for detailed description). They were heard to say they had set the flow rate to 4 litres/min. It is believed that the cylinder was then turned off to preserve oxygen.

After cold inflation the pilot inspected the balloon externally (twice) and internally, before hot inflation commenced. Hot inflation commenced using an external cylinder, which was subsequently disconnected and left on the ground as planned. This was to ensure the maximum amount of fuel from the four cylinders in the basket was available for the flight.

The pilot got into the basket first and the passenger then joined him whilst the balloon was still attached to a recovery vehicle by a tether. Witnesses observed that a parachute valve check was completed successfully by the passenger pulling on the parachute valve operating line and saying "parachute released", to which the pilot replied "yeah ok".

The pilot then coiled up the end of the lock top arming line and secured it under a Velcro tape, out of the way on top of the uprights on the burner frame and said "we don't touch that". It is believed, from photographs taken at the launch, that the lock top arming line had not been secured to the 'lower tie point' within the balloon envelope, leaving the possibility of the lock top being accidentally armed before the line was secured.

The end of the parachute valve operating line was attached to a cylinder and the end of the crown line was clipped to the frame.

At this point the pilot made a radio call to Bristol ATC requesting takeoff clearance. After takeoff the balloon was seen to rise quickly before it disappeared into the cloud.

The ground crew cleared the launch site and drove off in a south/south-easterly direction towards Radstock/Midsomer Norton. The ground crew driver believed the flight would last at least one hour as the pilot had suggested that the descent would be at approximately 500 ft/min and hence would take around 40 minutes from 20,000 ft.

At about 0936 hrs the ground crew received a call from the passenger saying they were at 4,000 m and that they had burnt the fuel in the 60 litre cylinder , more than they had expected, and were not sure if they would achieve their objective. At the same time the pilot transmitted to Bristol ATC that they had a "small problem" with the balloon and were descending. The balloon was then observed on radar to continue climbing. About 2 minutes later the pilot transmitted to ATC that they had fixed the problem and were continuing the climb.

At 0940 hrs there was a short exchange between the pilot and ATC as he sought confirmation from the radar of their current passing level. After he was informed that the balloon was at FL205 he told ATC that they were "now descending". ATC transmitted their level as FL215 at 0942 hrs. This was the highest altitude indicated on the radar; there was no reply to this transmission. The ATCO later commented that he was not concerned when he saw the balloon pass FL210 in the climb. He added he would have questioned the pilot's intentions if he saw it climbing through FL250.

The ground crew heard from the passenger at about 0942 hrs when he transmitted that they were at 6,600 m (21,780 ft amsl) and were starting their descent. Nothing further was heard from the balloon by the ground crew or ATC. There was a carrier wave transmission at 0943 hrs, though its source could not be verified. There was no sign of stress in the voices of the balloon occupants during any of the transmissions.

The balloon was 'heard' by several witnesses and then seen in a 'streamered' condition by several witnesses as it appeared below the cloud falling vertically down at speed. Some of the witnesses believed they saw the burners lit during the final moments of the flight, which might have been indicative of attempts to re-inflate the envelope. The balloon crashed in Midsomer Norton, Somerset, on a bowling green, after which an intense post-impact fire ensued. Video footage of the fire on the ground was captured by a passer-by, in which intense vertical flames were visible from the location of the basket on the ground. Both occupants died as a result of the accident.

Weather information

An aftercast was provided by the Met Office for the period of the flight. In summary it stated that at the time of the accident the Midsomer Norton area was dominated by a ridge of high pressure. This maintained a fairly uniform sheet of broken or overcast cloud with a base of approximately 2,000 to 2,500 ft and a cloud top of 3,500 to 4,000 ft. Above this level the aftercast indicated that there was likely to be little or no cloud.

At the surface, the aftercast indicated that the visibility was 11 to 13 km and with a 5 to 10 kt westerly surface wind. The ground air temperature was approximately +4ºC. Through the depth of the atmosphere, the temperature fell with height to -34ºC at FL240, with the temperature at FL210 being -30ºC.

Wreckage site

The wreckage was located on a bowling green. The envelope had collapsed on top of the basket and there was significant fire damage. The crown ring had not fallen on top of the basket; instead it was approximately 8 m from the basket in a direction consistent with the wind direction. A fire had consumed most of the basket and most of the envelope within a radius of approximately 6 m from the basket. The parachute valve, which would normally be underneath the crown ring and inside the envelope, was found in a position consistent with the parachute valve having been above and outside the main envelope when the envelope struck the ground. The snap shackle was found in the open position and with the cord tangled around it several times. All the wreckage was found within the boundary of the bowling green club, and there was no evidence of an in-flight break-up.

The two burners were found intact and still attached to the burner frame; the latter was severely deformed, probably as a result of the landing forces. The pilot light on each burner was in the ON position, and on one of the burners the whisper burner control was in the half open position. Such a position would not be unusual and might have indicated that the whisper burner was effectively being used as a pilot light. At higher altitudes, where there is a reduced level of oxygen, problems with pilot lights can occur. Two of the propane cylinders were attached to the burners with both vapour and liquid hoses consistent with normal operation. There were two other cylinders. All four cylinders were found empty and fuel remaining in any of the cylinders would probably have vented out as a result of the pressure relief valves operating during the fire. There was significant heat damage to the cylinders' seals and the aluminium hand wheels on each of the main valves had melted.

The supplementary oxygen cylinder was found in the wreckage of the basket. It was badly fire damaged and the hand wheel on the main valve was missing. The short rod that connected the hand wheel to the main valve was found approximately 10 m from the cylinder and on an area of the bowling green away from other items of wreckage. There were scorch marks on the grass around the rod.

Aircraft mass

The Cameron O-120 envelope has a volume of 120,000 cubic feet, for which the flight manual specifies a Maximum Take Off Mass (MTOM) of 1,088kg. The Cameron Flight Manual (Issue 10, amendment 8) states:

> *'For balloons of 105,000 cubic feet and above the Minimum Landing Mass (MLM) for normal operations must not be less than 50% of the Standard MTOM. For special flights, record attempts etc., with only necessary crew on board, lower masses may be used at the pilot's discretion.*
>
> *The maximum rate of climb for balloons with a volume of greater than 105,000 cubic feet and less than 340,000 cubic feet is 1,000 ft/min.'*

The pilot had elected to fit a smaller basket from another balloon to reduce mass and hence give better climb performance. The estimate of the mass of the balloon at the apogee of the accident flight and at zero fuel is contained in Table 1.

	Mass at apogee (kg)	**Mass with zero fuel** (kg)
Envelope	145	145
Burner	24	24
1 x 60 litre cylinder (empty)	22	22
3 x 40 litre cylinders	102 (assumed 2 full cylinders)	60 (3 empty cylinders)
Basket	75	75
2 pilots + kit	180	180
Other equipment	27	27
Total	575 (53% of MTOM)	533 (49% of MTOM)

Table 1

Estimate of balloon mass

Typical balloon operation tends to be at around 70-80% MTOM. This balloon was being operated close to the 50% of the MTOM limit, and as such would have had handling qualities that were slightly different from those at higher masses.

Flight Manual information for the parachute valve

The Flight Manual contains the following information in the Normal Procedures section for lock top operation:

> *'To release hot air during the flight the venting line should be pulled. Great care must be taken not to stall the parachute valve when the arming line is not used.*
>
> *Warning: in the unlocked state an extended pull on the parachute operating line beyond the limits in section 2.11 may cause the parachute to 'stall'. The parachute will not then re-close.*
>
> *Note: when the take-off mass of the balloon exceeds half of the standard MTOM, it is no longer necessary to arm the vent prior to use. It is therefore not necessary to rig the arming line after the parachute has been tabbed into place. Great care must be taken however not to stall the parachute when the arming line is not used.'*

And in Section 2.11 Limitations:

> *'The parachute valve must not be held open for periods longer than 3 seconds during flight. The envelope must be allowed to re-inflate fully and the envelope mouth must be seen to be fully open before subsequent operations of the vent.'*

Flight manual information for hard landings

The Flight Manual contains the following information in the Emergency Procedures section:

> *'If the rate of descent cannot be controlled, consider jettisoning all disposable ballast, including fuel cylinders which are not in use, if it is possible to do so without endangering people or property on the ground.*
>
> *A burner or envelope failure results in a 'heavy' landing where the speed is mostly vertical…*
>
> *In a heavy landing the occupants should brace themselves against vertical compression, with their knees only slightly bent. The rope handles or cylinder rims should be firmly held.…*
>
> *Extinguish the pilot light(s), shut off at all cylinders in use and empty the hoses if time permits.'*

Maintenance records

The balloon envelope had recently had its annual inspection and had been issued with a Certificate of Release to Service on 18 December 2010. The accident flight was the first flight of the envelope after the inspection. The envelope material had passed a 'grab test' to check the structural integrity of the material, 110°C was the recorded tempilabel value and the envelope had flown for a total of 270 hours at the time of the accident.

Recorded information

Radar

Recorded radar data from Clee Hill and Burrington radar heads, giving positional information for G-BVXF during the accident flight, were available for the investigation. The radar ground track is illustrated in Figure 4. The track starts at 0923:10 hrs just to the south-east of the launch site with the first altitude returns starting 4½ minutes later as the balloon passed through 6,300 ft amsl (probably when the transponder was switched on). The track ends at 0946:30 hrs north-east of the accident site with the balloon at 2,000 ft amsl (ie about 1,600 ft agl), descending rapidly.

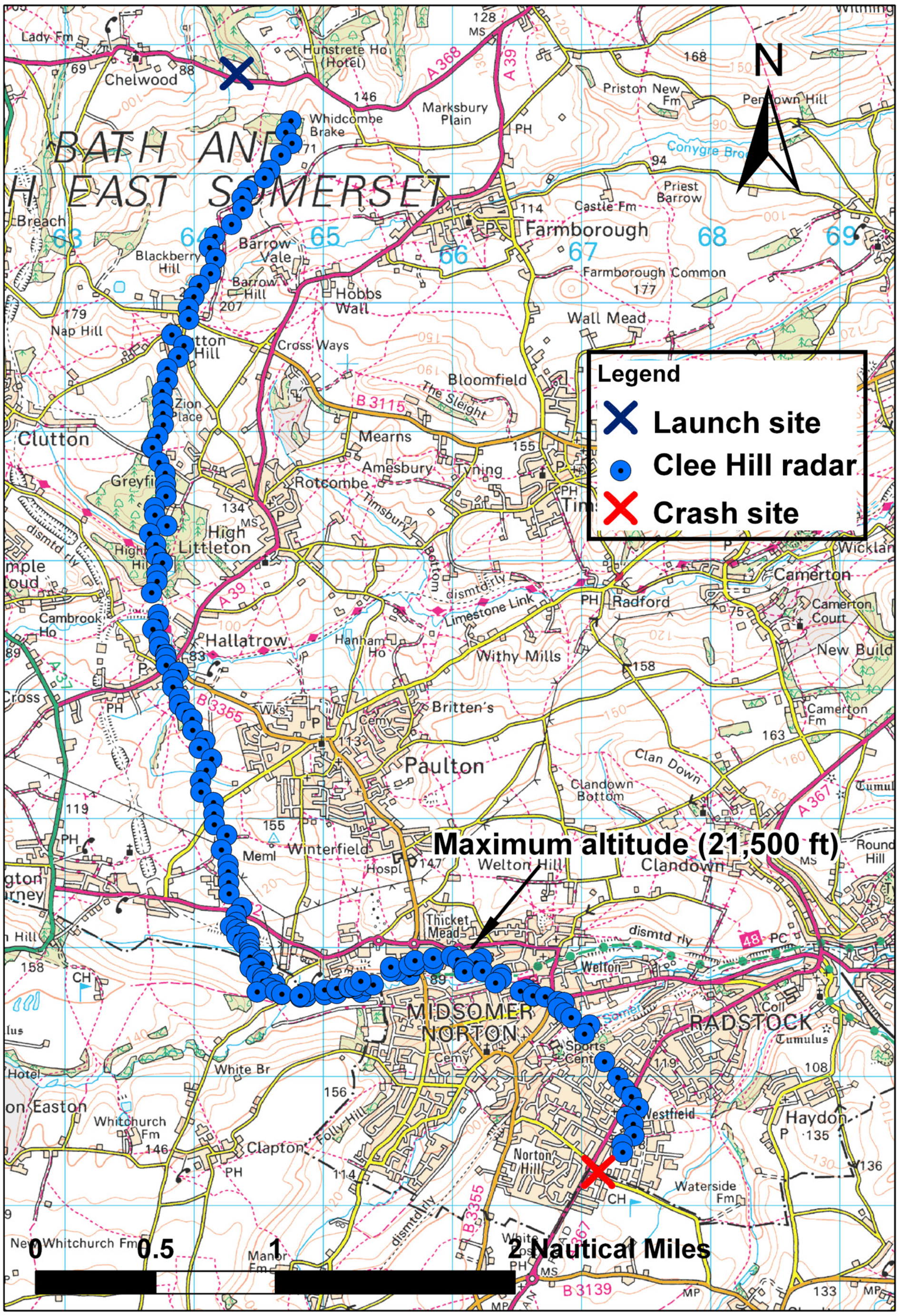

Figure 4

Accident track of G-BVXF from radar information

The altitude profile of the accident flight, near the top of climb, is shown in Figure 5 and shows that a maximum altitude of 21,500 ft amsl was reached just before 0942 hrs. The vertical climb rate and acceleration, calculated from the altitude and time information is also shown. During the ascent the rate of climb exceeded the 1,000 ft/min maximum specified in the Flight Manual.

The figure also compares the accident flight to a successful Gold Badge flight from a different, but similarly sized, balloon as well as to the non-fatal accident flight of N61ZL in the USA in August 2008. During the flight of N61ZL part of the top of balloon was destroyed by heat from excessive use of the burners and as a result the envelope deflated and 'streamered'[1].

Of note is that the transition from climb to descent for G-BVXF was more marked than the gradual transition on the comparison Gold Badge flight, which was made by turning off the burners and waiting for cooling to initiate a 'cold descent' and was without any venting.

There are broad similarities between the data for the G-BVXF and N61ZL accident flights. In the case of G-BVXF there were approximately 80 seconds of descent (after the maximum altitude) at approximately 1,500 ft/min before it commenced a high-speed descent at around 5,500 ft/min. This high-speed descent from 19,750 ft to the ground took approximately 3½ minutes. It was confirmed by calculation that the gradual decrease in rate of descent was consistent with the air density increasing closer to the ground and hence the balloon was almost certainly 'streamered' for these 3½ minutes.

Footnote

[1] Source: National Transportation Safety Board - August 2008 Aviation Accidents

GPS and loggers

A number of GPS units and flight data loggers were recovered from the accident site; however, these were damaged during the post-impact fire such that no recorded data was recoverable. No meaningful information could be obtained from the memory in the variometer/altimeter.

Detailed examination of the wreckage

The envelope was inspected. Approximately 40% of the area of the envelope had been destroyed by fire and there was no evidence of a significant tear in the remaining panels. The panels that were fire damaged were those closest to the basket at the wreckage site, which was consistent with fire damage occurring on the ground. Several panels were 'grab' tested by an experienced BBAC inspector to assess the material strength of the canopy; all panels that were tested passed the test.

The tempilabel indicated that 121°C had been reached on the accident flight, as this was the first flight since the envelope inspection (when the tempilabel was noted as 110°C). The tempilabel was sufficiently far from fire damaged panels that it was unlikely to have been affected by heat from the post-impact fire. The temperature streamer was missing (it was present before flight), indicating that 127°C had been reached. Whilst the solder attachment for the streamer was within a metre of part of the envelope that had been heat damaged, there were no traces of solder close to the attachment location and hence it was concluded that the temperature streamer had dropped during the flight. Although the envelope had exceeded 127°C during the accident flight, this slightly elevated temperature was not considered a factor in the accident.

A detailed inspection was made of the top of the envelope, including the parachute valve, and approximately 30% by

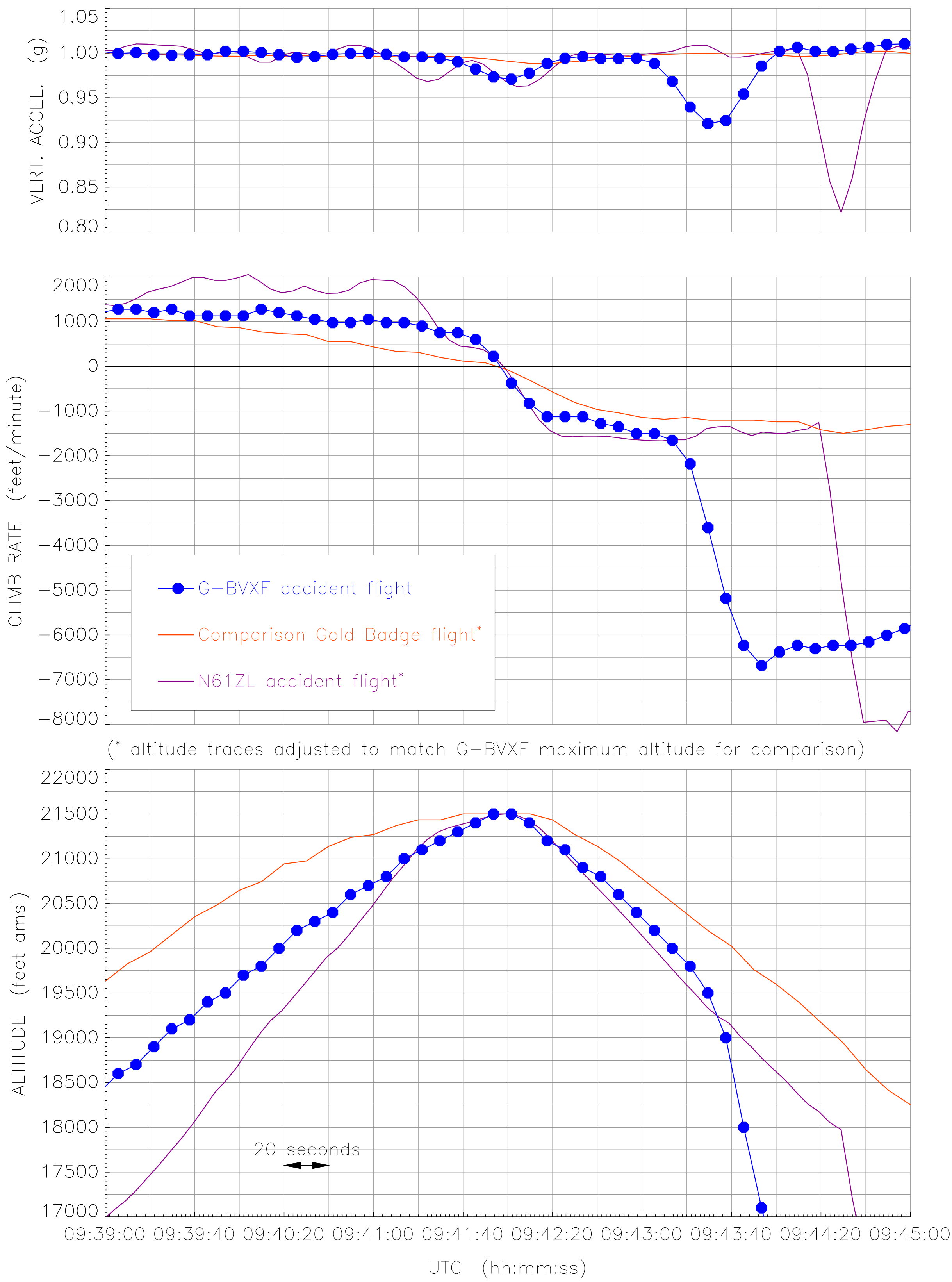

Figure 5

Altitude, climb rate and acceleration comparison at top of climb of G-BVXF, 'Gold Badge' flight and accident flight of N61ZL. Climb rate and accelerations calculated from altitude and time information area of the parachute valve had been destroyed by fire. There was a small tear, approximately 35 cm long, across the central circular panel, a complicated tangle of line around the snap shackle and several areas of damage to the loading tapes. All these areas of damage could be explained by turbulent aerodynamic forces on the collapsed envelope taking place over a significant period of time, possibly several minutes. The snap shackle was found to operate correctly, and it was concluded that for the complicated tangle to occur the snap shackle would have to have been open for a significant portion, if not most, of the descent. It was also concluded that the parachute may have exited through the crown aperture during the descent, the mechanism for this being the parachute capturing a small amount of air and the main envelope 'concertina-ing' in the turbulent flow.

The four propane and the oxygen cylinders were inspected and filled with water to check for leaks; no leaks were found.

Personal equipment

The pilot had hired a supplementary oxygen system which supplied oxygen from a single bottle which was connected to individual pulse dose meters and then to nasal cannulae (Figure 6). The oxygen bottle had a hand wheel to open and close the main valve, mounted at the top of the cylinder, and next to the valve was a regulator. The regulator had a rotary flow control, with an integrated dial for flow settings 1-6. The nasal cannulae were mounted in a circular length of tubing placed over the wearer's head, and this circular tube was connected to the output of the individual pulse dose meters.

The system was hired a few days before the accident with a cylinder pressure of 200 bar, which was sufficient oxygen for approximately 4 hours for two adults. The equipment that was hired included four nasal cannulae; two had an additional in-line indicator mounted 100 mm from the end of the circular length of tubing, such that each time oxygen is supplied a bright green indication is made, and two cannulae were without the inline indicator. A review of photographs taken just prior to the flight confirmed that the supplementary oxygen system appeared to have been set up correctly; however, both occupants were wearing the cannulae without the in-line indicators. The passenger was wearing the oxygen bottle in a bespoke rucksack, with the hand wheel valve and regulator exposed at the top of the rucksack behind his neck, in this position the valves would not have been readily accessible to the passenger.

Neither occupant was wearing a parachute.

Inspection of supplementary oxygen system

The remains of the supplementary oxygen system were inspected. The two pulse dose meters and nearly all of the tubing were not found and would have been destroyed in the fire. The oxygen cylinder was inspected with the manufacturer present. Whilst the hand wheel for the valve was missing, probably consumed in the fire, it was possible to determine with high confidence that both the

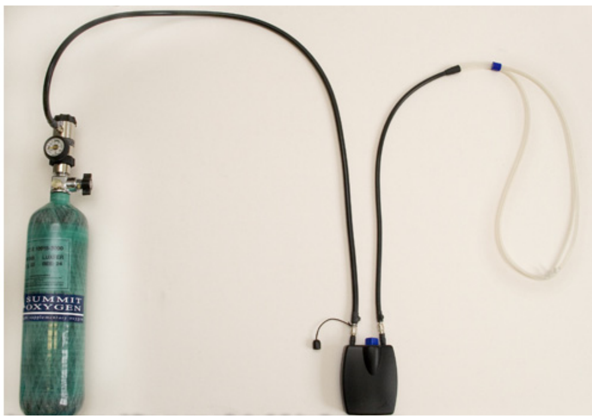

Figure 6

Supplementary oxygen system similar to that carried on the accident flight (one pulse dose meter and one nasal cannula attached) main valve and the regulator were closed. Either one of these being closed would result in no oxygen being supplied to either pulse dose meter.

There was no oxygen left in the cylinder and there was damage to the housing for the main valve. This damage, and the fact that the connecting rod for the hand wheel had been found approximately 10 m from the oxygen cylinder at the wreckage site, was strong evidence that the oxygen cylinder had contained gas at pressure when the balloon struck the ground, and that the pressure had been released as a result of the post-impact fire.

Medical information - hypoxia

A lack of oxygen in the blood and ultimately the brain is a condition known as hypoxia. The effects of hypoxia on the individual are related to altitude and are for practical purposes negligible under 10,000 ft for a healthy individual. As altitude increases then the effects of hypoxia become more pronounced although there is considerable variation between individuals. At between 10,000 and 15,000 ft symptoms in resting individuals are likely to be minimal, but mental performance is likely to be impaired. At between 15,000 and 20,000 ft mental performance deteriorates further, with loss of critical judgement and mood changes, and a lack of awareness of the adverse effects. Above 20,000 ft the symptoms are markedly worse and unconsciousness can rapidly occur.

At 22,000 ft (just above the peak altitude of the accident flight) the time of useful consciousness is around 10 minutes, although there is great variation depending on the individual. This figure also relates to sudden exposure to that altitude. A gradual increase in altitude, as happened during this flight, would mean that the effects of hypoxia would build up during the ascent, so the time of useful consciousness at the peak altitude would be considerably less than this figure.

Medical information - pathology

The post-mortems were carried out by a consultant aviation pathologist. He concluded that the pilot was killed as a result of the injuries sustained in the impact. The passenger, while severely injured in the impact, died in the post-impact fire. There were no signs of drugs or alcohol in either occupants' blood.

The pathologist reviewed the photographs taken before the flight to assess the suitability of the occupants' clothing. Both occupants appeared to have been wearing warm clothing suitable for use at or around sea level in the UK on a cold day in winter. Physical activity and exposure to a cold environment increases the body's demand for oxygen. Whilst it is unlikely that the occupants would have been engaged in strenuous physical activity, they would have been exposed to an outside air temperature of -30°C at the peak altitude. The pathologist commented that, if the occupants' clothing did not keep them thermally neutral, then they would have had an increased susceptibility to hypoxia.

Pilot's and passenger's experience

The pilot gained his PPL(B) in November 2001. He had logged a total of 194 hrs, of which 160 hrs were in command, in various types and sizes of envelopes. While some of the types listed had a rapid deflation system none of them had a lock top fitted.

He worked for the balloon manufacturer from April 1995 until June 1997 and again from May 1998 until 2004. During that time he was employed principally as a mechanical engineer working on burner units. However, he also often acted as a member of the team taking balloons out for test inflations where he may have helped to operate some of them on test and gained some knowledge about lock tops.

The passenger had completed his PPL(B) General Flying Test (GFT) on 14 April 2010 and had a total of 39 hours under training. As he had not completed his ground exams he had not applied for his licence to be issued. His log book showed that he had predominately flown with the accident pilot since he had completed his GFT. He had no experience of lock tops.

The pilot had used a nasal cannula on a flight to approximately 12,000 ft amsl in 2003, albeit using a different supplementary oxygen system from that on the accident flight. The other occupant on that occasion noticed that the accident pilot was breathing through his mouth for the majority of the time.

There was no evidence that either occupant had experience of flying in controlled airspace at altitude.

Analysis

There were several items that require analysis to determine the causal or contributory factors in this accident.

Radar information

A key piece of evidence was the height profile from the radar, Figure 5. Comparing the altitude profiles of the accident flight with another Gold Badge flight (for which the descent was initiated by not using the burners and not venting) strongly suggests either the envelope of G-BVXF was vented or there was a significant leakage of hot air due to an envelope failure. The high rate of ascent, which reduced only slightly prior to the apogee at 21,500 ft, is indicative of an intact balloon envelope at that stage; it is likely that the CAA approval to FL210, already passed, could have led the pilot to decide to initiate a more rapid descent than he had originally planned.

Supplementary oxygen system

Another key piece of evidence was that the main valve, and the regulator, on the oxygen cylinder were found in the closed position. It is possible that these had been opened at high altitude but were closed during the descent. However, given that both valves were found closed, that the valves were located in a rucksack and hence not readily accessible, and that the pilot and passenger were probably focussed on trying to re-inflate the envelope during the rapid descent, the closing of the valves during this descent is unlikely.

There was evidence from the communications with Bristol ATC that both occupants were conscious and not in distress just prior to the descent. The radio call suggested that the descent was being initiated, which implies that a pull on the parachute valve line was planned, rather than simply turning off the burners and allowing time to transition to a cold descent. If the supplementary oxygen was not being used during the flight then the occupants would have been subjected to conditions where hypoxia would have had the potential to affect their decision making, their performance and, ultimately, the ability of the pilot to control the aircraft safely.

Envelope inspection

The inspection of the envelope did not reveal any abnormality that could have contributed to the accident. The tear in the parachute valve, which probably occurred after the balloon was 'streamered', was in itself too small to cause the envelope to deflate rapidly and would not have significantly affected flight performance. The temperature indicator revealed that the balloon had been hot, but not excessively so, and hence any heat-induced failure of the envelope is unlikely. There was significant fire damage to the envelope, which could readily be explained by the proximity of these areas of the envelope to the basket where video evidence confirmed there was an intense ground fire. If there was a large tear at the top of the balloon, the evidence could have been destroyed by ground fire. However, such a tear would have to have occurred shortly after the radio call informing that the descent was commencing, which, whilst possible, is very unlikely.

Post-impact fire

The pilot lights and burners were found in positions that were reasonable for normal operations. At high altitudes pilot lights are susceptible to going out and a partially open whisper burner being used as a pilot light is not unusual. Given the 3½ minute duration of the descent with the envelope collapsed, the pilot and passenger did, in theory, have enough time to shut off the cylinders and switch off the pilot lights; however, they were probably focussed on trying to re-inflate the envelope. Whilst it was not possible to determine precisely how the ground fire started, the pilot lights and/or the whisper burner would appear to be the most likely ignition source, with propane (either through fuel pipes or through a leak or rupture sustained when the system struck the ground) being the most likely fuel source. Once the fire took hold, propane in the remaining cylinders would have been vented through the pressure release valves, supplying additional fuel to the ground fire.

Pilot's experience

The pilot had flown several types of balloon and was familiar with the basket and burner systems used on the accident flight. However, he might have found this flight challenging given that:

a) This was the first flight he had made with a lock top deflation system

b) This flight was made with a large balloon, at a low mass and at a high rate of climb, which probably handled differently from other combinations he had flown

c) He had not used this type of supplementary oxygen system before

d) He may have been concerned about exceeding his altitude clearance with ATC.

It was not possible to determine accurately how much the pilot knew about the lock top deflation system, but he did have 194 hours on all balloon types and had significant experience with parachute valve systems. The evidence from the ground crew suggests that the lock top was correctly rigged prior to flight. The comments the pilot made about the lock top arming line suggests that he was aware that care was required when using it.

Parachute valve operating and lock top arming lines

The parachute valve operating line was attached to a cylinder prior to launch. This is not the normal location and there is a possibility that it did not allow sufficient slack in the line to accommodate changes in the envelope shape during the climb. However, it is considered very unlikely that this was a factor in the accident.

Witnesses observed that the lock top arming line was secured to the burner frame prior to launch, although the line had not been secured to the 'lower tie point' within the envelope. There is, therefore, a possibility that the lock top might have been inadvertently armed before the line was secured. However, had this occurred, a flag marker would have appeared within the envelope and it is considered unlikely that an inadvertent arming was a factor in the accident.

Summary

There was no evidence of a technical defect in the balloon or of an in-flight structural failure. It is likely that the accident occurred as a result of some combination of a mishandled parachute valve, inexperience of lock tops, inexperience with a large balloon at high rates of ascent, degraded human performance due to some level of hypoxia and pressure to descend as the approved Flight Level was about to be breached. However, it was not possible to determine which factors were most applicable in this accident.

Safety advice and safety actions

The advice and warnings in the Flight Manual about use of the lock top deflation system and venting line are considered valid and hence no additional safety action or Safety Recommendation is appropriate.

The post-mortem revealed that one of the occupants survived the ground impact, but not the post-impact fire. Both pilot lights were found in the ON position, and one of the whispering burners was partially open. Had the valves on the propane cylinders been closed and the pilot lights extinguished, the accident might have been survivable. The advice in the Flight Manual is considered valid and is as follows:

> *'If the rate of descent cannot be controlled, consider jettisoning all disposable ballast, including fuel cylinders which are not in use, if it is possible to do so without endangering people or property on the ground.*
>
> *A burner or envelope failure results in a 'heavy' landing where the speed is mostly vertical…*
>
> *In a heavy landing the occupants should brace themselves against vertical compression, with their knees only slightly bent. The rope handles or cylinder rims should be firmly held.…*
>
> *Extinguish the pilot light(s), shut off at all cylinders in use and empty the hoses if time permits.'*

It was apparent during the investigation that the pilot of G-BVXF had prepared for this flight over several months. However, it is possible that relatively small changes in the conduct of the flight, such as initiating a cold descent near the apogee, might have resulted in a safe outcome and as a result of this accident the BBAC is producing guidance information for high-altitude flights. This will cover, for instance, changes in balloon handling qualities at high rates of climb and low mass, use of burners and pilot lights, clothing, planning, use of oxygen systems, ATC and wearing a parachute.

BULLETIN CORRECTION

AAIB File: EW/C2011/01/01

Aircraft Type and Registration:	Cameron O-120 hot air balloon, G-BVXF
Date & Time (UTC):	1 January 2011 at 0947 hrs
Location:	Midsomer Norton, Somerset
Information Source:	Field investigation

AAIB Bulletin No 10/2011, page 113 refers

In the report published in Bulletin 10/2011, the supplementary oxygen system was mistakenly identified as being supplied with a cylinder pressure of '200 psi'. This was a typographical error – the system was supplied with a cylinder pressure of **200 bar**.

This was corrected in the online version of the report on 31 October 2011 and a correction will appear in the December 2011 Bulletin.