Accident

Aircraft Type and Registration:	Amateur-built balloon (DB-6R), G-CMFS
No & Type of Engines:	1 Ultra Magic Mk 21 LPG twin burner
Year of Manufacture:	2022
Date & Time (UTC):	25 June 2023 at 0519 hrs
Location:	Ombersley Court, Worcestershire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Balloon destroyed
Commander's Licence:	Commercial Pilot's Licence (Balloon)
Commander's Age:	25 years
Commander's Flying Experience:	569 hours (of which 33 were on type) Last 90 days - 10 hours Last 28 days - 3 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot was taking part in a balloon competition. One part of the competition involved dropping a marker as close as possible to a target location. The accident occurred whilst the balloon was climbing rapidly away from this target. The balloon envelope collapsed, and the basket descended to the ground, fatally injuring the pilot.

The investigation found the balloon was likely to have suffered a parachute stall[1]. The balloon design, the weather conditions, and the rapid climb are all likely to have contributed to the accident.

Three Safety Recommendations are made to the British Ballooning and Airship Club (BBAC) to: develop an effective reporting culture within the ballooning community; issue guidance on the prevention and recovery from unsafe conditions such as parachute stalls; and issue guidance regarding jettisoning of fuel tanks during an emergency. Two Safety Recommendations are made to the CAA to: publish guidance on the design, testing and inspection of amateur balloons insofar as these activities relate to unsafe conditions such as parachute stalls; and publish guidance related to the oversight of competition balloon flying.

Footnote

[1] An explanation of parachute stall is given in the section titled '*Parachute stall*'.

History of the flight

On the morning of Sunday 25 June G-CMFS was participating in a competition event, which was part of the British Grand Prix 2023 series. This was the second flight of the event; the first took place the day before. Four other balloons, G-DANJ, G-CLHS, G-LOKI and G-CLDJ, took part in the event. The launch site was Worcester Racecourse, with all the balloons launching just after 0500 hrs.

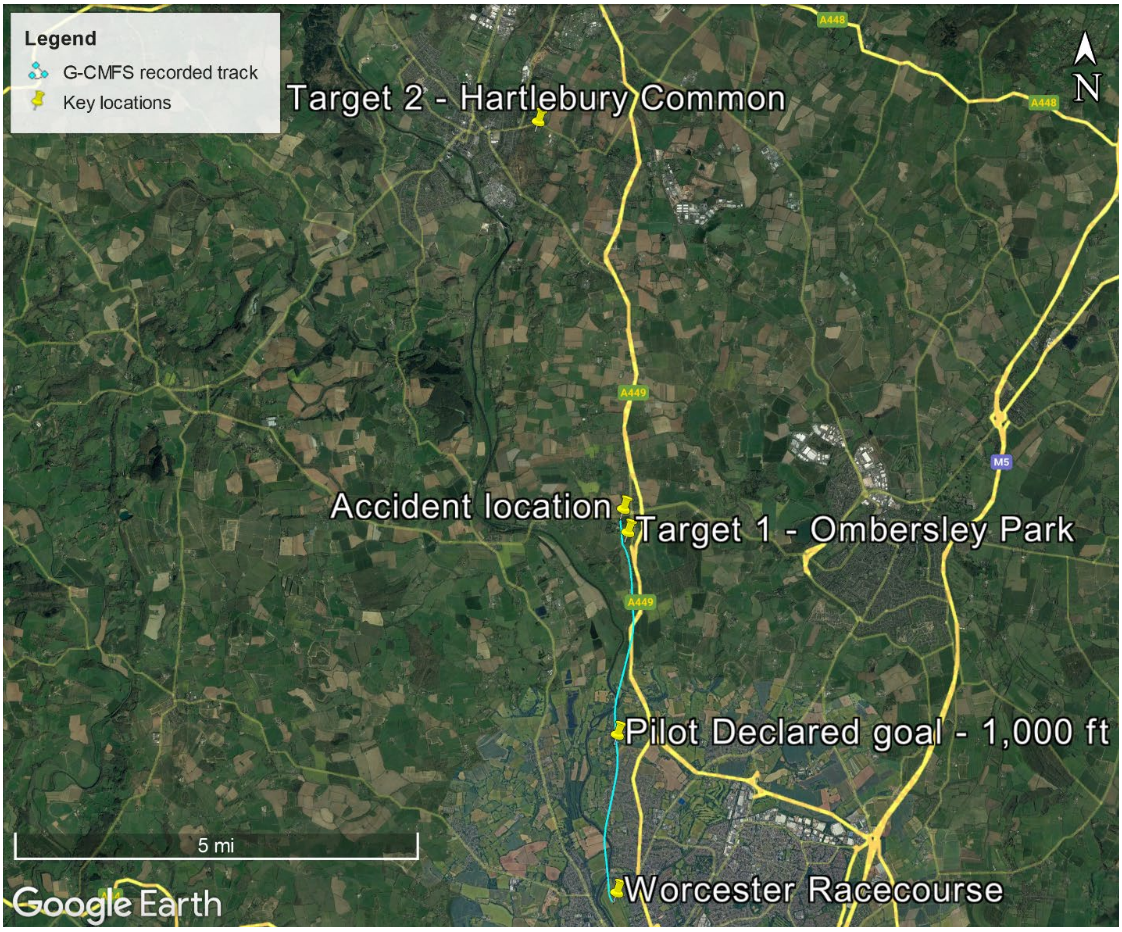

Figure 1

Launch, Accident and Target Locations

Figure 1 shows the three elements of the competition task along with the launch site and route flown:

- Task 1 - A 'judge declared goal' where the pilot was required to drop a marker as close as possible to a specified location; Ombersley Park.
- Task 2 - A 'Gordon Bennett memorial' which similarly required the pilot to drop a marker within a specified scoring area; Hartlebury Common.
- Task 3 - A 'pilot declared goal' where the pilot was required to nominate a position and altitude before takeoff and then try to fly to as close as possible to that point.

Figure 2 shows the balloons prior to launch. G-CLDJ was the first balloon to launch, followed between two and three minutes later by G-LOKI, G-CLHS, G-CMFS, and lastly G-DANJ. Figure 3 shows the balloons after the first three had launched. G-LOKI landed again at the launch site as the pilot had forgotten her markers, so was then behind G-CMFS.

G-CMFS launched at 0506 hrs and Figure 4 shows it just after launch (the balloon parachute can be seen correctly seated at the top of the envelope[2]). The three ground-crew that helped launch G-CMFS reported the launch was normal and that all pre-flight checks were completed successfully. They reported that everything looked fine during the launch.

G-LOKI's pilot stated that she was close enough to G-CMFS during the first part of the flight for them to talk and everything seemed normal. At 0611.05 hrs the accident pilot recorded his 'pilot declared goal' at an altitude of 1,253 ft amsl.

G-CLDJ was the first to reach the Ombersley Park area but missed the target so continued flying to the second location. He did not see any part of the accident.

Figure 2

Five balloons before launch (accident balloon is one in from the left)

Footnote

[2] The 'parachute' is described in detail in later sections.

Figure 3

G-DANJ and G-CMFS just before launch with the other three ahead

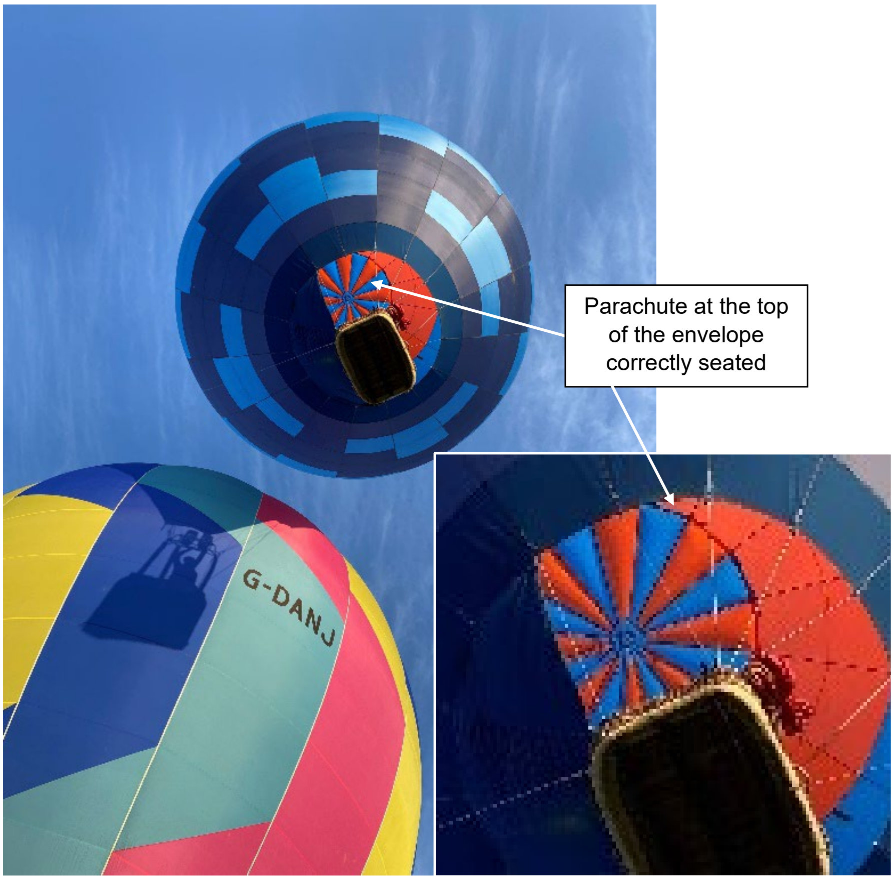

Figure 4

G-CMFS just after launch showing the parachute correctly seated

G-CMFS was the next balloon to approach the target. The pilot's electronic logger recorded that he dropped his marker at 0618:02 hrs at an altitude of 499 ft. The marker landed approximately 40 m from the target. G-CMFS was then seen to climb rapidly. G-LOKI and G-DANJ were close behind, followed by G-CLHS (which had flown at a lower altitude in slow wind so had taken longer to reach the target). Figure 5 was taken from G-CLHS as the balloons approached Ombersley Park.

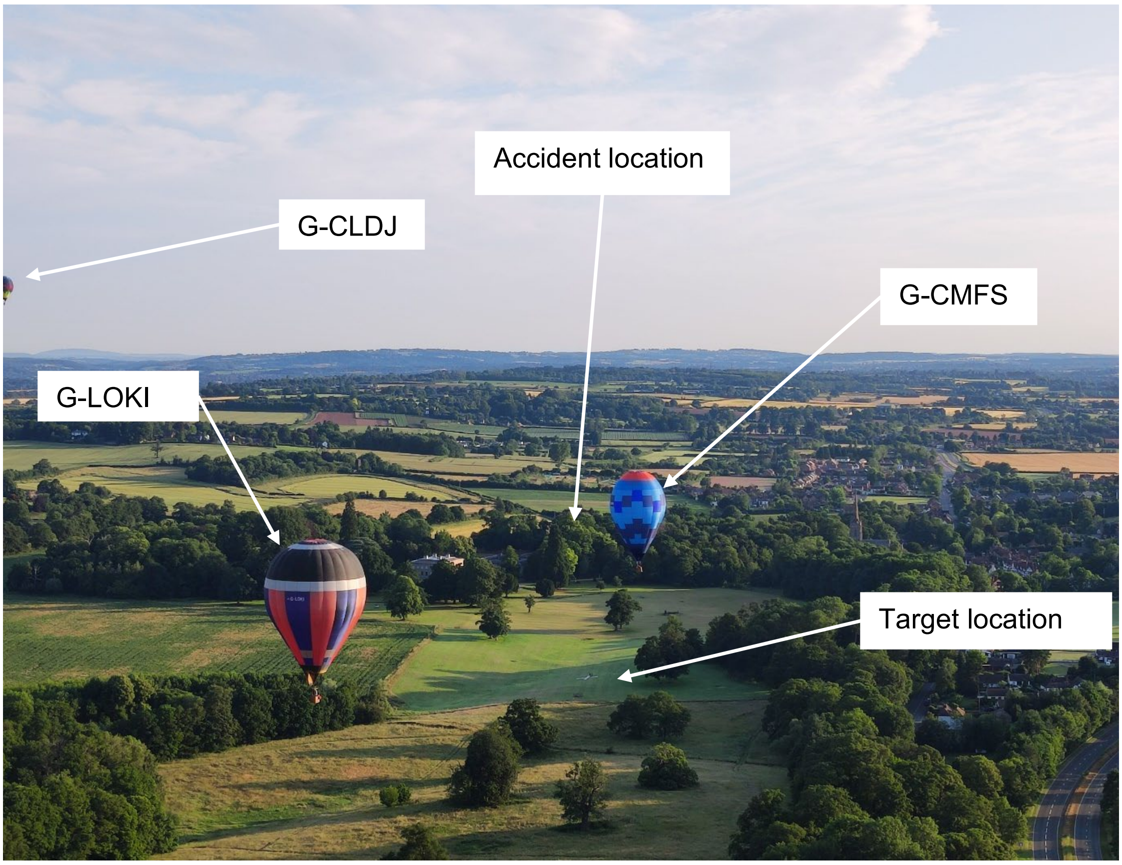

Figure 5

Balloons approaching the target at Ombersley Park (taken from G-CLHS)

G-CLHS's pilot recalled G-CMFS had just flown over the target and was climbing rapidly. He recalled seeing grey smoke coming from G-CMFS, although he stated this was not unusual and it just suggested the pilot was using the burner frequently and for long enough to cause the heat resistant material at the base of the balloon to singe. The next time he looked up he saw the balloon 'streamered' and descending rapidly (Figure 6).

G-LOKI's pilot reported seeing G-CMFS climbing fast, she also recalled seeing the smoke. She recalled that she then heard the sound of fabric "whipping", "the crack of fabric, like you might hear during inflation when the wind caught the balloon". This sound caused her to look up and she saw G-CMFS falling with the balloon streamered. She recalled just seeing burnt fabric streaming above the basket.

G-DANJ's pilot also recalled seeing the balloon envelope streamered and dropping to the ground.

Two scorers were on the ground at the target location and they filmed and photographed the balloons as they approached the target. The footage showed G-CMFS's pilot approaching the target then climbing away and dropping his marker. 46 seconds later, one of the scorers saw G-CMFS falling and, as they both looked around their camera captured the final moments of G-CMFS's descent. Figure 6 was extracted from the video.

Figure 6

G-CMFS descending to the ground with the balloon streamered

All three pilots landed; G-LOKI and G-DANJ in the next field, G-CLHS in the target field. Everyone present ran to the accident site. G-CLHS's pilot was the first pilot to reach the accident scene. He reported that the burner pilot lights were still lit when he arrived, so he switched them off and later turned off the gas cylinders and vented the supply lines. They administered CPR to the pilot until the emergency services arrived.

Witnesses

Several people saw the accident sequence and gave similar accounts of what happened. The witnesses all reported seeing G-CMFS climbing rapidly and then the balloon appearing to deflate and descend rapidly before striking the ground.

One couple at a petrol station on the A449 saw the balloons flying and took some photographs, which were all time-stamped at 0518 hrs (Figure 7). One of them commented that, within seconds of taking the second photo, "the blue one didn't look inflated properly, it looked like it did not have enough air in it". They described that one side of the balloon looked like it was pushed in at its widest part and "it looked like a half-moon shape". As this happened, they instantly saw the burner come on but described that "it caught the right side of the balloon" with "the flame on the outside of the balloon". They then saw the basket fall to the ground. They described seeing "just the basket" and what looked like "a long piece of string". They said it looked like "tissue paper or a shoelace with a thin flame and black smoke", "just a basket on its own dragging a piece of string".

Another witness also took some pictures from the A449 (Figure 8), all time stamped at 0518 hrs. A further witness on the A449 recalled that the burner was still burning during the descent, but there was no fire other than the flame from the burner. A witness, who was 150 – 200 m away from the eventual accident location, was watching G-CMFS as it ascended. He described hearing a "loud puff" and said it was like all the air suddenly disappeared from the balloon, "like the top had opened up" or "someone had lifted the lid on it". He said there was no fire or explosion.

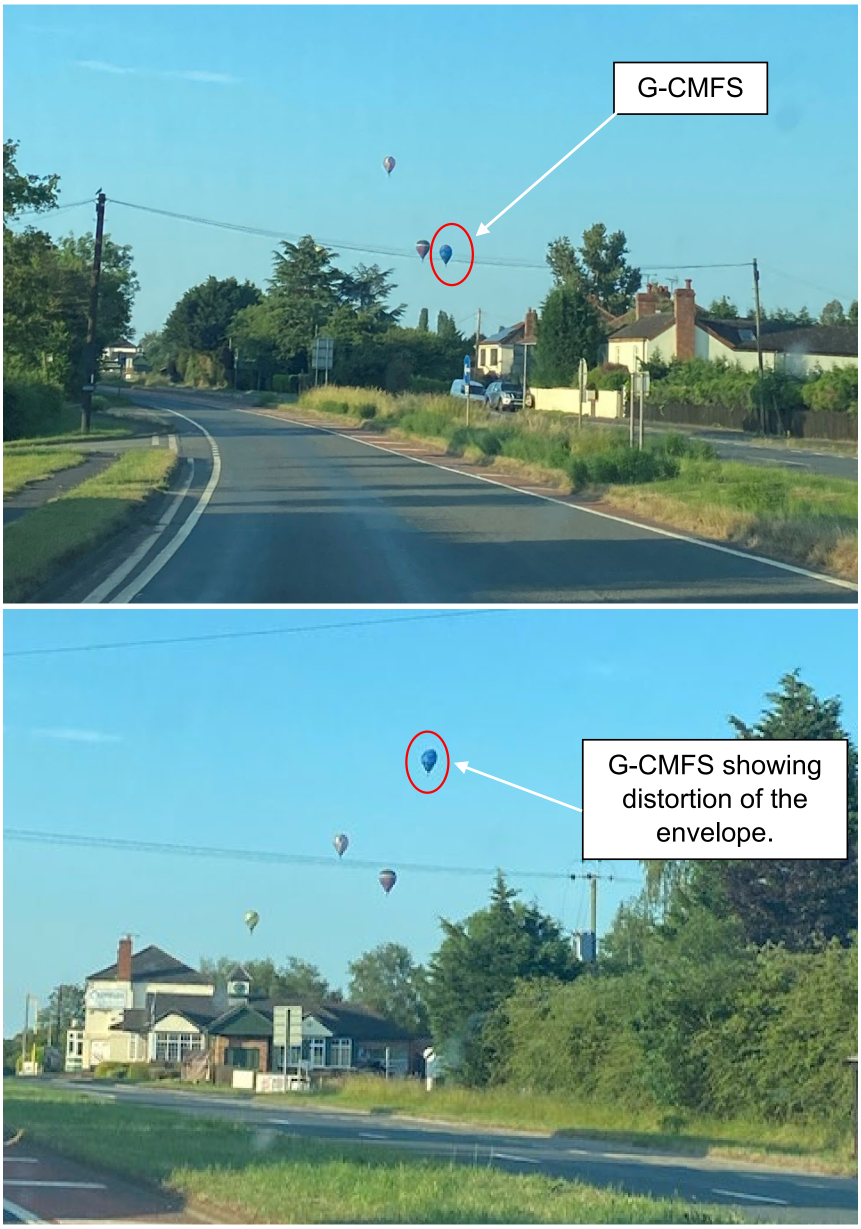

Figure 7

Photos taken by a witness on the A449 both taken at 0518 hrs

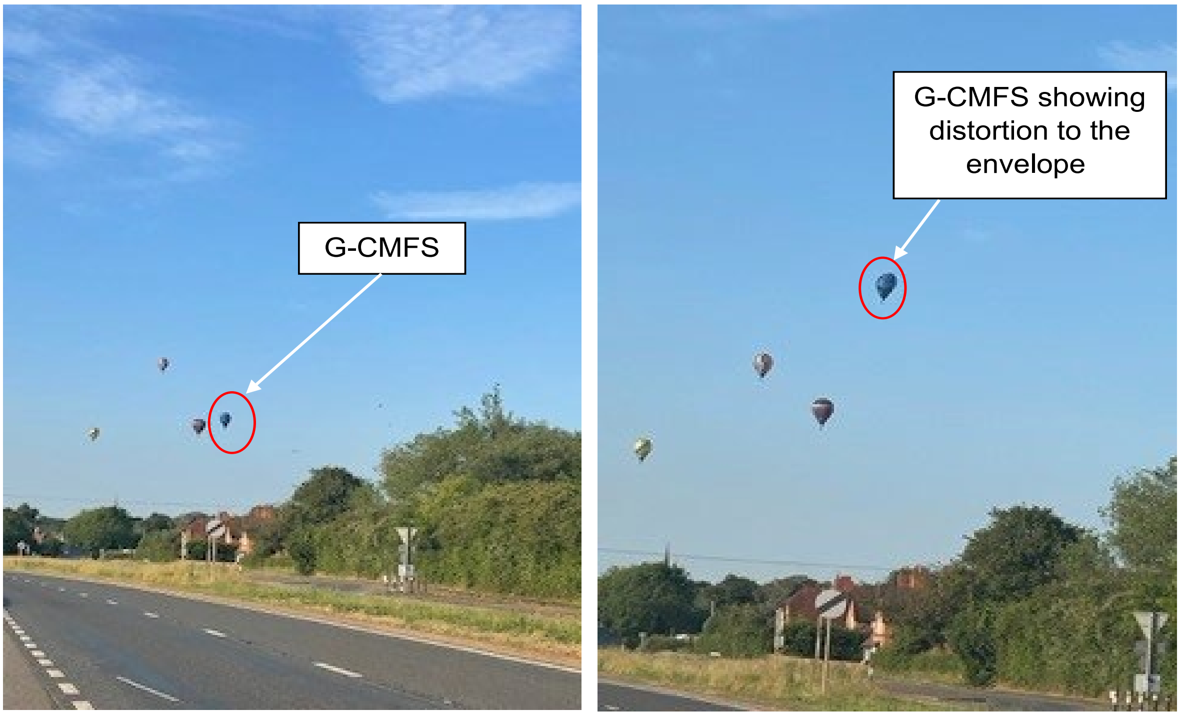

Figure 8

Sequence of photos taken by a witness on the A449 at 0518 hrs

Generic racing balloon design

Figure 9 shows some features of a generic racing balloon design to illustrate subsequent sub paragraph descriptions:

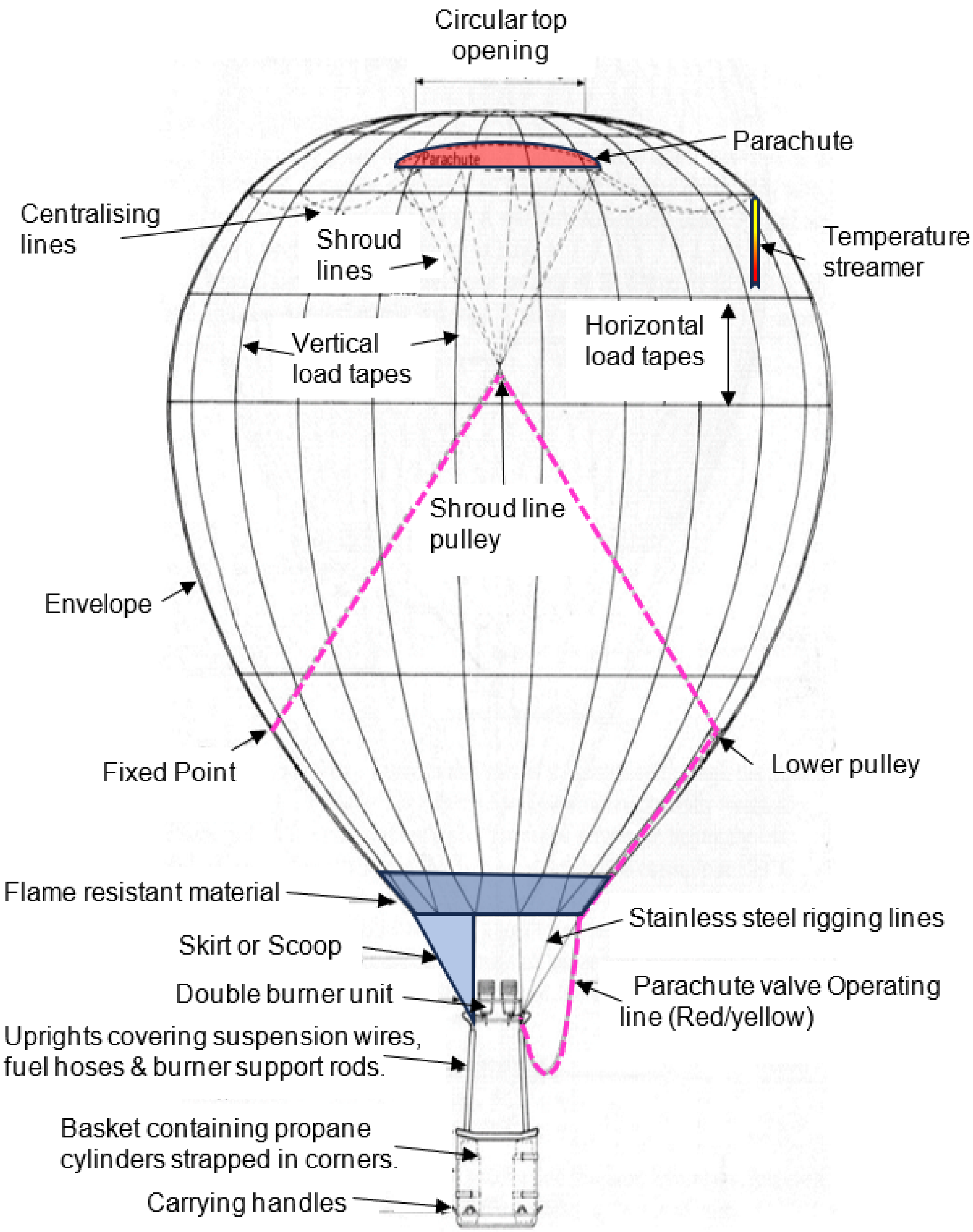

Figure 9

Basic features of a generic racing balloon showing internal rigging arrangements

Envelope

The hot air balloon envelope gives the balloon its well-known shape and provides the lifting force when inflated with warm air. The fabric used to create balloon envelopes must be light but resistant to tears and is generally made from materials such as ripstop nylon or Dacron polyester fabric[3]. The inlet or throat of the balloon and the skirt (or scoop) are

Footnote

[3] Dacron is a strong, durable, abrasion resistant and moisture-wicking brand of polyester made by DuPont.

made from a fire-resistant material because they are very close to the heat and flames from the burners (See the *Burner* section below).

The simplest and most recognisable hot air balloon shape, often used by amateur builders, is a hemisphere on top of a truncated cone, referred to as a natural balloon shape. Specialized 'racing' balloon envelope shapes are generally slimmer to reduce aerodynamic drag in the vertical axis, which improves the rates of climb and descent.

During manufacture, the balloon envelope material is cut into panels and sewn together, along with vertical structural load tapes that carry the weight of the gondola or basket. Horizontal load tapes are also sewn into the inside of the envelope which maintain and strengthen its circumferential shape. The individual fabric sections, which extend from the throat to the crown (or top) of the envelope, are known as gores or gore sections. Envelopes usually have between four and twenty-four gores.

At the top of the envelope (the crown) is a circular opening (aperture). The aperture is vented and sealed by a vent device such as a parachute vent valve (see next section – *Parachute vent valve*). Balloons use a crown ring, which is a metal hoop, designed to attach the vertical load tapes to the centre of the envelope's aperture. The load tapes are then extended to the bottom of the envelope where they are sewn into loops and connected to stainless-steel rigging lines (one line per vertical load tape). Karabiners connect these rigging lines to the basket.

Parachute vent valve

The balloon's vent device is designed to enable the pilot to control the release of hot air through the aperture of the balloon to slow an ascent, start a descent, increase the rate of descent, or enable rapid deflation of the envelope on landing. Natural cooling of the hot air inside the envelope allows the balloon to descend at a slower rate than venting, so it is possible to descend without using the vent. The most common top vent valve is a disk-shaped layer of fabric called a 'parachute' vent. The parachute is connected around its edge to a set of shroud lines that converge below the centre of the fabric disk. (The arrangement of the fabric layer and shroud lines roughly resembles the shape of a parachute, hence the name). The edge of the parachute fabric is also connected to centralising lines which extended out to the edge of the envelope and are each fixed in place around the inside circumference. The centralising lines are designed to ensure the parachute remains within the vertical centreline of the envelope during operation. The converged parachute shroud lines are tied to a shroud line pulley through which a brightly coloured parachute operating line runs internally down, from a fixed point on the inside of the envelope, via a series of pulleys and into the basket.

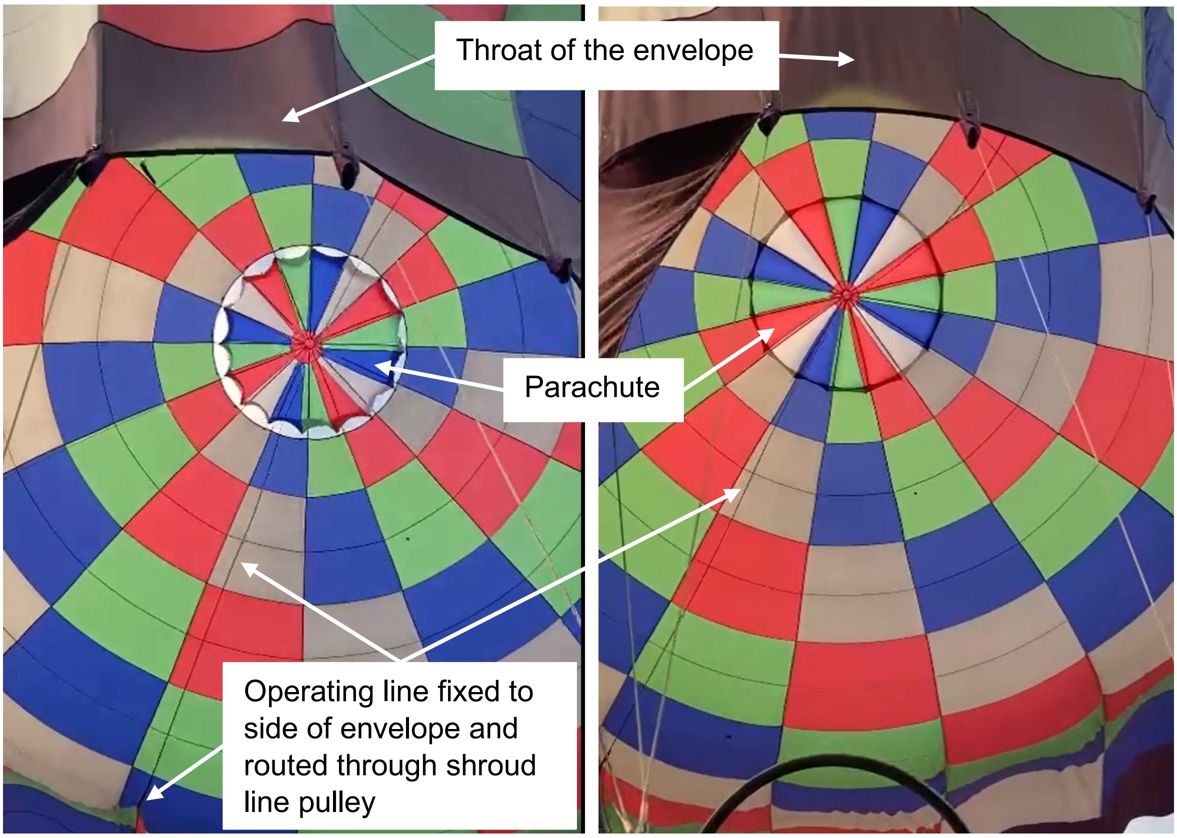

Figure 10

Looking up through the throat of a balloon of the same design as G-CMFS, showing the parachute valve open (left) and closed (right)

When the pilot pulls on the operating line, the parachute is forced down and away from the aperture in the crown of the envelope allowing air to vent. As hot air escapes through the gap between the parachute fabric and the aperture, the buoyancy of the balloon is reduced. Once the operating line is released, a pressure differential above and below the parachute valve sucks it back into place sealing the aperture again (Figure 10). The burners can also be used to send a stream or bubble of heated air upwards to assist the parachute to reseal.

Basket or gondola

Hanging below the envelope is a gondola or basket. In this example it's a wicker (or rattan) basket (Figure 11). The base of the basket is a wooden platform with runners attached to the bottom. The basket frame is attached to basket wires, which in turn are attached to the balloon envelope by the burner frame, karabiners and rigging lines.

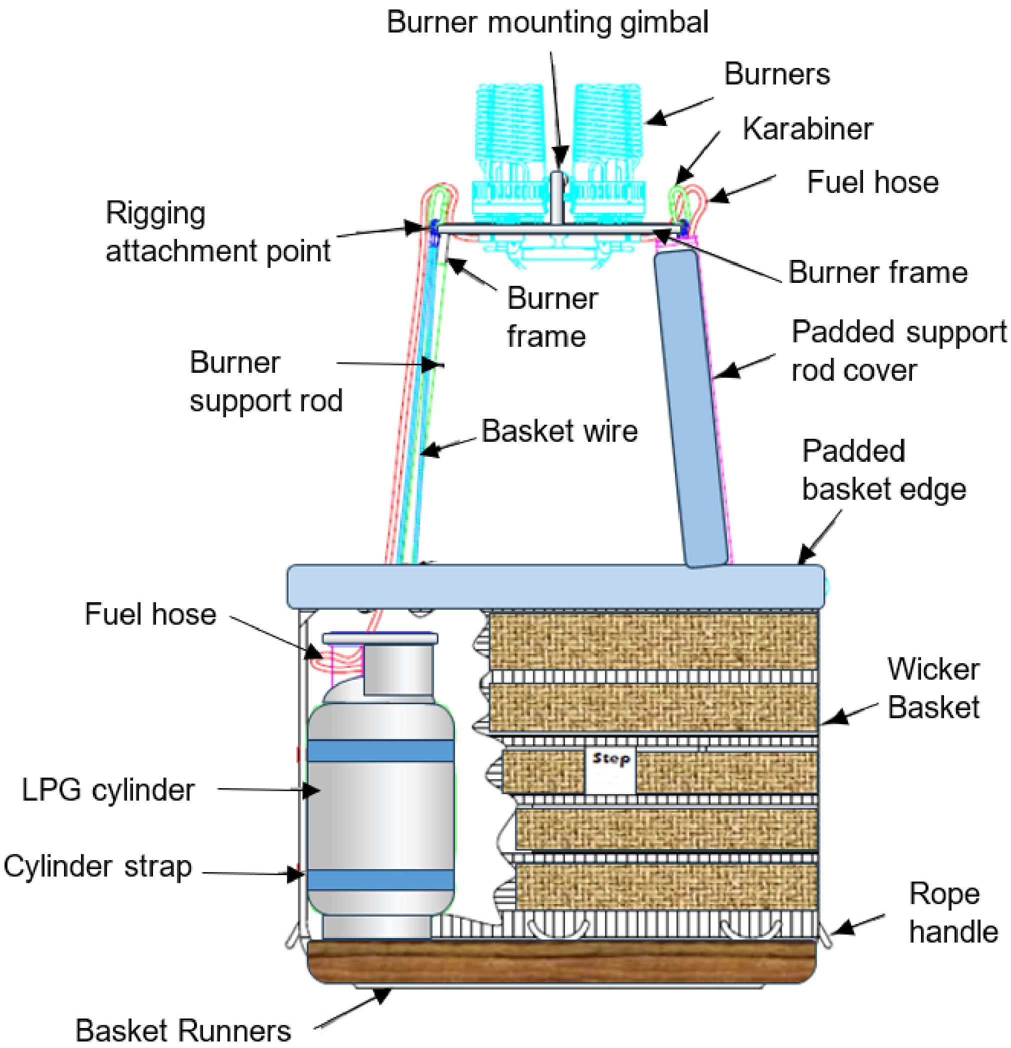

Figure 11

Basket layout showing basic features.

The basket houses cylinders containing liquid propane gas (LPG). These cylinders supply fuel to the burners which in turn produce hot air to inflate the balloon envelope and to adjust its buoyancy in flight.

Burners

In this example, two stainless steel LPG burners are mounted on a simple mechanical gimbal that is hinged on a burner frame above the basket (Figure 12). The burner frame is elevated above the basket by burner support rods. The gimbal frame allows the pilot some limited adjustment to the direction of the burners so the flames can be directed into the centre of the envelope as the throat flexes and moves during flight.

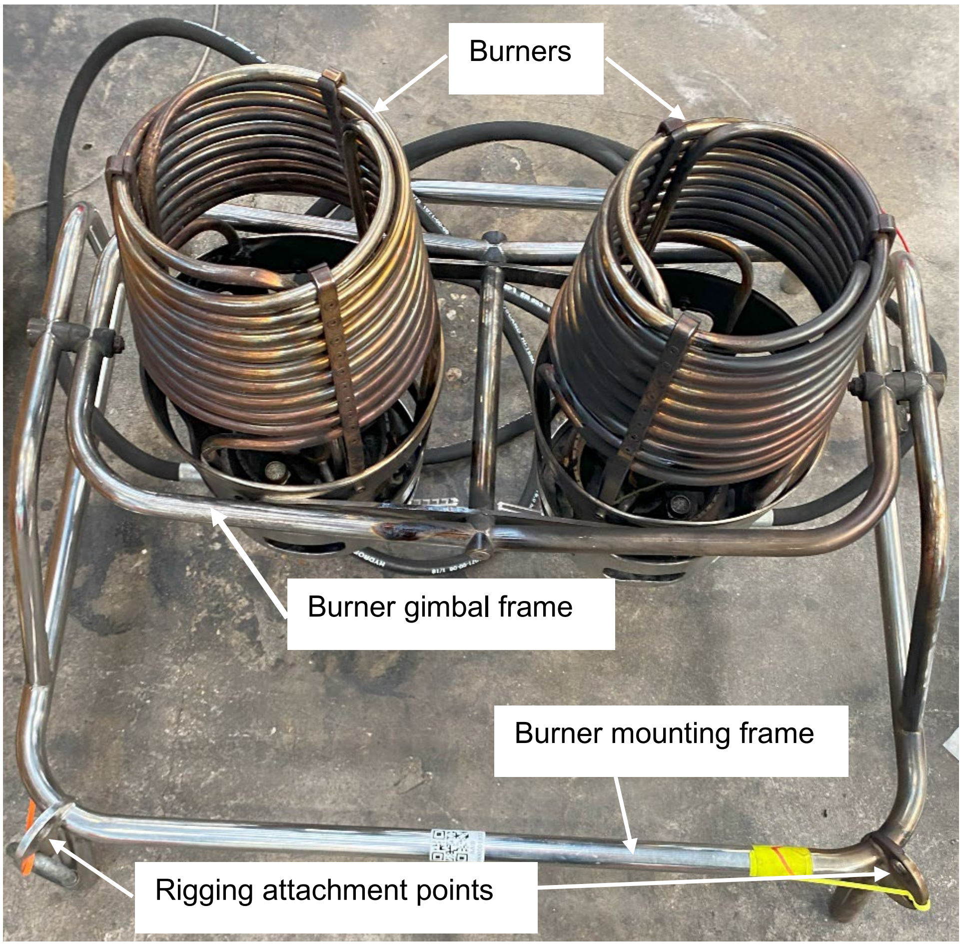

Figure 12
Twin burners mounted on a frame above the basket.

Liquid propane is fed into each burner's vaporising coils and then into the combustion chamber, where it is mixed with air and ignited by a manually operated ignition switch. To control how long the flame burns, a manually operated 'blast' valve allows the pilot to substantially increase the flow of propane to produce a large flame. Burners are often fitted with 'whisper' valves that can be used instead of blast valves to avoid disturbing people or frightening livestock when flying over farmland. On average, burners produce approximately 400,000 BTUs (British Thermal Units) of heat.

Aircraft description

G-CMFS was an amateur-built racing balloon and was manufactured by the accident pilot from the DB-6R design plans. The balloon had a 16-gore envelope with a parachute aperture diameter of 4.4 m, throat diameter of 3.6 m and an envelope height of 18.8 m from the crown to the throat. The volume of the envelope was calculated to be 1,698 m^3. It was powered by an Ultra Magic Mk 21 LPG twin burner system mounted onto a wicker basket (Figure 12). The CAA registration G-CMFS was issued on 28 April 2022 and the balloon had its first test inflation at the Midlands Air Festival on 2 June 2022, although it wasn't flown during this event. The first test flight occurred at the Cheltenham Festival on 19 June 2022.

The logbook for G-CMFS recorded the balloon had flown a total of 21 hours 40 minutes before the accident flight.

Accident site examination of the wreckage

The balloon's envelope was suspended vertically above the ground where it had snagged on the fractured remains of tree branches (Figure 13). Broken branches were scattered around the base of the tree with some landing on top of the balloon's basket.

Figure 13

Balloon envelope suspended by broken tree branches above the basket

The envelope appeared to have been torn by the sharp remains of the branches as it descended through the foliage. Further damage was caused to the envelope as the wind increased throughout the day and conditions became increasingly blustery, resulting in additional tearing as the material billowed in the turbulent air.

At the base of the tree, the balloon's basket was on its side with the burners still mounted to the basket by burner support rods. The rigging points and karabiners were intact and remained attached to their steel rigging lines. The charred remains of blue heat-resistant material were wrapped around the burners, rigging lines, and the bright orange and yellow fluorescent parachute operating line (Figure 14).

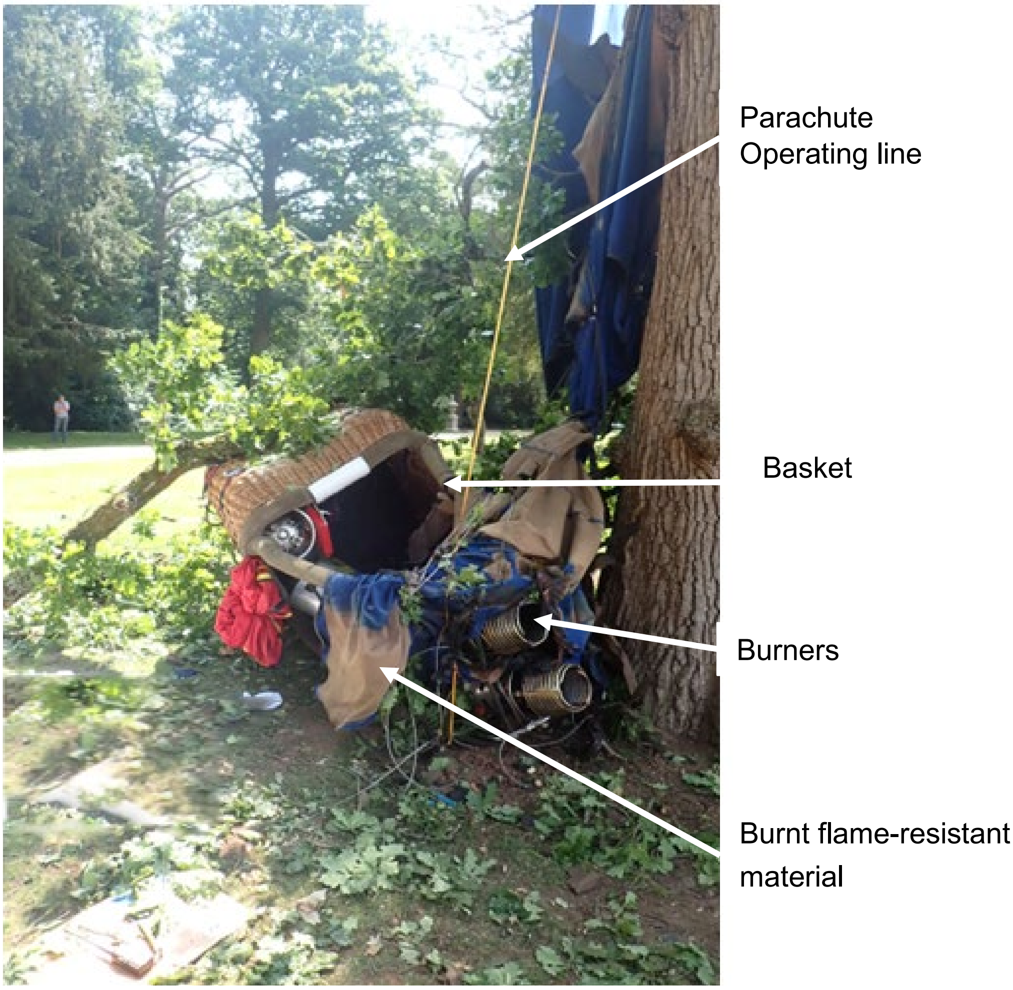

Figure 14

Basket on its side showing burners, operating line and burnt heat-resistant material

Inside the basket were two LPG cylinders used to provide fuel to the burners, a blue jacketed steel cylinder and a yellow jacketed titanium cylinder (Figure 15). The yellow cylinder was still strapped to the corner of the basket and connected to the burners by a flexible fuel supply hose. The blue cylinder was not fully strapped to the basket with the lower buckle undone. A third blue jacketed aluminium LPG cylinder, not connected to the burners or strapped into the basket, was found loose on the ground just outside the open end of the basket. Witnesses stated that this tank had been unbuckled and moved out of the way of the basket to provide room to administer first aid to the pilot.

Figure 15

Three LPG cylinders with one loose and resting on the ground

Whilst the loose cylinder was empty of fuel, the yellow jacketed cylinder, shown in Figure 15, was connected to the burners and was found to be approximately half full. The blue jacketed cylinder seen at the top of Figure 15 that was partially strapped to the basket, was not connected to the burner unit and had a damaged contents gauge. It was found to be full during fuel transfer to an undamaged cylinder.

Once the balloon envelope had been recovered from the tree, examination at the site showed the envelope material had been extensively torn by the tree branches. The lower panels, around the throat of the balloon and the skirt, or pressure scoop, showed clear signs of discoloration consistent with being subjected to flames and significant heat. The material had burned through in some areas and the edges of the material had become rigid with the consistency of thin cardboard, also a sign of heat damage. Some small pieces of the heat resistant material were scattered around the site, particularly downwind of the basket location, indicating that the pieces may have floated down as the flames from the burner burned through the material.

There were no signs of fire damage on the ground, around the tree or on the tree trunks. The carbon fibre parachute operating line had suffered some heat damage, with small amounts of orange and yellow nylon rope material that had melted and dripped onto the lower panels of the envelope and the basket. However, the carbon fibre line had not burned through and was still in one piece.

Recorded information

Several data logging devices were recovered from the accident site. No transponder was fitted to the balloon, nor was there a requirement for one to be installed[4].

Competition Logger (Balloon Live Sensor)

A competition logger was recovered which logged barometric altitude and GPS position and altitude data once per second. Climb and sink rate information was calculated from the barometric altitude data which was accurate to ±1 m/s. Figure 16 shows the variation in barometric altitude (blue curve) and calculated vertical speed profile (purple curve).

On several occasions during the accident flight, the data indicated that G-CMFS flew at close to the maximum climb and descent rates allowed by the competition rules[5] (±8 m/s, or about ±1,575 ft/min). This is illustrated by points 1, 3 and 4 in Figure 16.

On the two occasions where G-CMFS climbed at close to or at the allowed limit, it reached this climb rate quickly (points 2 and 5). These climb rates occurred as the pilot climbed away from his pilot declared goal and from the first target drop zone respectively.

During the final climb, after G-CMFS climbed away from the first target drop location, four data samples were recorded which corresponded to a calculated climb rate of 9 m/s (1,771 ft/min) as G-CMFS was climbing through about 500 ft amsl (point 6).

G-CMFS attained 1,200 ft amsl (point 7), before it entered a rapid descent towards the ground. The competition logger recorded a maximum sink rate of about 19 m/s (3,740 ft/min) during this descent.

Footnote

4 Unless entering Controlled Airspace where the AIP requires the use of a transponder. See UK AIP, section ENR 1.4, at https://nats-uk.ead-it.com/cms-nats/opencms/en/Publications/AIP/ [retrieved 10 October 2023]

5 See the '*Organisational Information'* section of this report for further information.

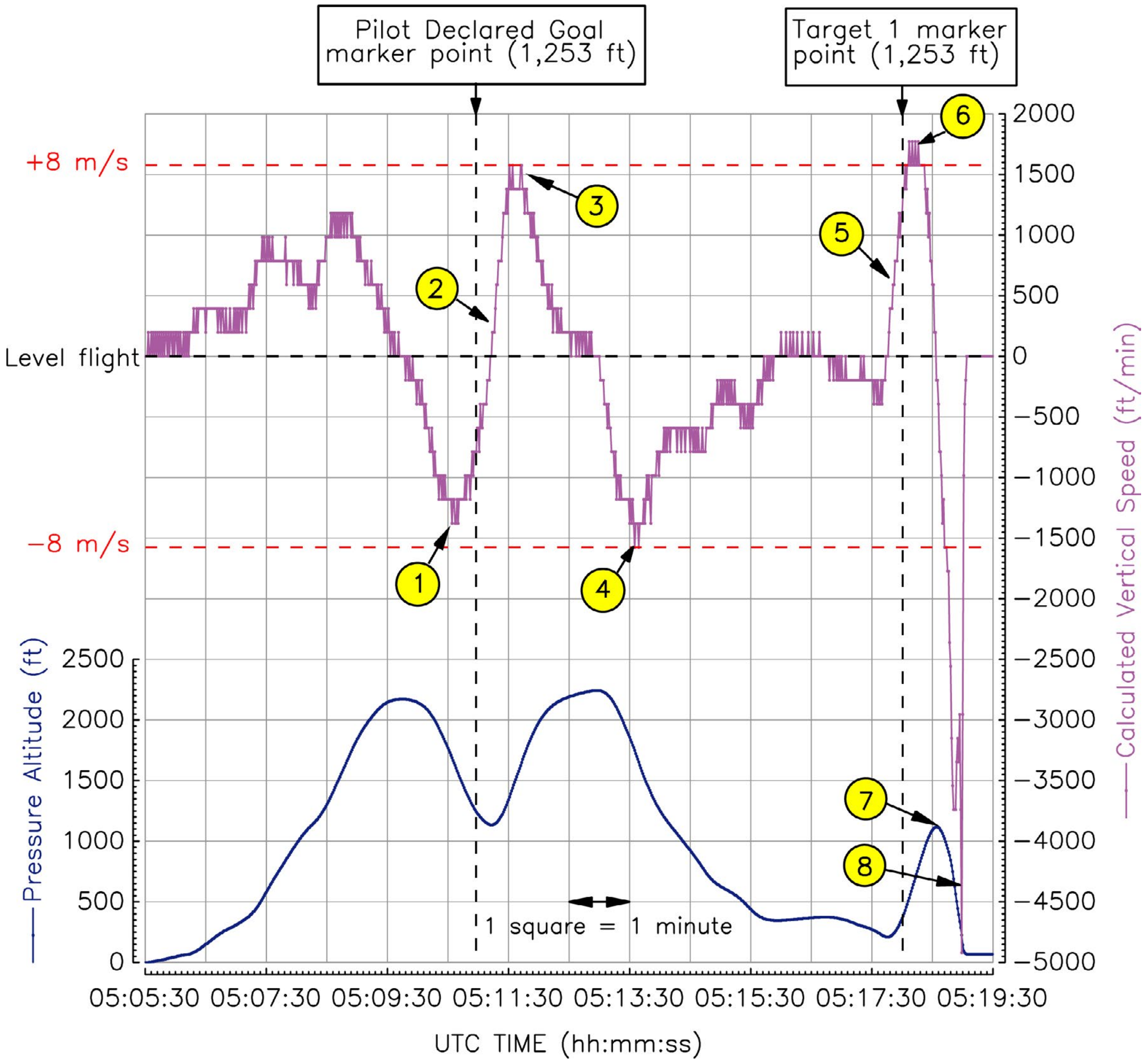

Figure 16

Altitude (blue) and vertical speed (purple) profile of the accident flight

A spike in the vertical speed marked by point 8 differed significantly from other vertical speed samples recorded by the sensor, and from other data sources recovered by the AAIB.

The data logger had recorded many previous flights which corresponded with the pilot's logbook entries indicating when he flew in G-CMFS. The data recorded the pilot attaining an 8 m/s climb rate in G-CMFS on at least three previous flights, including a flight the evening before the accident.

Variometer (FlyTec 6005)

A variometer was recovered, which displayed height, time, and climb/sink rate information in real time to the pilot on an LCD display. The AAIB was assisted by the variometer's manufacturer, which recovered maximum climb and sink rate values for the last 40 flights from a memory chip on the internal circuit board. The data corroborated the peak climb and sink rates obtained from the Balloon Live Sensor, recording the parameters in Table 1 for the accident flight.

Parameter	Value
Max. climb rate	8.3 m/s (1,650 ft/min)
Max. sink rate	17.8 m/s (3,525 ft/min)
Max. altitude reached	2,273 ft

Table 1

Maximum climb and sink rates logged by the variometer for the accident flight

The variometer was configurable to sound an aural alarm at a user-defined sink rate, but there was no option to configure a climb-rate alarm. To perform the data readout, it was necessary to remove the batteries from the device, which caused the settings to be lost. The investigation therefore did not determine whether a sink rate alarm was configured.

360-degree action camera

The pilot often flew his balloon with a 360-degree action camera mounted on a boom, but this was not used during the accident flight because its battery was not charged. The AAIB reviewed its footage from a flight on the evening before the accident, which took off from Worcester racecourse and flew locally. The climb/sink rate indicator on the variometer's display was visible from the video under most lighting conditions.

Part of the balloon envelope's interior was visible on the video. The temperature streamer was partially visible, and the operation of the parachute and pulley systems could be seen. The video showed that on twenty-one occasions when the pilot operated the parachute[6], the operating line was pulled firmly but smoothly. The pilot was seen to make short glances upwards on eight of these twenty-one occasions The videos indicated that he generally did not look up, particularly when focussed on other tasks such as identifying landing locations, navigating, or maintaining a look-out for other traffic.

The pilot operated the parachute for between five and ten seconds on about half of its uses during the 24 June flight. On a few occasions, the parachute was operated for more than 10 seconds, though it was not pulled deeply, and the balloon was either descending or landing during these times. On all occasions after he released the operating line, the parachute re-seated centrally. On two occasions during the 24 June flight, there was a short delay between the operating line being released and the parachute re-seating, and it appeared to 'float'[7] momentarily. Recorded data indicated that G-CMFS was in a climb on both occasions. The pilot appeared to be in control of his balloon but was not looking in the direction of the parachute when this occurred. The burners appeared to operate normally during the flight.

Footnote

6 Three occasions were observed that have been excluded from the count, because they occurred during landing when the pilot's focus was on the landing point.

7 The 'floating' parachute anomaly was observed during ground testing of a similar balloon design G-CKUN which is described in the *'Amateur-built hot air balloon design, construction and testing'* section in this report.

On one occasion during the 24 June flight, the balloon descended at about 1,200 ft/min through a wind layer at about 3,000 ft amsl. As it did so, the balloon was turning and oscillating slightly. The envelope appeared fully inflated. The wind distorted the envelope on one side, and the throat closed slightly. The video showed the pilot monitoring the envelope as it descended through the wind layer and applying a few short bursts of heat using the burner, which quickly restored the balloon's shape. There was no indication that the pilot was concerned, or that the balloon's behaviour was unusual to him.

Shortly afterwards, the balloon climbed to about 1,200 ft. Recorded data from this flight indicated that it resembled the climb immediately preceding the accident on 25 June. The video showed the burner being operated continuously for about 14 seconds during this climb and the vertical speed increasing quickly. Shortly after reaching 8 m/s, the pilot used the parachute operating line for approximately six seconds, with the sky visible through the opening. When released, the edge of the parachute momentarily fluttered as it re-seated. Intermittent and smaller parachute operations were made by the pilot until the balloon levelled off at around 1,300 ft amsl. When the pilot operated the parachute on this occasion, he looked up at the start and at the end of its use, for slightly longer than on other occasions seen in the video.

Mobile data stream

The pilot also used his mobile phone to log the flight, using a mobile application. Its position and height data were consistent with the track logged by the Balloon Live Sensor.

Handheld GPS

The pilot flew with a handheld GPS navigation device. The unit was significantly damaged, with the display not working and some components having broken off the circuit board. Previous positions logged by the unit or any routes which may have been loaded to the device by the pilot could not be recovered.

Data from other competitors

The AAIB obtained data from the other competitors' balloon sensors, which had been streamed to the cloud. Their height and calculated vertical speed data was compared against that from G-CMFS by aligning the data at their approximate takeoff times[8], illustrated by Figure 17. Some data exhibited errors for undetermined reasons.

Footnote

[8] For G-LOKI, the time was taken from the second takeoff after the pilot collected her markers.

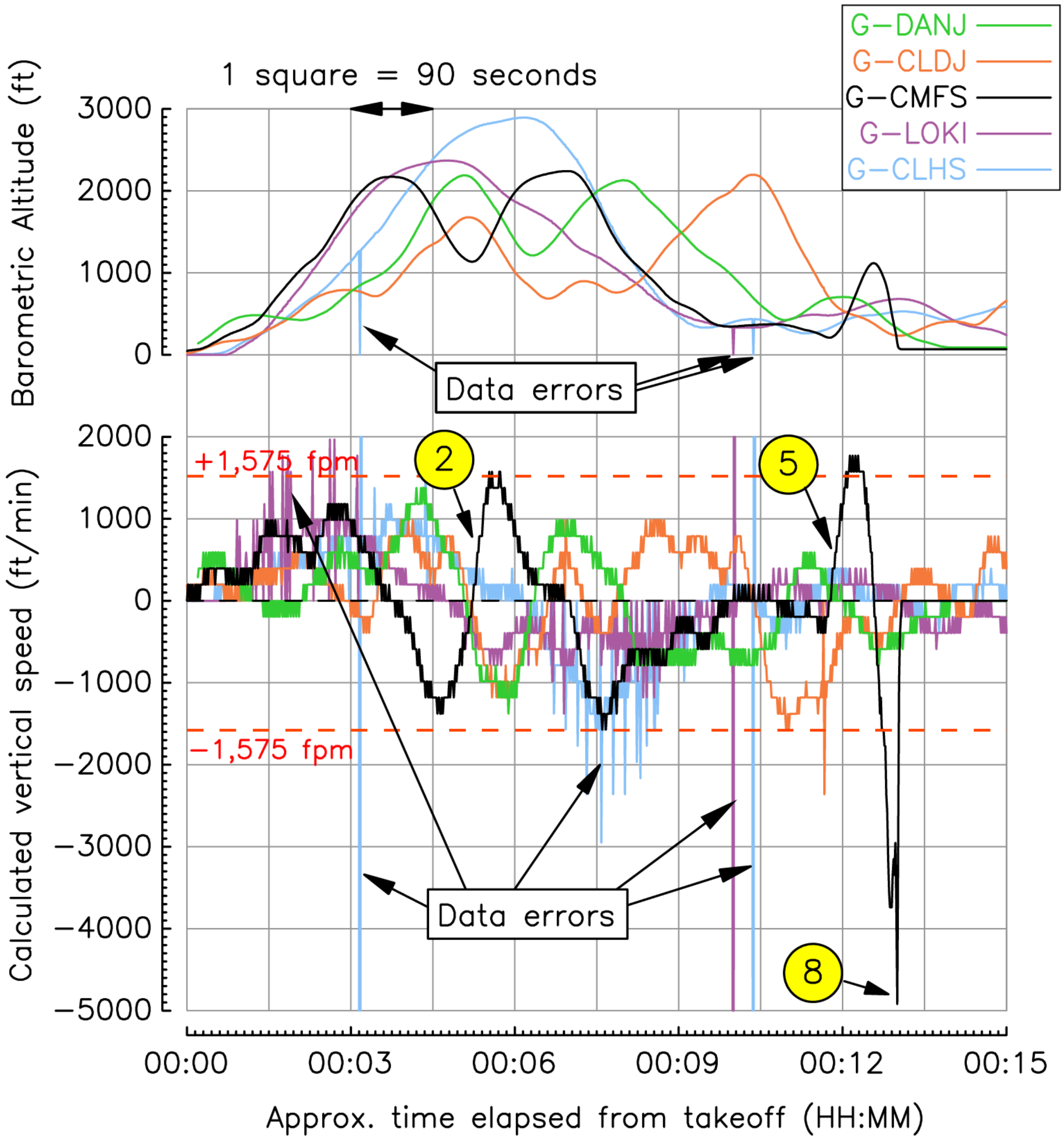

Figure 17

Comparison of altitude and vertical speed for each competitor.

The vertical speed calculations suggest that three balloons, including G-CMFS, descended at the 8 m/s rate allowed by the competition rules. Only G-CMFS attained the maximum 8 m/s climb rate. G-CMFS flew at similar heights to the other balloons in the competition.

Calculated vertical acceleration data indicated that when G-CMFS climbed at points 2 and 5, its acceleration upwards was about 40% greater than the maximum attained by the other balloons. When G-CMFS' climb rate was being slowed and when its rate of descent was being increased, the accelerations were consistent with those achieved by the other balloons, except from the final descent on the accident flight before it struck the ground.

Balloon examination

Envelope

The envelope material was substantially ripped and torn where it had been dragged through the broken tree branches during the accident and later by the sharp edges of the broken tree limbs when the wind increased. Where the material had been ripped and the tear had reached load tapes or seams, the rip had not propagated further. The seam around the circular aperture at the top of the balloon was in good condition with no rips or tears and no sign of distortion or melting from potential overheating. Whilst the temperature streamer had separated from its soldered link, which was clipped to the envelope (Figure 18), there were no signs of heat damage on the upper sections of the envelope. The streamer flag material had also been torn in half widthways. The temperature sensor did not indicate that there had been excessive air temperatures present in the upper areas of the envelope, although the 93°C indicator showed potential signs of discolouration.

Figure 18

Temperature sensor (left) and damaged streamer showing soldered link (right)

The aluminium crown ring was still in place in the centre of the aperture. The 16 vertical load tapes were each still looped around the ring with no signs of damage to the tapes or the ring observed. When the load tapes were measured from the edge of the aperture to the crown ring, there were differences of up to 2.5 cm in length between them.

At the bottom of the envelope, all the vertical load tapes that connected the envelope to the steel rigging lines remained fastened to the lowest edge of the heat resistant throat material. The throat panels showed significant signs of heat damage (Figure 19). The original blue colour of the material was discoloured in multiple, vertical burn patterns. The horizontal load tape seams along the lower edge of the envelope had melted in several places together with some of the vertical load tapes and envelope material.

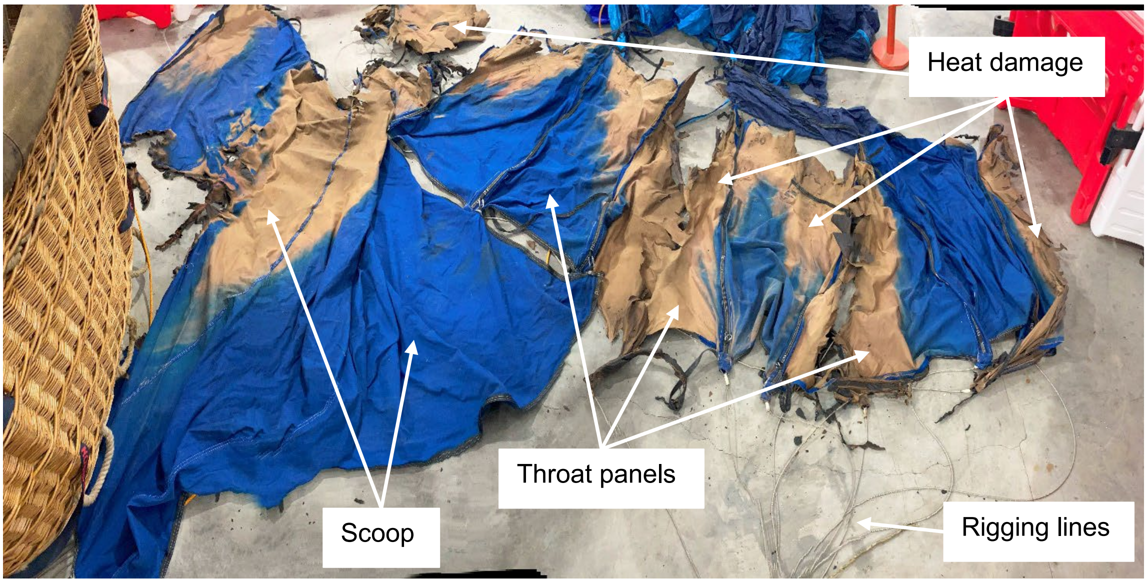

Figure 19

Panoramic picture of the heat resistant throat section with the scoop attached and showing multiple areas of significant heat damage

Figure 20

Scoop showing a hole burned through the material and V-shaped burn patterns

When the throat and the scoop were separated, the full extent of the burn patterns were revealed. The scoop shown in Figure 20 had a large hole burned through the fabric and two V-shaped burn patterns. Much of the upper horizontal seam of the scoop had melted and separated from the edge of the scoop.

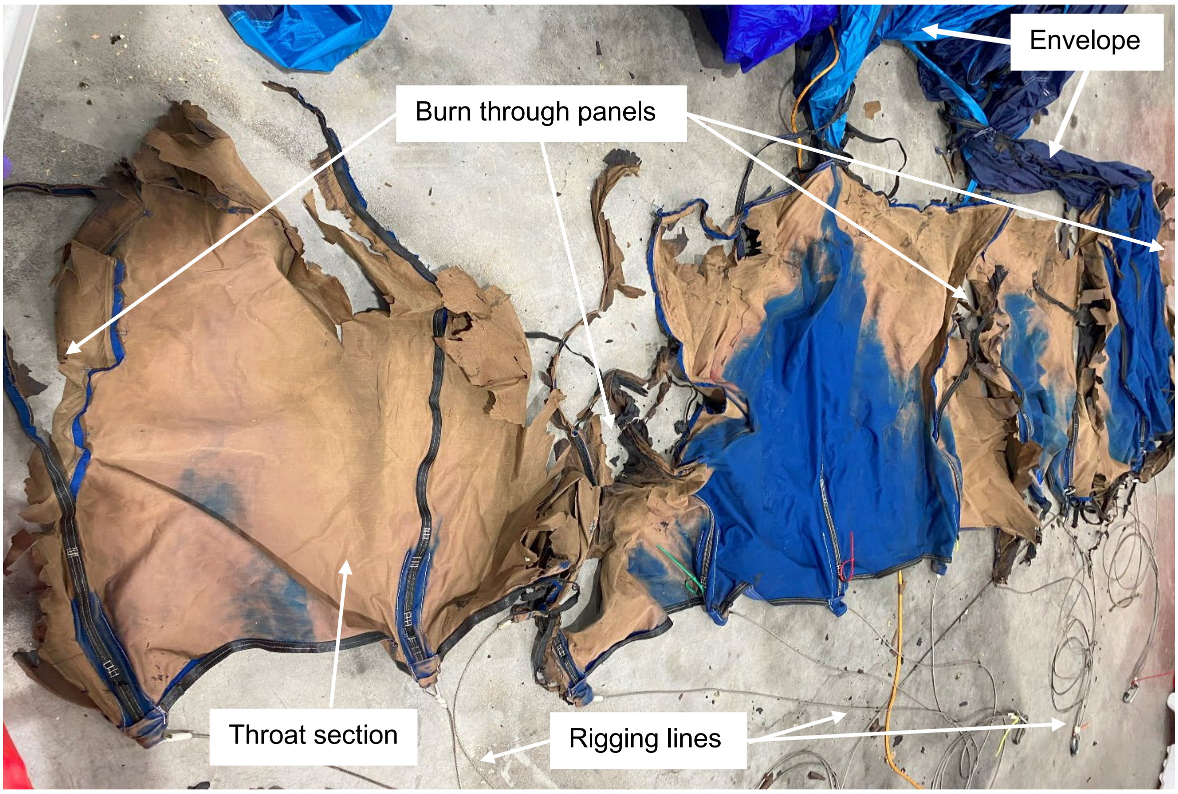

Figure 21

Heat resistant material that formed the throat of the balloon showing multiple, vertical heat damaged areas and burn through

The throat material was in poor condition having been significantly damaged by heat from the burners (Figure 21). There were several burn-throughs and the horizontal load tape attached to the upper edge of the throat panels had melted, separating most of the throat material from the envelope.

Aside from the partially melted lower panels adjacent to the throat material, the remaining envelope material was in good condition with no visible signs of damage or wear prior to that caused when it snagged on trees during the accident.

Parachute

The parachute material was in good condition with no visible signs of damage or wear. The 16 centralising lines were still attached between the edge of the parachute and the junctions between the horizontal and vertical load tapes at the third panel down from the crown. It is more common for the centralising lines to be fixed two panels down from the top. There were differences in length of up to 6.5 cm between the centralising lines. The 16 parachute shroud lines were still attached between the parachute and the shroud line pulley (Figure 9). The orange and yellow operating line remained fastened to the inner surface of the balloon and was routed through the shroud line and lower pullies and into the basket. Where the operating line had passed close to the burner units, some of the line's bright coloured nylon sheath had melted but the line had not broken.

Basket

The wicker basket and frame structure were distorted and the wooden base and runners cracked due to the ground collision. The rigging attachment points, karabiners and burner frame support rods were visually in good condition and still in place.

Burners

The burner frame and gimbal assembly had been distorted by the ground collision and was removed for inspection by a maintenance company. The maintenance inspection report highlighted some damage due to distortion, probably due to the ground collision forces, and one of the piezo electric ignitors was not functioning, but the burners were still functional.

Loading

The mass at takeoff was estimated to be 350 kg (including the basket, equipment, envelope, burners, pilot and full propane tanks). The mass when the accident occurred was estimated to be 335 kg.

As this was an amateur-built balloon there are no published maximum or minimum weights. However, using calculations from similar production balloons, the maximum permitted lift on the day was estimated to be 455 kg. The minimum landing weight published for a similar production balloon was 276 kg.

Meteorology

The Met Office report on the weather stated that:

> *'The morning of the 25 June 2023 could be described as fine, with clear skies and light surface winds. However, the issued forecast indicated wind strengths increasing with altitude to become 35 kt at 2,000 ft. This was coupled with an elevated inversion with the top of the inversion forecast to be between 2,000 and 3,000 ft. Although the light surface winds would not lead to any turbulence, the vertical shear due to the increasing wind speeds aloft could lead to turbulence which could then also be exacerbated, by any localised directional shear associated with the top of the inversion.'*

An extract from the ballooning forecast for Worcester is shown in Figure 22 forecasting an increasing wind with altitude and a temperature inversion. Some competitors chose not to fly on 25 June, based on the forecast they saw on the evening of 24 June.

WORCESTER

Time (UTC)	0400	0500	0600	0700	0800	0900	1000
Surface Wind Dirn.	130	130	150	170	190	190	200
Surface Wind Spd/Gust (kts)	3	3	4	8/13	10/18	11/22	11/23
Surface Air Temp (Deg C)	PS17	PS18	PS19	PS21	PS22	PS24	PS25
500' Wind Dirn	160	160	160	170	190	190	200
500' Wind Speed (kts)	7	9	11	12	15	17	18
500' Air Temp (Deg C)	PS18	PS18	PS18	PS19	PS20	PS22	PS23
1000' Wind Dirn	170	170	170	170	190	190	200
1000' Wind Speed (kts)	15	17	19	17	17	18	19
1000' Air Temp (Deg C)	PS18	PS19	PS18	PS18	PS19	PS20	PS21
2000' Wind Dirn	180	190	190	190	200	190	200
2000' Wind Speed (kts)	30	32	33	31	25	20	20
2000' Air Temp (Deg C)	PS20	PS20	PS20	PS19	PS18	PS18	PS19
Thermal Strength *	Nil	Nil	Weak	Weak	Weak	Mod	Mod
Thermal Height (ft)	0	0	500	1000	1500	2000	4000
Wind Shear	Yes	Yes	Yes	Yes	No	No	No
QNH (Hpa)	1015	1014	1014	1013	1013	1013	1012
Humidity (%)	80	75	70	65	60	60	50

Figure 22

Extract from the ballooning forecast valid from 0400 hrs to 1000 hrs on 25 June 2023 (relevant times highlighted with a red box)

Actual weather

Prior to launch the competition organisers measured the wind at the launch site using a weather balloon and theodolite (the data is shown in Table 2). This data was sent to all the competitors.

Using the position and time data from the competitors' competition loggers, the AAIB calculated the ground speed profiles for each competitor balloon. The data in Table 2 was broadly consistent with the ground speeds attained by the balloons, and with the approximate 6 kt wind gradient between 975 ft and 1,170 ft recorded by the weather balloon and theodolite (Table 2). Most of the balloonists attained around 2,000 ft amsl, where their ground speeds averaged about 30 kt. One balloonist attained about 3,000 ft, where his ground speed averaged about 25 kt.

Height (ft)	Direction (°)	Speed (kt)
195	305	2.8
390	328	5.8
585	342	7.6
780	347	10.0
975	349	13.9
1,170	349	19.5
1,365	354	22.2
1,560	355	26.4
1,755	003	27.0
1,950	000	26.4
2,145	009	25.1
2,340	005	25.5
2,535	001	23.2
2,730	006	20.2
2,925	006	22.9

Table 2

Wind data sent to all competitors prior to launch

Other pilots who flew on the day of the accident reported that the conditions were good, with strong winds at altitude as forecast but no significant turbulence.

Pilot information

The pilot held a current Commercial Pilot's Licence (Balloons) and was rated on Class A, B and C balloons. He was an experienced competition balloon pilot having competed for several years all over the world.

His logbook showed he had 569 hours of balloon flying including 460 hours in command. He had flown 91 hours in competition flights, and 33 hours in the DB-6R type including 17 hours in G-CMFS. He also held a commercial fixed wing licence, had approximately 1,000 hours of fixed wing experience and flew for an airline.

Several people who knew him well said that he was a “very safe pilot” and was often talking about safety. They also said that he was competitive and wanted to win. A friend said that he was one of “the world’s best pilots, but [he] would push the limits of what [he] could do”. It was stated that “the competition held more significance as he hadn’t been able to make many of the competitions that year due to work [and] in order to quality for international events next year, he had to perform well to get a high enough average score”.

Post-mortem examination

The post-mortem report stated that death was caused by ‘*multiple injuries caused by a fall from a height*’. The toxicological analysis found no alcohol or drugs.

Parachute stall

Principles of parachute stall

The parachute vent panel does not generate sufficient lift to support its own weight and that of the rigging, shroud line pulley and operating line. The force holding the vent panel in place is the difference (delta) between the outside air pressure above the vent panel and the pressure inside the envelope below it. Once the vent is operated, dynamic airflow around the edge of the vent panel and through the aperture opening will generate lift and suck the vent panel back into the aperture.

Design and handling considerations

There are known design and operator handling considerations that can lead to a parachute vent panel becoming susceptible to stall:

> Design Choices: If the centralising lines are located too far down from the top of the balloon, it allows the parachute to be pulled down into the envelope to the point where the pressure above and below the vent is equal, and this is the stall point. Below this point, the lift produced from hot air below the parachute is insufficient to overcome the weight of the panel and rigging. Whilst this is a useful feature when landing to rapidly deflate the envelope, it is a dangerous condition in flight. The situation is made worse in a racing balloon because an envelope already elongated by design is elongated more as the balloon deflates, bringing the centralising lines even further down from the top of the balloon. Conversely, if the centralising lines are located too high, the parachute is hard to open and easily snaps back into place, which can be dangerous during landing where rapid deflation is necessary. In this situation, the pilot must haul on the operating line the whole time just to keep the vent open.
>
> Excessive inputs by the pilot: Aggressive use of the vent line in flight can cause the parachute vent to stall. Strong, repeated or extended use of the parachute to vent hot air reduces the internal pressure, elongates the envelope and can cause the parachute to stall. If the pilot does not pay close attention to the parachute in this circumstance, deflation of the envelope can be rapid, causing a dramatic loss of lift.
>
> High rates of climb: With an increase in the rate of climb comes a corresponding increase in the pressure on top of the balloon envelope and above the parachute. The faster the climb rate, the higher the pressure. As this pressure increases, the difference between the pressure above and below the parachute valve decreases, resulting in a decrease in the distance the parachute can be pulled into the envelope before it reaches the stall point. Aggressive venting whilst in a fast climb could more easily result in a parachute stall.
>
> Windshear and turbulence: Windshear and turbulence can also adversely affect the pressure difference above and below the parachute. It can cause deformation of the envelope resulting in dynamic changes to the parachute rigging thereby potentially altering the stall characteristics of the parachute.

Loading of the balloon: A lightly loaded balloon requires a lower internal pressure for a given ascent rate. When venting under these circumstances, the reduced internal pressure and, therefore, delta pressure across the parachute valve, could cause the parachute to stall at a lower ascent rate, perhaps an even lower rate than the maximum ascent rate specified in a balloon's operating manual. Manufacturers of CAA Part 21 balloons specify a minimum loading of ½ the maximum takeoff mass (MTOM) for this reason.

BBAC guidance on avoiding a parachute stall

If the parachute cannot reseal the vent and stalls, the balloon envelope will collapse. The BBAC pilot training manual contains the following information about parachute stalls:

> *'The manufactures' manuals put the maximum opening time of a parachute vent at 3 seconds, after which it must be allowed to re-seal before being used again. Vigorous venting is still possible by a rapid succession of short pulls with complete closure between each operation. Each pull should be no more than 1.5 metres of line, and in practice the procedure may be quite energetic.*
>
> *If the valve is used repeatedly to produce a steep descent, then the pilot should take care to observe the amount of deflation that this is producing upon the envelope.*
>
> *In very lightly loaded conditions, it may happen that the parachute does not close automatically, because the balloon has cooled too much to support the weight of the parachute. A short blast of heat is usually sufficient to push the parachute back up into place, but this is a matter of judgement at the time. A parachute "stall" as it is called is extremely unlikely when airborne in balloons of normal size range and normally loaded, but a very large balloon with an absurdly light load may stray into this danger area. However, parachute stalls are by no means uncommon when balloons are standing inflated on the ground and are allowed to cool too far to support an action of the parachute.'*

The BBAC manual suggests that parachute stalls are *'extremely unlikely when airborne'* but reports submitted to the AAIB suggested they are more common than previously understood, particularly during competition flying. The reports described 12 previous parachute stall incidents which various pilots had experienced. The events occurred in balloons from several different manufacturers and different designs. There was no evidence that these events had previously been formally reported to the BBAC or CAA or any learning captured in a forum. Where details about the incidents were known, one or more of the following factors were described:

- The balloon was in a rapid climb. In some of the reports, the parachute stalled after it was opened to slow the climb rate.
- The balloon was lightly loaded.

- The balloon entered unstable air or wind gradients. In some cases, the envelope was described as having distorted or 'caved-in' on one side of the envelope.

Most reports described the balloon descending rapidly following the stall. In about a third of these, the pilot burned through the envelope to re-inflate it, which slowed or stopped the descent.

The AAIB obtained flight data from one case involving a lightly loaded balloon that climbed from a low height at 8 m/s, a similar rate to G-CMFS's last climb before the accident. The pilot described a parachute stall which caused the throat to close. The balloon stopped climbing and began descending at about 6 m/s (1,200 ft/min). He managed to burn through the envelope to re-inflate it and landed shortly afterwards.

Several experienced competition pilots who had experienced parachute stalls, also suggested they tend to occur when lightly loaded, in turbulent or unstable air masses, and when using the parachute during a rapid climb. However, the AAIB did not find any published guidance on the factors that increase the likelihood of a parachute stall or the best technique to recover from a stall.

Other pilots who had flown G-CMFS or the identical balloon G-CKUN were asked if they had experienced any problems with the parachute. None had experienced any difficulties, and all reported that the parachute had always resealed. However, none of the other pilots thought they had climbed at greater than 7 m/s (1,400 ft/min) with this design. Recordings of flights by pilots in G-CKUN were not available to the investigation to verify this from recorded data.

Amateur-built hot air balloon design, construction, and testing

Amateur-built balloons and airships[9] are not regulated with respect to airworthiness and there is no airworthiness assurance system in place. Aside from CAA SD-2021/004[10] issued on 21 September 2021, which limits the envelope size and occupancy of amateur-built balloons, design expertise depends very much on the knowledge and experience of the designer. For G-CMFS, construction was completed using high quality materials sourced from balloon manufacturers and in a workshop dedicated to amateur-build balloon construction and assembly. There was plenty of advice and knowledge available regarding balloon construction at the time the balloon was built.

As the balloon was an amateur-build project, there was no requirement to test fly it to determine its handling or flight characteristics or to have it independently examined for build quality or design. The AAIB found no evidence that performance limits for this design, including the rate of climb which could stall the parachute, had been determined.

Footnote

9 This inclusion "*recognises that balloons can be readily converted to airships by adding propelling and steering means*" CAA Safety Directive SD-2021/004 section 2 paragraph 2.1.

10 Safety Directive SD-2017/00n, https://www.caa.co.uk/publication/download/19083 [accessed 5 March 2024].

An identical envelope to G-CMFS was made available to the AAIB, and a series of four ground-tethered tests were conducted at a manufacturer's facility to observe the parachute's characteristics during operation. The tests showed that the parachute tended to 'float' when activated for between four and five seconds, before snapping back to seal the aperture at the top of the envelope (Figure 23).

When the parachute operating line was pulled for approximately six seconds, the parachute stalled (Figure 24 left) and the envelope started to collapse before the burners were promptly activated to reseat the parachute and re-inflate the envelope (Figure 24 right).

Figure 23

Parachute 'floating' during ground testing

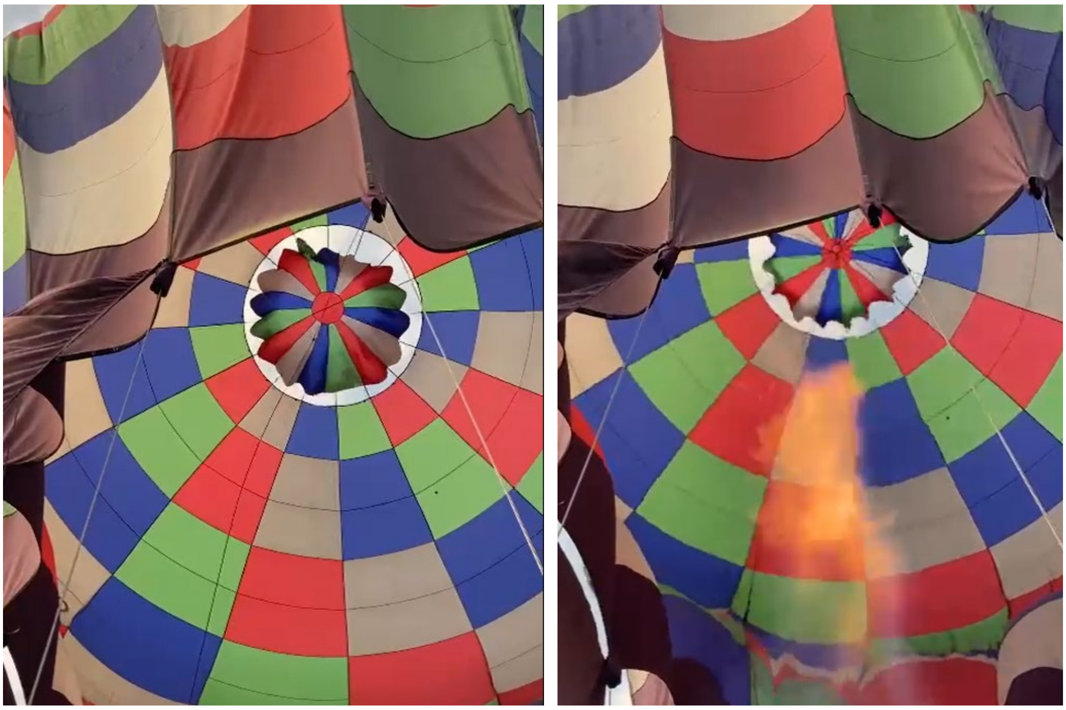

Figure 24

Parachute stalled (left) and burners used to reseat the parachute and reinflate the envelope as it started to collapse (right)

Organisational information

The competition event on 25 June 2023 was organised by the BBAC Competitions Club and was part of their British Grand Prix Series. The event had an Event Director who set the rules, targets and briefed all the pilots prior to launch. Other competitors who took part on the day of the accident reported that the briefing was good and included a discussion of the wind gradient. The rules for the competition were based on a standard set of rules published by the Fédération Aéronautique Internationale (FAI) Ballooning Commission[11].

One of the rules restricted the balloons' vertical speed, but the purpose of this rule was to reduce the chance of collisions. The limiting vertical speed reduced as the separation (proximity) between balloons decreased. The rules are shown in Figure 25.

VERTICAL SPEED (10.2)

Logger tracks may be checked using the Balloon Safety Analyzer. Competitors exceeding the limits of vertical speed below will be penalized:

Limit	3D Proximity	Relative Vertical Speed
Limit 1	25 m	3 m/s
Limit 2	50 m	5 m/s
Limit 3	75 m	8 m/s>

Limit 4: Exceeding the absolute vertical ascent speed of 8 m/s will be penalized.

Figure 25

Vertical speed limits specified in the competition rules

The FAI Ballooning Commission event rules give the following statements regarding weather information and the responsibility of competitors:

> *'Any meteorological report or forecast, or other safety or navigational information, is provided in good faith for the guidance of competitors. Officials may be appointed to regulate the inflation and launching of balloons. However, nothing shall diminish the responsibility of competitors under this chapter.'*
>
> *'Entrants and competitors remain completely responsible for the safe operation of their aerostats[12] at all stages of inflation, launch, flight and landing. They must ensure that their equipment, their crew and their own level of skill and experience are suitable for the conditions in their own judgement.'*

Footnote

[11] The FAI is an international federation for the conduct of air sports internationally. It has a constitution and defined sporting codes for each air sport that it covers and for which it recognises awards. The Ballooning Commission is the arm responsible for conducting International Ballooning Competitions and World Record attempts.

[12] An aerostat is a lighter-than-air aircraft that gains its lift through the use of a buoyant gas.

The BBAC is a volunteer organisation that promotes the enjoyment, advancement and safety of lighter-than-air flight. It aids in the training of pilots and crew members, and encourages the growth of lighter-than-air flying (hot air balloons, gas balloons and airships), from individual flying to large events. It also promotes competitive ballooning at both national and international level.

During the investigation the BBAC raised concerns about the reporting culture in the ballooning community because it was aware that many incidents were going unreported. These concerns were supported by the fact that the AAIB was made aware of previous similar parachute stall events that had not been formally reported. The BBAC considered that the lack of reporting limited its ability to extract learning from previous incidents and share that knowledge with the ballooning community.

To address this the BBAC proposed to promote the importance of safety reporting via its monthly newsletter, bi-monthly magazine and website, and to hold a Safety Day to raise awareness of the issues raised by this accident. To promote best practice in the organisation of all balloon events in the UK, the CAA intended to produce a guidance document about organising ballooning events.

Parachute anti-stall systems

After extensive testing and trials, some manufacturers concluded that whilst a parachute vent remains suitable for balloons where the rate of climb is limited in the Pilot's Operating Manual to between 1,000 and 1,200 ft/min, it may not be suitable for racing balloons with rates of climb as high as 1,800 ft/min. Their conclusions were based on the parachute vent's propensity to stall and their sensitivity to unstable weather conditions at those higher climb rates.

Manufacturers have developed anti-stall vent systems for balloons, some examples of which are in Appendix A. One of the anti-stall vent systems is free from Intellectual Property Rights and is illustrated and described on the respective manufacturer's open-source website. Adding one of these systems to an amateur-designed racing balloon is unlikely to be cost-prohibitive and is likely to improve handling and safety.

Survivability

During a similar incident reported to AAIB inspectors during the investigation, an envelope had collapsed but the pilot had managed to reinflate it in time to prevent a ground collision by using the burners to burn through the scoop and lower heat resistant panels. Sufficient hot air was eventually streamed into the envelope to reseat the parachute and re-inflate the envelope. The pilot also jettisoned the LPG cylinders over the side of the basket to reduce the weight of the basket.

The AAIB was unable to find any guidance which established the benefit and risks of jettisoning heavy cylinders during an uncontrolled descent. Discussion with experienced balloon pilots generated varying opinions about whether jettisoning tanks in an emergency affected the outcome.

Analysis

During a rapid climb from the first target location the balloon envelope was seen to collapse. The pilot was unable to re-inflate the envelope before the basket struck the ground.

There was no evidence that the balloon envelope had suffered any structural failure prior to hitting the trees. The damage found to the lower fabric panels and load tapes was consistent with heat damage, caused by the pilot attempting to reinflate the envelope, and tearing from the collision with trees. Witnesses stated that the burners were still working during the descent, and testing during the investigation showed that the burners were still functional. A burner failure would not account for the sudden envelope collapse, rapid descent and burn patterns found on the scoop and lower sections of the envelope.

The likely explanation for the envelope collapse is that the balloon experienced a parachute stall during a rapid climb, which peaked at 8.3 m/s prior to the collapse. G-CMFS was an amateur-build balloon which was not required to complete any formal testing, so the maximum safe rate of climb was not known. However, data from the flight the previous day showed that the balloon had climbed at a similar rate on that flight with no report of a stall. It is likely, therefore, that other aggravating factors combined during the accident flight to cause a stall.

There was a strong wind gradient on the day of the accident. As the balloon climbed through 1,000 ft amsl it is likely the wind increased by at least 10 kt. This wind gradient was forecast and discussed at the pre-flight briefing the day before, but the competitors who flew reported the conditions were fine with no significant turbulence. Climbing into a changing wind can cause the balloon to distort, increasing the chance of a stall. This can be managed by climbing slowly and ensuring the balloon is heavily loaded so that the envelope pressure is relatively high and the envelope more rigid. On the accident flight, the load calculations showed that the balloon was loaded approximately midway between the advised minimum and maximum loading limits. Whilst climbing rapidly into the wind gradient (more rapidly than other competitors), photographs taken by witnesses (Figures 7 and 8) showed the envelope distorting during the climb. This factor was likely to have increased the chance of a stall.

One possible scenario is that the pilot used a high rate of climb to gain a competitive edge because of his desire to do well in the competition and, if he noticed he was exceeding the competition's climb rate limit, he is likely to have wanted to rapidly reduce his climb rate to avoid receiving a penalty. This may have caused him to use the parachute excessively or for an extended period, which could have triggered the rapid onset of a parachute stall. It is not known where the pilot was looking during the rapid climb. Video evidence from the previous flight showed he did not always look up at the parachute when operating it, and when he did, it was usually a quick glance. This may not have given him sufficient time to recognise what he was seeing and respond accordingly. If he was not looking up when he operated the line, he may not have immediately noticed that the parachute might not have re-seated correctly. An envelope collapse can occur quickly when the parachute stalls, so the opportunity to respond in time to correct it is limited.

Design factors affecting stall characteristics.

The parachute centralising lines on G-CMFS were attached to the envelope three panels down from the crown, rather than two panels down as more commonly found on other balloon types. Whilst this allowed the parachute to descend further into the envelope to improve the responsiveness and effectiveness of the parachute in flight, this also made it more prone to stalling.

As a racing balloon design, the diameter of the upper envelope of G-CMFS was smaller than that of a conventionally shaped balloon. Therefore, if the envelope distorted, the contraction in the envelope's diameter was likely to be faster than that of a conventionally shaped balloon, slackening the parachute's centralising lines more quickly. As a result, the parachute would be free to fall further into the envelope, increasing the stall risk further and reducing the time available for the pilot to react to prevent a collapsing envelope from developing into a streamed envelope.

The testing of an identical balloon showed that the parachute was susceptible to floating and easy to stall. However, since the balloon was tethered to the ground, the testing was not fully representative of in-flight conditions on the day of the accident and may not have reflected how the pilot of G-CMFS used the parachute during the accident flight.

The investigation considered the possibility that the balloon's limit of performance was reached on the accident flight when the recorded data indicated that G-CMFS climbed at slightly above 8 m/s before it was seen descending to the ground. Because there was no requirement for performance testing on amateur-built balloons, it was likely the pilot was not fully aware of the operating limits of G-CMFS and the rate of climb at which there would be an increased risk of experiencing a stall. The increased climb speed would have reduced the differential pressure securing the parachute vent, and hence the margin before stalling, although there was insufficient evidence to conclude that this alone caused the accident. Knowing the performance limits of an aircraft is essential because those limits are likely to be approached when pilots attempt to maximise their aircraft's performance in a competition.

Two overseas balloon manufacturers stated that they would not use a basic parachute vent system on racing balloons which are expected to ascend at high rates of climb. Instead, they had developed alternative anti-stall vent systems for designs expected to achieve rates of climb above 1,200 ft/min (about 6 m/s). Anti-stall vent systems have been designed to avoid or quickly rectify a parachute stall, and had one been fitted to G-CMFS the accident may have been avoided.

There is no written guidance or best practice to assist amateur designers in ensuring their balloons avoid features that might impinge on safety, such as the potential for parachute stall. There are no requirements for amateur designers and amateur manufacturers to determine essential performance limits. The finished product is not required to be inspected, and there are no inspection criteria to apply to amateur-built competition balloon designs other than the general criteria that would be applied regardless of type. Therefore the following Safety Recommendation is made:

Safety Recommendation 2024-008:

It is recommended that the Civil Aviation Authority publish guidance on the design, testing and inspection of amateur-built balloons to reduce the risk of accidents due to unsafe conditions such as parachute stall.

Whilst there were some differences in the lengths of the centralising lines between the sides of the envelope and the edge of the parachute, and some differences in vertical load tape lengths from the aperture to the crown ring, these were not considered contributary to the accident. The video footage from 24 June showed the parachute remaining centred both when closed against the crown and when pulled to vent hot air.

Prevalence of parachute stalls

Twelve previous parachute stall events were reported to the AAIB during the course of the investigation. These occurred in various balloon types and under similar conditions to G-CMFS, suggesting that the risk was not unique to the DB-6R design. The reports also suggested that a parachute stall is more likely in a climb than in a descent. However, none of these events had been formally reported, meaning that any opportunity to learn from them has not been captured. An effective reporting culture is an important way to improve safety and therefore the following Safety Recommendation is made::

Safety Recommendation 2024-009:

It is recommended that the British Balloon and Airship Club routinely communicate the importance of safety reporting to its members to promote an effective reporting culture, capture safety learning and help prevent a recurrence of ballooning accidents and serious incidents.

Operational prevention of and recovery from parachute stalls

Several experienced balloon pilots reported to the investigation their experience of a parachute stall, and options on how best to prevent and recover from one. However, this guidance and experience is not captured in any document.

The evidence suggested that the pilot of G-CMFS tried to reinflate the balloon by burning through the fabric after the envelope and throat collapsed, which was an action taken by some of those who shared with the AAIB their experiences of a parachute stall. Whilst the AAIB has learned of these parachute stall events in which pilots recovered successfully, the knowledge and best practice has not been collated and published. Therefore the following Safety Recommendation is made:

Safety Recommendation 2024-010:

It is recommended that the British Balloon and Airship Club publish guidance on best practice for the prevention of and recovery from unsafe conditions such as parachute stalls.

Jettisoning one of the cylinders to reduce weight, which has been suggested as one possible action a pilot could take in these circumstances, in order to slow the descent, is only likely to be effective in cases when a balloon is still partially inflated and exerting a buoyancy force, which is not the case when in a streamered state. Experienced balloon pilots shared varying opinions with the AAIB on the effectiveness of jettisoning heavy cylinders during an emergency. A lack of guidance on this subject means it is unclear whether this is the best course of action in either an uncontrolled descent due to a parachute stall, or in some other emergency. Therefore the following Safety Recommendation is made:

Safety Recommendation 2024-011:

It is recommended that the British Balloon and Airship Club publish guidance material on best practice regarding jettisoning of fuel tanks during an emergency.

Safety oversight of competition flying

Competitors who took part on the day of the accident reported that the event was well organised and they received a good pre-flight briefing. They were aware of the significant wind gradient and, although the day before some competitors had chosen not to fly based on the forecast, those who did fly reported the conditions were fine. The rules make it clear that the decision to fly rests with the pilot of each balloon.

It is important that competition pilots balance the desire to do well and compete with the need to operate safely. The advice in strong wind gradients, to climb slowly and fly at a relatively heavy weight (which results in an increased pressure in the envelope), can conflict with the desire to push the balloon to its limits to win the competition. It is vital that all competition organisers ensure that this risk is well managed. Therefore the following Safety Recommendation is made::

Safety Recommendation 2024-12:

It is recommended that the Civil Aviation Authority publish guidance for the safe oversight of competition balloon flying in the UK, to ensure the risks associated with the activity are appropriately understood by competitors and managed by competition organisers.

Conclusion

Whilst the AAIB could not establish the exact cause of the accident, G-CMFS was likely to have suffered a parachute stall whilst climbing rapidly from the first target location. It is likely that the rapid climb, wind gradient, and the balloon design all contributed to the stall occurring.

Recommendations are made to the BBAC to publish guidance about unsafe conditions such as parachute stalls and to establish the efficacy of jettisoning fuel tanks in an emergency. A recommendation is made to the CAA to review the rules and provide guidance for amateur-built balloons.

The investigation found a lack of safety reporting in the ballooning community and a recommendation is made to the BBAC to proactively address this. It was also recommended that the CAA publish guidance about the safety oversight of competition balloon flying in the UK.

Appendix A

DESCRIPTIONS OF THREE ANTI-STALL VENTING SYSTEMS

Paralite system

The Kubicek Balloons Paralite system, (Figure A-1), is similar to a parachute system except that the centralising lines are free to travel through pulleys near the edge of the vent aperture at the top of the envelope. The opposite end of the centralising lines is connected to a weight that ensures the vent panel is easier to reset. Two vent operating lines are fitted, a red and white line which is pulled to vent the hot air in the same way that it is for a parachute valve. When released, the Paralite resets itself by internal overpressure and the action of the weight. The weight provides some compensation for pressure increases above the vent panel during a rapid climb or during turbulent conditions, effectively adjusting the stall point to a higher-pressure delta. The white operating line is designed to close the vent aperture manually if necessary.

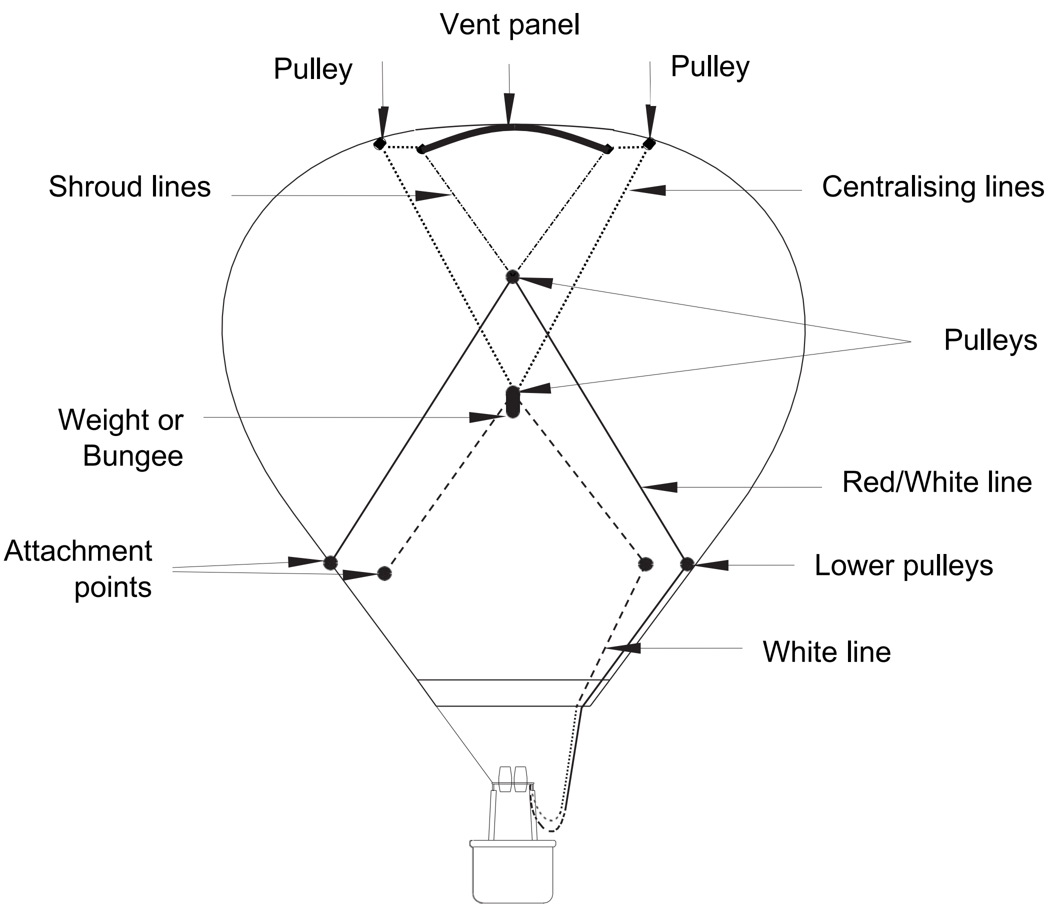

Figure A-1

Diagram of Paralite venting system.

Table A-1 below shows the action and controls of the operating lines to open and close the vent aperture:

Paralite controls	Desired action	Control motion required
In-flight venting and deflation	Open Paralite	Pull and hold RED-WHITE line
	Close Paralite	Release RED-WHITE line – Paralite closes itself Pull WHITE line if necessary

Table A-1

Paralite control actions using the two operating lines.

Lite Vent deflation system

The Kavanagh Balloons Lite Vent deflation system (Lite Vent) was developed in 1998 and was fitted to racer type balloons to prevent dangerous situations developing from a stalled vent. The Lite Vent uses a floating centralising/reset line system that allows free movement of the panel when operating the parachute vent. Shown in Figure A-2[13], the reset lines travel a short distance to a pulley (A) on the side of the balloon adjacent to the vent aperture. From that point they travel down to a reset weight (B) where the lines join. A control line at the base of the reset weight allows the pilot to haul the vent closed manually if necessary. The weight works to balance the mass of the rigging lines in the system and keep the vent panel stretched open to cover the aperture.

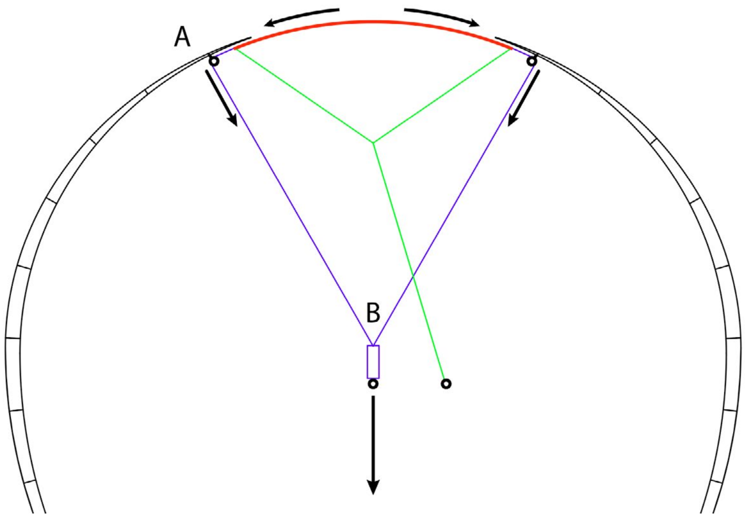

Figure A-2

Lite Vent diagram showing rigging and reset weight.

When activating the vent, Figure A-3, the reset weight is drawn up towards the vent allowing the centralising lines to extend as needed during activation. The vent panel edges are rolled inwards to allow air to flow out of the aperture (Figures A-4 and A-5).

Footnote

[13] All images in Figures A-2 to A-5 are used with permission.

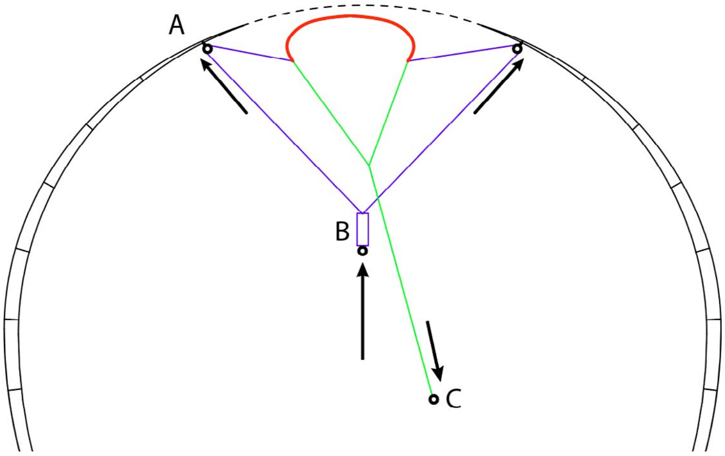

Figure A-3
Lite Vent diagram showing activation of the vent when (C) is pulled.

Figure A-4
Picture of Lite Vent showing vent edges rolled inwards.

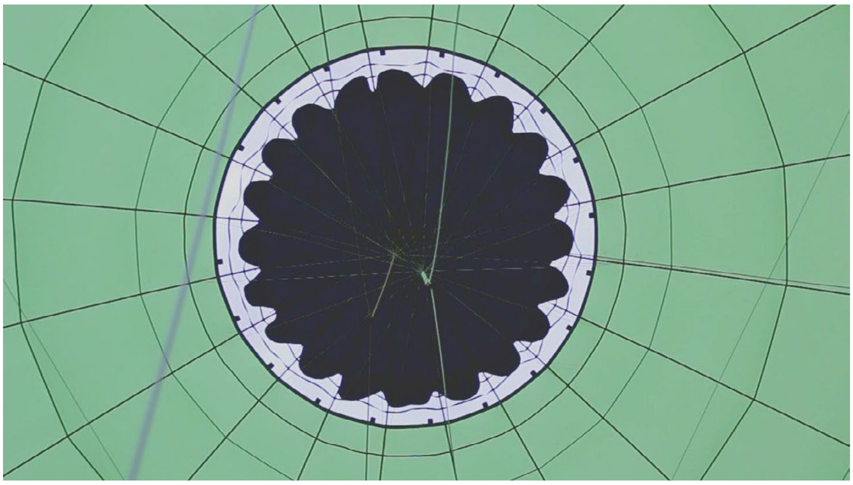

Figure A-5
Lite Vent open as seen from throat of envelope.

Whilst the vent panel can still be pulled away from the crown ring with some effort or during extreme rates of climb, a pull on the reset line closes the vent again with no requirement for the use of the burner. The manufacturer stated that this vent design is free from Intellectual Property Rights, therefore, it can be copied for use in any balloon design to enhance safety.

Para Plus system

The Cameron Balloons Para Plus system is a blend of the venting and deflation action of a standard parachute vent but with the centralising lines of a rapid deflation system. This results in light operating line loads for venting and deflation, with extra security during fast climbs but without the need for Velcro tabs to hold the vent in place to enable the envelope to be inflated on the ground (Figure A-6).

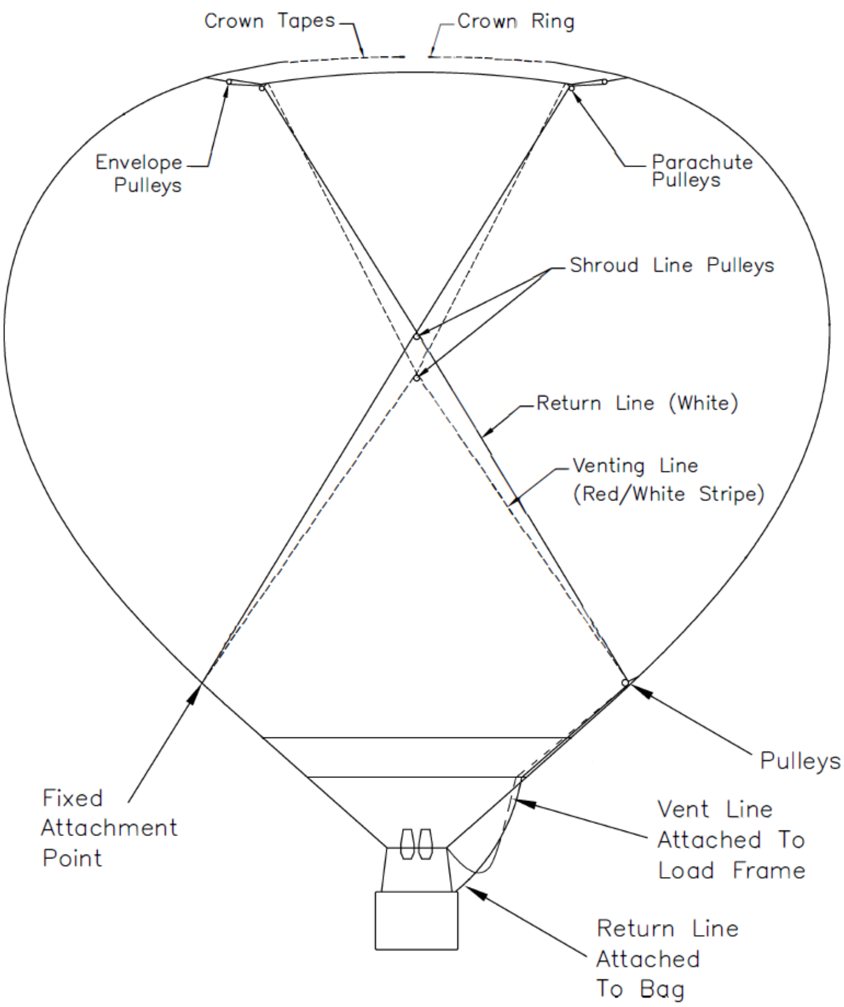

Figure A-6

Schematic of the Para Plus venting and deflation system

The Centralising lines of the panel are run through pulleys on the envelope and parachute edge, allowing them to extend when the red-and white line is pulled. The centralising lines are attached to a white "return" line which can be used to force a closure of the panel (Figure A-7).

In normal operation the panel will automatically close after each vent operation, but the white closing line may be operated to re-seat the panel if it doesn't close automatically.

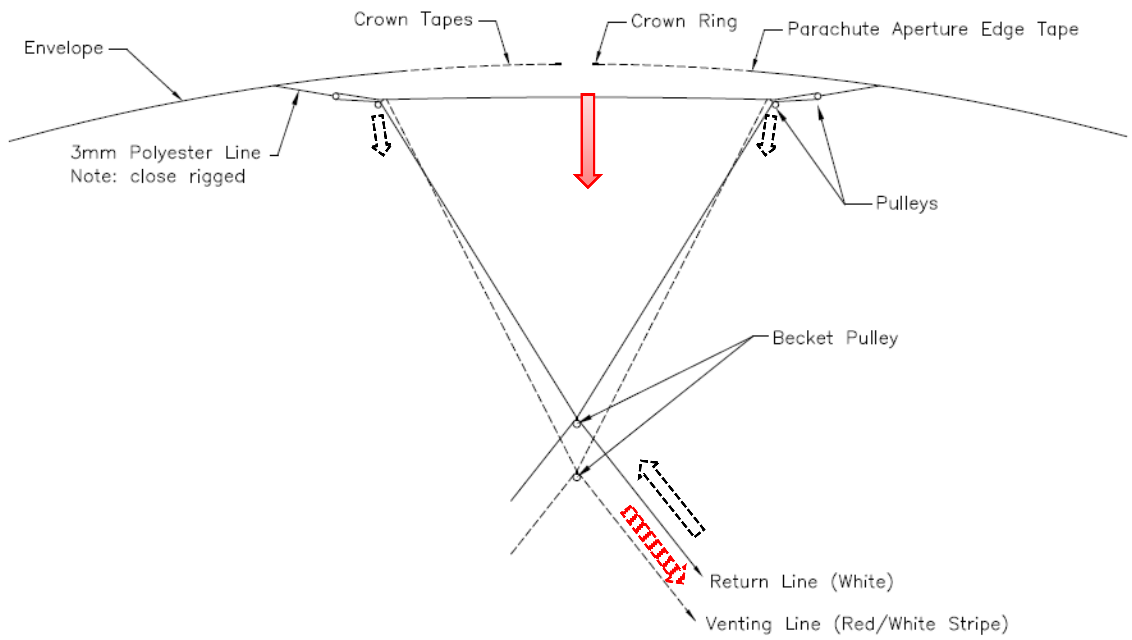

Figure A-7

Schematic showing a detailed view of the vent and return line system (Arrows depict movement of lines and parachute valve when vent operating line pulled)

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