Australian Government
Australian Transport Safety Bureau

In-flight fire involving Kavanagh B-350 hot air balloon, VH-ZYO

near Coldstream, Victoria on 26 December 2018

ATSB Transport Safety Report
Aviation Occurrence Investigation
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Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office: 62 Northbourne Avenue Canberra, Australian Capital Territory 2601
Telephone: 1800 020 616, from overseas +61 2 6257 4150 (24 hours)
Accident and incident notification: 1800 011 034 (24 hours)
Email: atsbinfo@atsb.gov.au
Website: www.atsb.gov.au

Addendum

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Safety summary

What happened

On 26 December 2018, a Kavanagh B-350 hot air balloon, registration VH-ZYO, operated as a scenic charter flight by Go Wild Ballooning, departed from Wandin, Victoria with the pilot and 15 passengers on board.

After 20 minutes in flight, and while operating at an altitude of about 800 ft, the pilot recalled hearing a small explosion from the front left burner and observed that a small fire had started on the outside of the burner. The pilot switched off the vapour valve at the fuel tanks to the front two burners and disconnected the hoses.

About a minute later, the pilot attempted to put out the fire using one of two on-board extinguishers, but the fire re-ignited almost immediately. After a further minute, the pilot discharged the second fire extinguisher, but again the fire re-ignited.

Moments later, the pilot's compartment caught fire. The pilot was wearing a cotton shirt, synthetic vest, rolled-up pants, and rubber slip-on shoes and began to feel uncomfortable with his proximity to the fire. He then moved from the pilot's compartment to the back left compartment of the basket.

About 8 minutes after the fire started, the pilot identified a suitable landing position and began the approach. During the descent, the basket struck some treetops and the ropes became tangled in the branches. Passengers reported that the branches whipped around and into the basket, with one passenger sustaining cuts to his hand. The pilot freed the ropes from the tree and brought the balloon to rest in the paddock below. As the basket touched the ground, the passengers jumped out and ran to safety.

The fire continued to burn as the pilot secured the balloon. When emergency services arrived on site, flames had engulfed the balloon. By the time firefighters extinguished the flames, the fire had destroyed the balloon.

What the ATSB found

The ATSB found that the in-flight fire was the result of a fuel leak at the front left burner. Due to severe fire damage, the source of the leak could not be determined conclusively, but it was considered most likely to be the main ball valve, liquid fire valve or liquid fire valve connection to the main valve block.

The hand-wheel valve on the liquid outlet of the fuel tank and the pilot burners were not shut-off, which resulted in the pilot being unable to control the fire. Installation of a 90-degree valve on the liquid fuel outlet may have assisted the pilot to recognise that the liquid fuel valve was not shut-off.

In addition, the pilot's clothing did not meet the recommended industry standards for personal protective equipment, which increased the risk to his personal safety.

What's been done as a result

As a result of this occurrence, the Civil Aviation Safety Authority released an Airworthiness Bulletin (AWB 02-063) to address some of the pertinent issues surrounding this occurrence. The AWB included:

- a recommendation to inspect critical componentry
- the use of 90-degree shut-off valves for the fuel tank liquid outlets
- a reminder to close off liquid and vapour valves in the event of a fire
- a reminder to wear appropriate personal protective equipment.

In addition, Go Wild Ballooning has advised the ATSB that they have replaced all hand-wheel valves with 90-degree valves on all fuel tanks and reviewed the company policy on protective clothing.

Safety message

In the event of an in-flight balloon fire, the first priority is isolation of the fuel supply at the fuel tank. It is good practice to rehearse emergency procedures by standing in the basket to run through the checklist steps.

Further ways to reduce risk to individuals and improve survivability outcomes include:

- wearing appropriate protective clothing that includes cotton long-sleeved shirts and long trousers, leather gloves, and enclosed footwear
- utilising componentry that provides a visual indication of the system status, for example, 90-degree valves on liquid outlets.

On-board view of in-flight fire involving VH-ZYO

Source: Passenger photo

The occurrence

What happened

On 26 December 2018, at about 0500 Eastern Daylight-saving Time,[1] a Kavanagh B-350 hot-air balloon, registration VH-ZYO, operated as a scenic charter flight by Go Wild Ballooning, was being prepared for departure from Wandin, Victoria.

Prior to take-off, the pilot, together with another ground crew member, conducted the pre-flight check on the balloon, while a ground crew member conducted a safety briefing with the passengers. Neither person inspecting the balloon observed any defects during the pre-flight check.

At 0537, the balloon lifted off with the pilot and 15 passengers on board. After about 15 minutes in flight, the balloon reached an altitude of 4000 ft. The pilot maintained level flight for a few minutes and then began to descend. At about 800 ft, the pilot recalled hearing a small 'explosion' from the front left burner (Figure 1) and observed that a small fire had started on the outside of the burner. The passengers observed that the fire was concentrated around the base of the burner, shooting outwards to the front of the basket.

The pilot switched off the vapour valve (see the section titled *Aircraft information*) at the fuel tanks to the front two burners and disconnected the hoses. Shortly after, the vapour hose connected to the front left burner burnt through and fell away from the burner.

About a minute later, the pilot attempted to put out the fire using one of two on-board extinguishers, but the fire re-ignited almost immediately. After a further minute, the pilot discharged the second fire extinguisher, but again the fire re-ignited. The first flames appeared in the vicinity of the burner can base, towards the front side of the basket, with the flames directed outwards.

Moments later, the pilot's compartment caught on fire. The pilot was wearing a cotton shirt, synthetic vest, rolled-up pants and rubber slip-on shoes and began to feel uncomfortable with the proximity of the fire. As a result, the pilot moved from the pilot's compartment to the back left compartment of the basket. The pilot made a call over the radio, repeating MAYDAY[2] three times followed by the balloon registration. Air traffic control acknowledged the call and initiated the appropriate emergency procedures in response.

About 8 minutes after the fire started, the pilot identified a suitable landing position and began the approach. During the descent, the basket struck treetops in the landing area undershoot and the ropes became tangled in the branches. Passengers reported that the branches whipped around and into the basket, with one passenger sustaining cuts to his hand. The pilot freed the ropes from the tree and brought the balloon to rest in the paddock below. As the basket touched the ground, the passengers on the right hand side of the basket jumped out causing the right side of the basket to lift off the ground again. In response, the pilot quickly pulled the red line[3] to evacuate the hot air from the envelope and brought the basket back down to the ground. The remaining passengers then jumped out and ran to safety.

The fire continued to burn as the pilot secured the balloon. When emergency services arrived on site, flames had engulfed the balloon. By the time firefighters extinguished the flames, the fire had destroyed the balloon.

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1 Eastern Daylight-saving Time (EDT): Coordinated Universal Time (UTC) + 11 hours.

2 MAYDAY: an internationally recognised radio call announcing a distress condition where an aircraft or its occupants are being threatened by serious and/or imminent danger and the flight crew require immediate assistance.

3 A rope or nylon strap connected to the top of the envelope, which the pilot uses to vent some or all of the hot air inside the envelope in order to descend or land.

Pilot's comments

The pilot later commented that:

- he was carrying a long woollen coat in the basket as additional protective clothing, however, it was not accessible
- he had not been wearing protective gloves, as they had been burnt earlier in the flight, when he had put them aside to adjust the radio
- during the incident, he followed the priority of, 'aviate, navigate, communicate'.

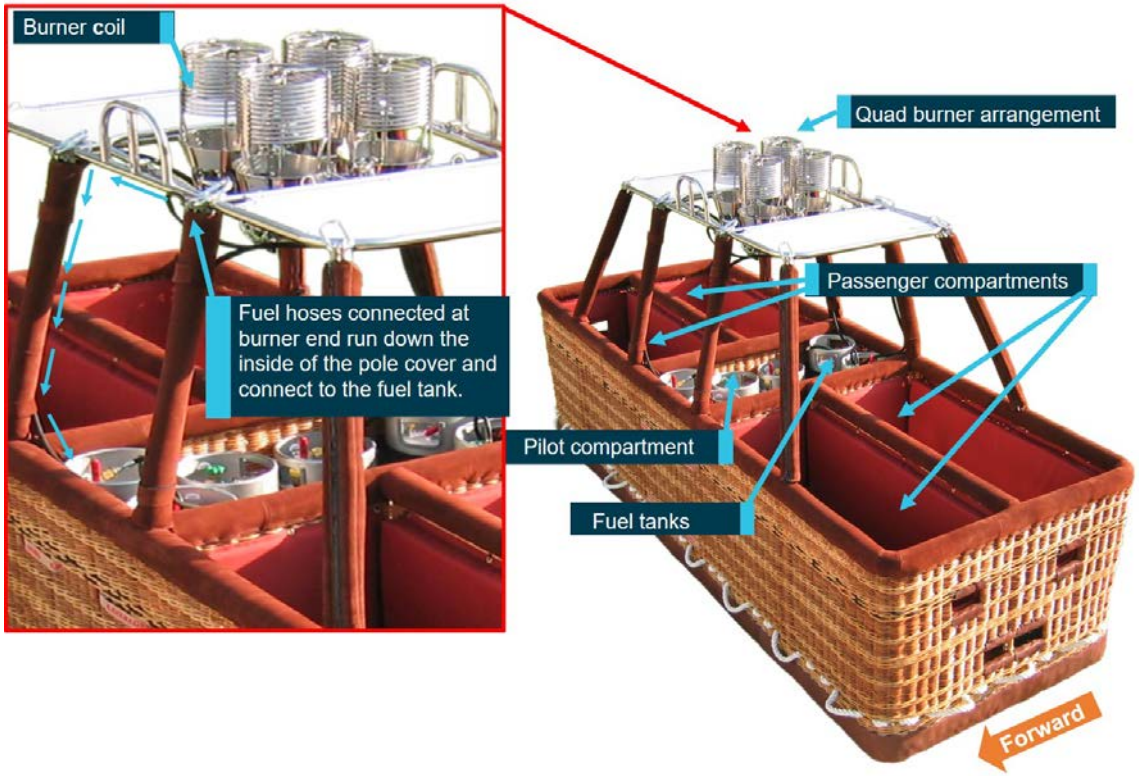
Aircraft information

VH-ZYO was a Kavanagh B-350 balloon. The balloon consisted of an envelope, a 16-person basket, a quad burner system and four propane fuel tanks.

Kavanagh Balloons series 3 burner and fuel system

A Kavanagh series 3, quad burner system was installed on the aircraft. The burner unit consisted of four high-pressure propane burners. Each of the burner units had two connections to the fuel tank: a vapour hose (connected to the pilot burner) and a liquid hose, which connected into the burner coil (Figure 1). A standard feature of the system included a secondary burner, known as 'liquid fire'. This system bypassed the heat exchanger coil and fed liquid propane directly into the burner. The vapour hose drew gaseous propane from the top of the fuel tank and the liquid hose drew liquid propane from the bottom of the fuel tank. The fuel tanks on VH-ZYO had hand-wheel shut-off valves installed at the connections for both the liquid and vapour hoses. The alternative certified configuration was a 90-degree valve. Both valve configurations are shown in Figure 3.

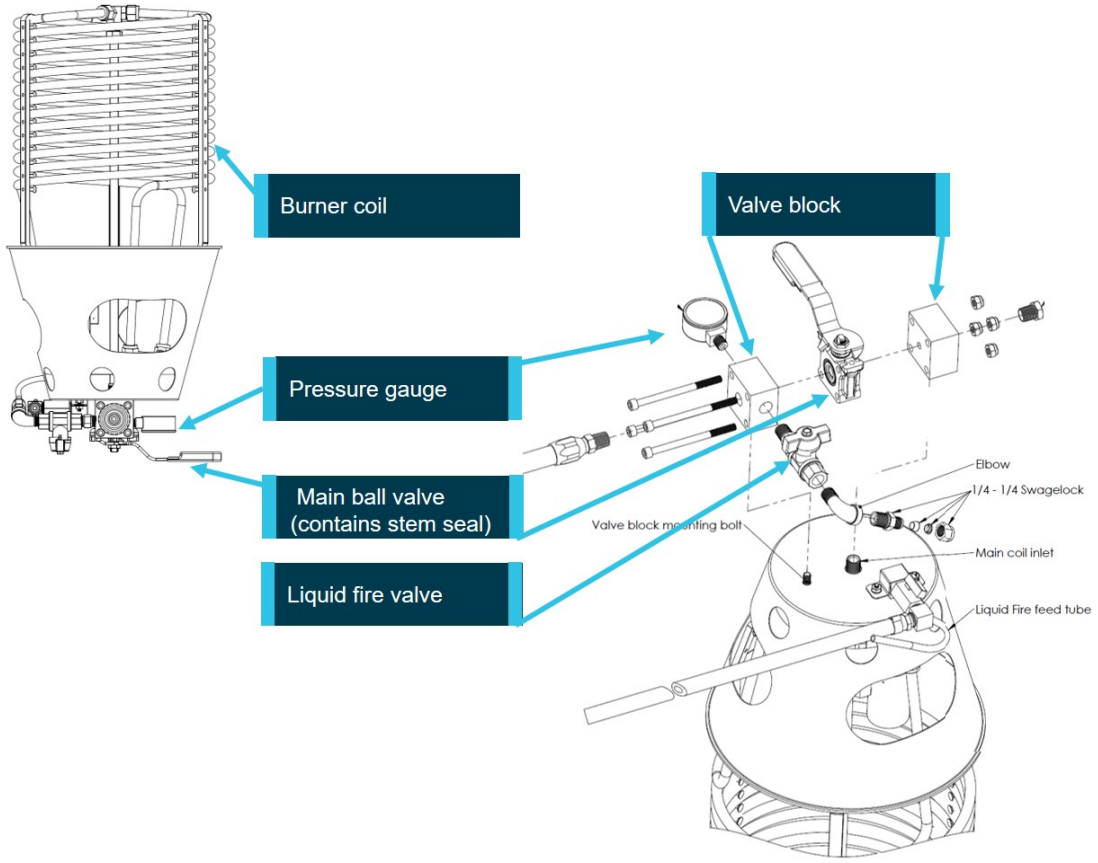
Figure 1: Basket and burner arrangement similar to VH-ZYO



Source: Kavanagh Balloons, annotated by ATSB

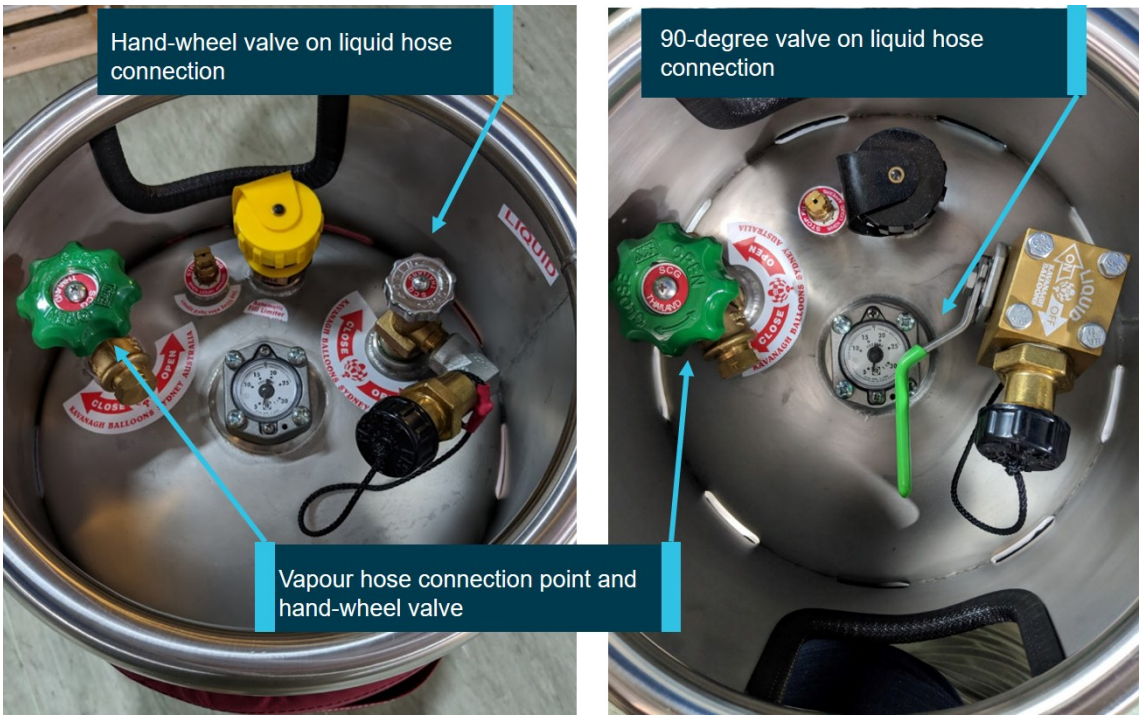
An illustrated diagram of a burner unit is shown in Figure 2 below.

Figure 2: Illustrated diagram of the burner system on VH-ZYO



Source: Kavanagh Balloons, annotated by ATSB

Figure 3: Valve types on propane tank



Source: Kavanagh Balloons, annotated by the ATSB

The European Aviation Safety Authority (EASA) has previously published a safety information bulletin (SIB 2018-14) highlighting the advantages of using 90-degree valves over the hand-wheel valves. EASA recommends operators of hot air balloons use the 90-degree valves for propane fuel cylinders as they had been found to improve the survivability outcome in the event of fire due to their easy and quick actuation.

Liquid and vapour hoses

The Kavanagh Balloon's maintenance manual mandates that the liquid fuel hoses have a 10-year life from the date of manufacture. The liquid hoses on VH-ZYO were last replaced in October 2018. Leak checks were conducted as part of the standard replacement procedure and the aircraft had been used multiple times since the replacement.

The liquid hoses were constructed from three layers of material: an inner rubber tubing, an encasing metal braid, and a rubber outer casing. Vapour hoses have a similar construction but do not have a time-limited life.

Main valve block

The main valve block (Figure 2) was an assembly of two solid pieces of aluminium, fastened either side of the main ball valve with four bolt and nut combinations. The liquid fire valve, liquid fuel hose, pressure gauge and cross flow plug each screw into a threaded hole in the main valve block.

Pressure gauge

The manufacturer rated the pressure gauge to a maximum operating pressure of 230 psi,[4] with design testing conducted to around 345 psi. The normal operating range for the series 3 burner (the same burner installed on VH-ZYO) is 50 – 218 psi. The pilot indicated that the system was generally operated at around 180 psi.

Liquid fire valve and main ball valve.

The liquid fire valve was a small ball valve, housed in a steel casing, with no replaceable parts. The maintenance manual specified that the valve was to be replaced as a full unit (based on the valve's condition). Conditions indicating replacement was necessary included seizing of the valve, the valve not shutting off, or signs of leaking.

The main ball valve was a 90-degree, quick shut-off valve, designed to stop the flow of fuel into the burner can.

Kavanagh Balloons flight manual

Mandatory equipment

The flight manual specified that at least one dry powder (1 kg capacity) fire extinguisher must be carried during each flight.

In-flight fire

The manufacturer's required actions for managing an in-flight fire were:

- turn off fuel at main tank valves and turn off pilot burners
- put out fire with the fire extinguisher
- if it is safe, re-light pilot burner, proceed as normal and make a landing as soon as possible
- if it is unsafe to re-light the burner, prepare to make an emergency hard landing.

[4] The imperial unit for pressure, pounds per square inch (psi) is equal to 6.895 kPa.

Clothing recommendations

The regulatory bodies in Europe and America have developed guidelines for balloon operators, including the following recommended protective clothing:

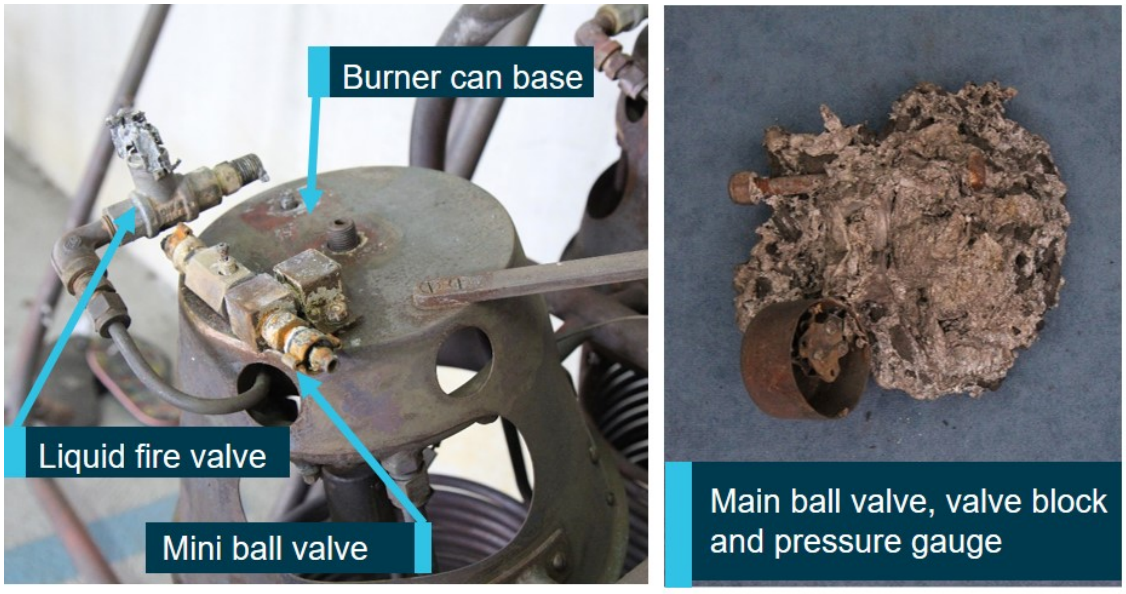
- long sleeves and trousers, preferably made of natural fibres
- protective footwear
- leather gloves.

Component examination

The ATSB conducted an examination of a number of balloon components. The examination was severely hindered by the extensive fire damage but the following observations were possible:

- the burner from which the fire was emanating still had the liquid fire valve, the mini ball valve (vapour pilot burner) and the burner coil attached (Figure 4)
- the main ball valve was not attached to the coil (Figure 4)
- in-flight photographs showed that the main ball valve was shut during the fire
- all of the main valve block assembly bolts (with nuts attached) and cross-flow plugs were found intact in the wreckage
- examination of the components did not identify any possible sources of a leak or failure that may have contributed to the in-flight fire
- determination of the integrity of the main ball valve and liquid fire valve could not be established as the internal structures were completely disrupted by the fire.

Figure 4: Underside of burner and main ball valve – fire location



Source: ATSB

Previous occurrences

A review of the ATSB occurrence database for similar occurrences identified that in the last 10 years there had been 10 instances of a hot air balloon catching fire. Of these, two incidents were the result of a fuel leak. In the first instance, the leak occurred at the main ball valve and in the other at the liquid fire valve. The pilots of the balloons controlled the fires by shutting off the fuel at the tank and then extinguishing the flames.

Safety analysis

The pilot first observed the fire coming from the front left burner. Physical examination of the components did not identify any possible sources of a leak or failure that may have contributed to the in-flight fire. However, the location of the fire (front left burner) eliminated any of the connections at the fuel tanks as a source of the leak. With the main valve switched off and the liquid fuel remaining on at the tank, only the pressurised components in between could have been the source of the initial leak. The most likely were considered to be the:

- threaded connection between the liquid fire valve and main valve block
- liquid fire valve
- main ball valve.

The direction of the flame (towards the front of the balloon) was in line with the connection of the liquid fire valve into the main valve block. On installation, over-torquing or cross-threading the connection could result in damage to the aluminium valve block. Stresses from pressurisation and thermal cycling over time can cause the damage to develop into a crack, resulting in a fuel leak. However, as this joint did not require frequent adjustment, the likelihood of damage due to installation error or handling was reduced.

The flames emanated from a location near the main ball valve and the liquid fire valve. The valves (moving components) were prone to wear and therefore at higher risk of leaking than static components. The valves were oriented vertically with a handle on the base. It can be expected that any leaking fluid would spray downwards, into the handle, making it unlikely to see the directional flame pointing outwards from the basket. However, given the fire continued for an extended length of time, it is likely that the initial fire heated the surrounding structure causing failure of seals and joint sealant in other components, leading to further leaks and a larger fire. In that context, images and accounts of the flames directed outwards from the basket may be the result of subsequent failures.

As the pilot did not shut the liquid fire valve on the fuel tanks or the pilot burners, the situation escalated rapidly and increased the pilot's workload in managing the situation. The leaking fuel near to the pilot flames on the adjacent burners caused the fire to re-ignite immediately after the removal of the fire extinguishers. Use of a 90-degree valve on the liquid fuel outlet may have better assisted the pilot to recognise that he had not shut off the liquid fuel valve, enabling him to control the fire.

The pilot's clothing did not provide adequate protection from burns, increasing the risk of personal injury. The pilot was carrying additional protective clothing, however, it was not kept in a readily accessible location, and therefore could not be used.

Finally, the MAYDAY broadcast did not provide air traffic control with a current or last known location of the aircraft. In this instance, the lack of information did not result in a delayed response from emergency services. It is important, however, for pilots to follow standard broadcast procedures when declaring an emergency.

Findings

These findings should not be read as apportioning blame or liability to any particular organisation or individual.

- A fuel leak at the front left burner resulted in an in-flight fire. Due to severe fire damage, the source of the leak could not be determined conclusively, but it was considered most likely to be the main ball valve, liquid fire valve or liquid fire valve connection to the main valve block.
- The hand-wheel valve on the liquid outlet of the fuel tank and the pilot burners were not shut off, which resulted in the pilot being unable to control the fire.
- The pilot's clothing did not meet the recommended industry standards for personal protective equipment, which increased the risk to his personal safety.
- Installation of a 90-degree valve on the liquid fuel outlet increases survivability in the event of fire and, may have assisted the pilot to recognise that the liquid fuel valve was not shut off.

Safety action

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence.

Civil Aviation Safety Authority

As a result of this occurrence, the Civil Aviation Safety Authority released an Airworthiness Bulletin (AWB 02-063) to address some of the pertinent issues surrounding this occurrence. The AWB included the following recommendations:

- Inspect the condition and operation of the fuel pressure gauge, stem seal and liquid fire valve.
- Review the fuel system pressurisation limitations. Pressurisation of the fuel gauge beyond the maximum reading may cause catastrophic failure of the pressure gauge.
- Use 90-degree (quick shut-off) valves for the fuel tank liquid outlets.
- Review and rehearse all emergency procedures including in-flight fire and burner malfunctions.
- Both the liquid and vapour valves must be closed on any tanks connected to the burner with a leak or malfunction before any effective firefighting methods can be performed.
- Minimum industry standard protective clothing should be worn, which includes fire-resistant gloves, long-sleeved cotton shirt and sturdy, enclosed footwear
- Carry fire blankets of a size of at least 1.5 m x 2 m.

In addition, CASA conducted a surveillance audit on Go Wild Ballooning. The audit returned a number of findings that the company will be required to rectify.

Go Wild Ballooning

As a result of this occurrence, Go Wild Ballooning has advised the ATSB it has taken the following actions:

- upgraded one basket to the new Kavanagh Quad Burner system and is considering phasing out the older Kavanagh series 3 systems
- replaced hand-wheel valves with 90-degree valves on all fuel tanks
- reviewed the company policy on protective clothing, and are researching new fire-proof gloves.

Safety message

Pilots experience a high workload during in-flight emergencies. However, in the event of an in-flight balloon fire, the first priority must be isolation of the fuel supply at the fuel tank.

The complex nature of emergencies highlights the importance of rehearsing response procedures. It is also good practice to do this standing in the basket. Further ways to reduce risk to individuals and improve survivability outcomes include:

- wearing appropriate protective clothing, which includes cotton long-sleeved shirts and long trousers, leather gloves and enclosed footwear.
- utilising componentry which provides a visual indication of the system status and is easy to use, for example, 90-degree valves on liquid outlets.

Civil Aviation Order 201.11, Appendix IV and Civil Aviation Regulation 5.143 provide requirements for pilots to maintain currency of skills. It is important to remember, however, that it is up to individuals to ensure that they maintain a good working knowledge of how to deal with the full range of abnormal indications. *Civil Aviation Advisory Publication 5.81-1(1)* provides a clear interpretation of the requirements.

General details

Occurrence details

Date and time:	26 December 2018 – 0615 EDT	
Occurrence category:	Accident	
Primary occurrence type:	Fire	
Location:	near Coldstream (ALA), Victoria	
	Latitude: 37º 43.7' S	Longitude: 145º 7.805' E

Manufacturer and model:	Kavanagh Balloons B-350	
Registration:	VH-ZYO	
Operator:	Go Wild Ballooning	
Serial number:	B350-368	
Type of operation:	Charter – Passenger	
Persons on board:	Crew – 1	Passengers – 15
Injuries:	Crew – 0	Passengers – 1
Aircraft damage:	Destroyed	

About the ATSB

The ATSB is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within ATSB's jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to operations involving the travelling public.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

About this report

Decisions regarding whether to conduct an investigation, and the scope of an investigation, are based on many factors, including the level of safety benefit likely to be obtained from an investigation. For this occurrence, a limited-scope, fact-gathering investigation was conducted in order to produce a short summary report, and allow for greater industry awareness of potential safety issues and possible safety actions.