How pilots deal with volcanic ash encounters

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News

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The overnight flight from Kuala Lumpur to Perth was just like any other for the crew of a Boeing 747-200 in June 1982. At 37,000 feet above the Indian Ocean, south of Java, all was well. That is until the crew and passengers began to notice a haze appearing in the cabin. Even though smoking was still allowed on flights at the time, this was different. It smelled of sulphur.

Passengers sat in window seats in front of the wings noticed that the engines appeared to be glowing blue. The aircraft had unknowingly entered the ash cloud from the erupting Mount Galunggung volcano and a few moments later, all four engines flamed out. The giant 747 aircraft had just become a glider.

Working through the checklists, the crew were able to restart the engines and land safely in Jakarta, Indonesia, a short time later.

At the time, the effects of volcanic ash on aircraft were not well understood. Today, pilots and airlines have procedures in place to enable us to safely deal with the threat that volcanic ash presents.

Why is volcanic ash a threat?

When a volcano erupts, it sends vast amounts of hot gases, rocks and ash up into the atmosphere. The size of these emissions can vary greatly, from blocks and bombs measuring over 64 millimetres to fine ash particles less than 0.063 millimetres. It's the smaller particles which pose the greatest threat to aircraft.

What is volcanic ash?

This ash is made up from tiny particles of volcanic glass, sharp-edged rocks and minerals. Unlike the soft ash created when burning wood, volcanic ash is hard and abrasive. The larger ash particles look and feel like grains of sand, the smaller particles have a powdery composition.

The Eyjafjallajökull volcano eruption in 2010 completely shut down European airspace. (Photo by Ingólfur Bjargmundsson/Getty Images)

These particles tend to be full of holes, giving them a low density. It's this low density which enables them to be kept aloft and form huge ash plumes which can travel thousands of kilometres.

After the 1883 eruption of Mount Krakatoa in Indonesia, volcanic ash was found on ships 6,000 kilometres away. The airborne ash travelled right the way around the earth, affecting the colour of sunsets as far away as New York.

Why it's a hazard for aircraft

Aircraft engines work on a four-part process, commonly known as “suck, squeeze, bang, blow”.

The first stage of the process requires a massive amount of air to be sucked into the engine. In a large engine like the GEnx on the 787 Dreamliner, only 10% of this air actually passes into the engine core. The other 90% bypasses the core to provide cooling and aiding noise reduction.

Once entering the engine core, the air is compressed, increasing its energy potential. As the pressure increases, so does the temperature.

The high pressure, high-temperature air is then forced into the combustion chamber. Here, fuel is sprayed into the fast-moving air by a ring of fuel nozzles. This high energy air is ignited, creating hot, expanding gases reaching temperatures of up to 2,700 degrees Celsius.

The high energy air exiting the combustion chamber flows into the turbine stage of the engine. Here, the energy is used to create thrust but is also where the problem of volcanic ash occurs.

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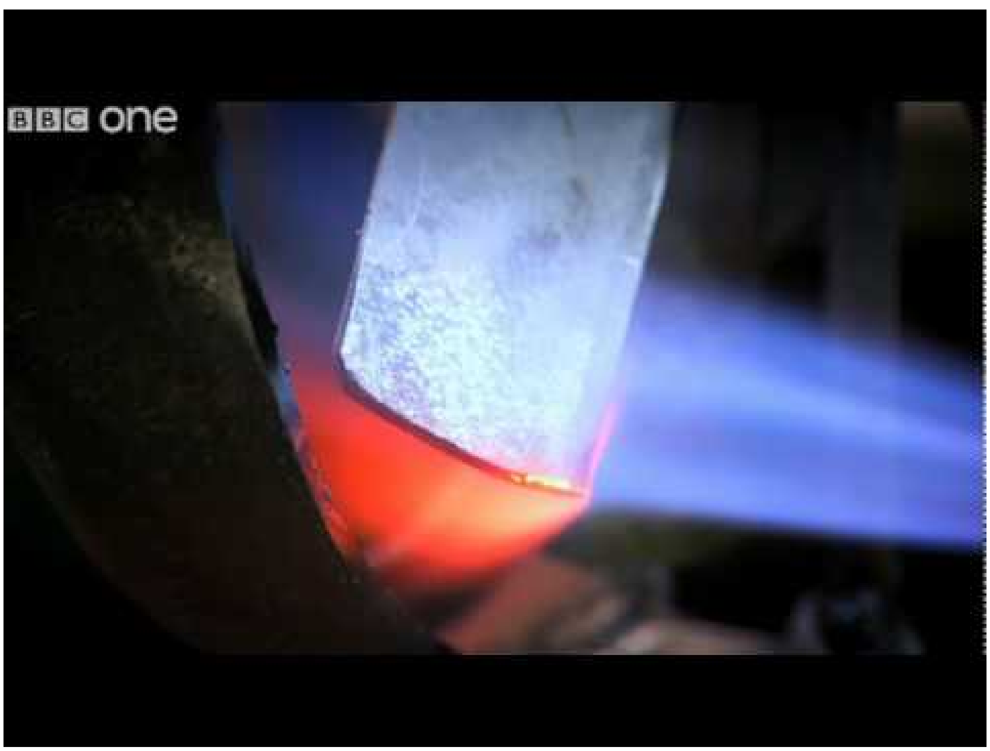

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Volcanic ash has a melting point of around 1,000 degrees Celcius. As it passes through the combustion chamber, it gets turned to molten glass and exits out with the airflow. It then hits the turbine blades where it solidifies.

Covered in molten glass, the turbine blades are no longer able to operate properly and are likely to cause the engine to shut down.

In addition to affecting the engines, the abrasive nature of the ash can also damage the flight deck windshields. The sandblasting effect can cause the glass to become worn down, reducing the opacity. The crew in the incident above were unable to see the runway on landing, despite the actual outside visibility begin very good.

Avoidance

Knowing the danger which volcanic ash poses to aircraft, like with most threats in aviation, the best course of action is to avoid it in the first place. As Frank Borman once said, "a superior pilot uses their superior judgement to avoid situations which require the use of their superior skill".

As part fo the preflight briefing, weather charts not only depict the meteorological conditions we can expect to encounter during the flight, but it will also highlight any active volcanos.

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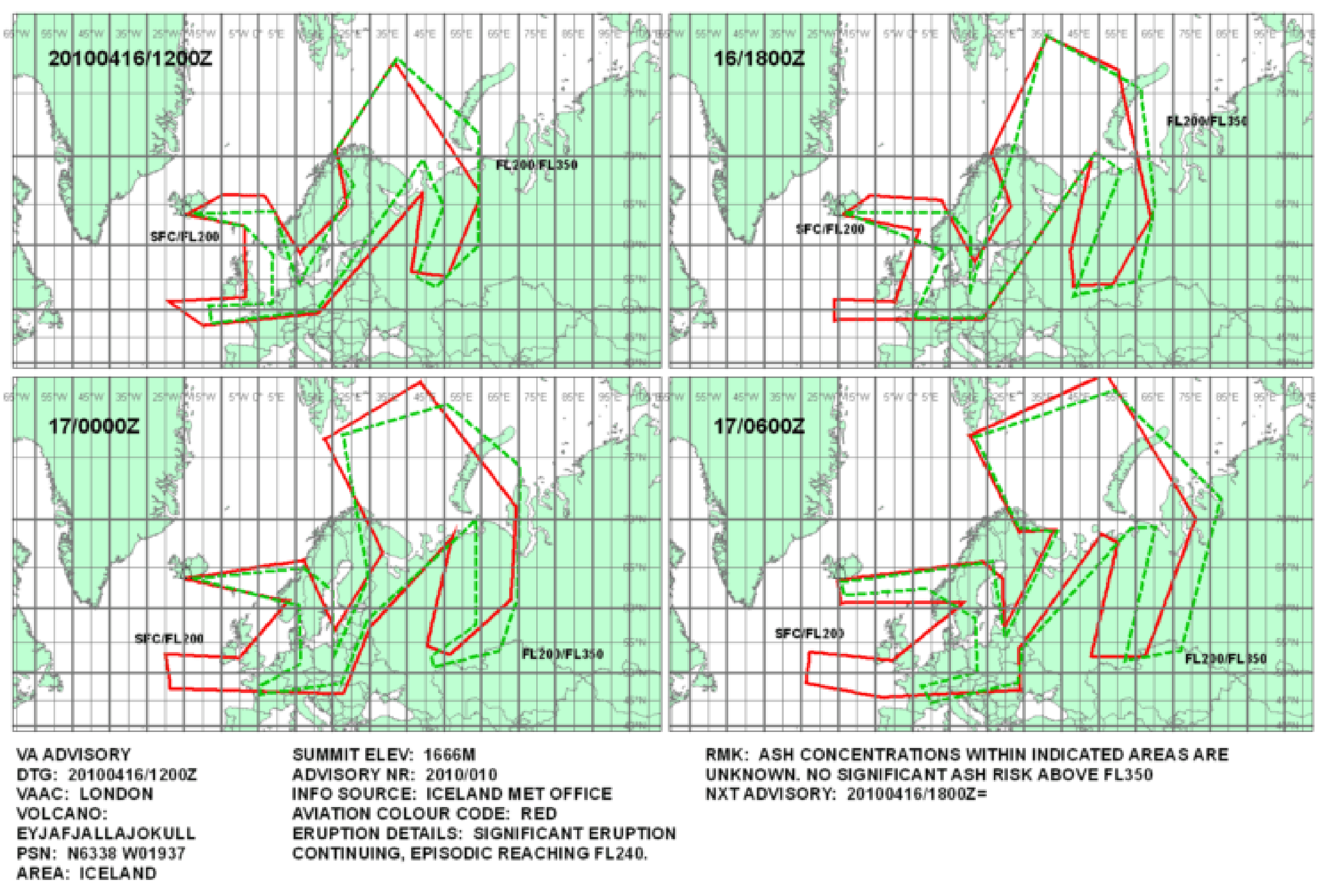
The London Volcanic Ash Advisory Centre (VAAC) is run by the Met Office and is responsible for issuing advisory information for volcanic eruptions in Iceland and the north-east section of the Atlantic Ocean. Using data collected from satellite and ground-based sources, in addition to observations from aircraft, forecasters are able to provide pilots with a range of information every six hours after an eruption.

During the 2010 eruption of Iceland's Eyjafjallajökull volcano, the London VAAC was able to issue charts like the one below to pilots. This enabled us to have a decent idea where volcanic ash may be a problem.

Flights are permitted to fly through areas forecast to have medium and low ash concentrations.

The Volcanic Ash Advisory (VAA) models ash in three vertical blocks of airspace — the surface to 20,000 feet, 20,000 feet to 35,000 feet and then above 35,000 feet. Additional ash information from The Weather Company gives a more accurate estimate of the greatest hazard level posed by the ash. This gives airlines a second source of information, enabling them to plan the flight more safely.



The volcanic ash charts issued to pilots during the 2010 eruption. (Image courtesy of the Met Office)

If a flight is planned to fly through an area which could be affected by volcanic ash, an airline's flight planners can adapt the route to avoid the worst of it. Many airlines have regulatory clearance to operate flights under and over areas forecast to have a high concentration of volcanic ash. If flights operate in this environment, there will be a minimum vertical clearance of 1,000 feet from the ash.

When planned to fly above an ash plume, the plan will also take the engine failure situation into consideration. When flying on a single-engine, normally and aircraft has to descend to a lower altitude. If this lower altitude will conflict with the ash plume then a different route will be used.

Recognition

No matter how vigilant the pre-flight planning is, once airborne there's always a chance that the forecast could be slightly off. If this is the case, the next step is for us to be able to recognise that we have encountered volcanic ash.

Unlike large clouds and thunderstorms, volcanic ash does not show up on our radar screens. As a result, when flying at night, an ash plume will be pretty much invisible. However, due to the physical nature of the ash, there are some tell-tale signs that an aircraft is flying through it.

Changing engine conditions

As mentioned above, one of the most serious effects of volcanic ash is on the engines. If enough ash is ingested, the engines can flame out and shut down. However, this may not happen immediately as there may be other indications that the engines are beginning to suffer.

An engine surge occurs when the flow of air through the engine is disrupted. It's normally accompanied by loud and startling bangs, along with dramatic-looking jets of flame out the back of the engine.

As alarming as it may seem, an engine surge is relatively straightforward to deal with. It involves reducing the power on the affected engine until such point that the surging ceases. At this point, we can then decide if want to continue operating the engine at the reduced power or try increasing it again to see if the surge returns.

Naturally, if the surge is accompanied by other indications of volcanic ash, it would be preferable to exit the ash before trying to resume normal engine power.

In addition to surges, the engine temperatures may unexpectedly change or a white glow can appear in the engine inlets. The crew of the 747 which encountered the ask cloud over Indonesia reported that they saw all four engines glowing before they flamed out.

Static discharge

A phenomenon very much like St Elmo's fire can occur on the windshield of the flight deck. St Elmo's fire is the discharge of electricity when an aircraft flies through charged air. This normally occurs when flying close to thunderstorms. As dramatic is it looks, it is harmless to the aircraft.

In the case of a volcanic ash encounter, blue-ish sparks appear to travel up the outside of the flight deck windshield. At the same time, the white glow seen in the engines can also appear on the leading edge of the wing.

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Smell

I'm sure you've been able to smell a thunderstorm before. That ionised air smell is normally your first clue that it's about to get very wet. The same happens with volcanic ash.

Pilots have reported experiencing an acrid, smoky odour which can smell like electrical burning, burnt dust or sulphur. With an unexpected odour suddenly perceptible in the flight deck, we have no idea how it might affect us. As a result, we will most likely don our oxygen masks until we can confirm that the smell does not pose a threat to our ability to fly the aircraft safely.

Haze

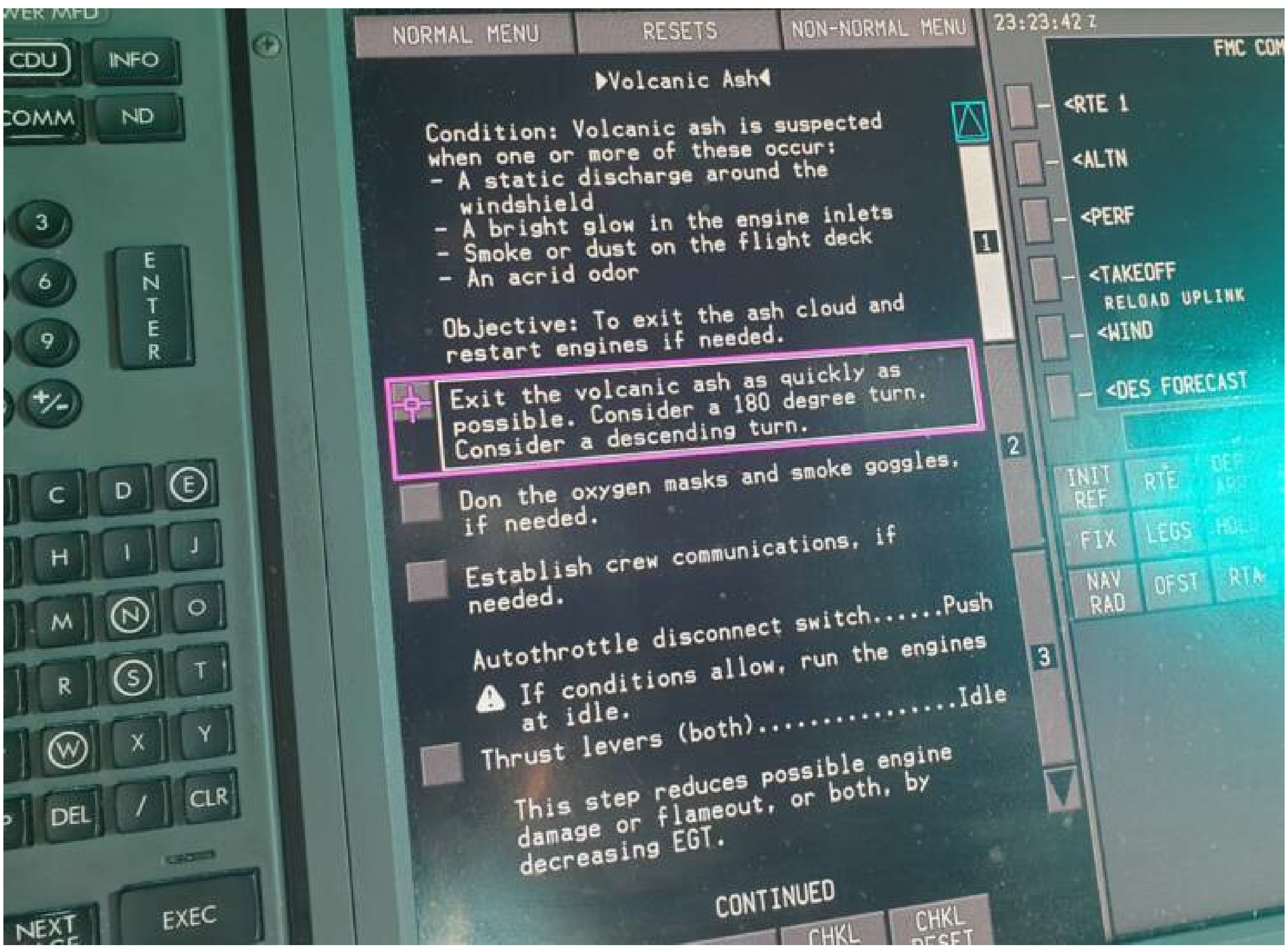
The volcanic ash is so fine that it finds its way through the air conditioning system and can enter the cabin as a fine haze. It can sometimes be seen to settle on surfaces.

Aircraft procedures

If we detect that we have entered a volcanic ash cloud, our number one priority is to exit it as soon as possible. As we have no idea how far the plume extends either in front of us or to the side of us, the quickest way to do this is by making a 180-degree turn. At the same time we will descend, both to find our way out of the bottom of the cloud and to reduce the engine power.

If we had not already donned our oxygen masks due to an acrid odour, the presence of dust in the flight deck will necessitate the use of the masks. These masks give us a full seal around the face, stopping any smoke or ash from getting into our eyes or lungs.

However, we would not necessarily deploy the masks in the cabin unless there was a loss of pressurisation. The cabin system only provides a flow of oxygen, it does not provide respiratory protection.



The volcanic ash electronic checklist on the 787 Dreamliner. (Image by Charlie Page/The Points Guy)

With our vision and breathing protected, our next steps involve protecting the aircraft and the engines as much as possible. Multiple changes in engine thrust increase the chances of the engine surging.

As a result, we turn off the autothrottle system and reduce the thrust to idle power. This reduces the heat in the engine, which will lead to less molten ash depositing on the turbine blades.

We will also start the APU, the small engine in the tail. This provides us with an extra source of electrical power which can be used to run systems in the event that both engines flameout. On the 787, this electrical power can be used to restart the engines.

Once out of the ash cloud, and both engines running normally, we will most likely divert to a nearby airport. Even if there were no obvious engine issues, there may be hidden damage which could cause problems later in the flight. It's far safer to divert and have engineers check the aircraft properly.

Bottom line

As with any threat in aviation, the best plan is to avoid it in the first place. However, even with the best planning, this isn't always possible. A quick and accurate diagnosis of volcanic ash can help a crew deal with the threat before it becomes too much of a problem.

By following the checklists laid out by the aircraft manufacturer, we aim to turn the aircraft out of the ash cloud and reduce the engine power to limit the effects of the molten ash. When away from the danger we will then divert to the nearest airport to ensure that the aircraft is safe.

Featured photo by Arctic-Images/Getty Images

Charlie Page Charlie Page is an airline pilot flying the Boeing 787 Dreamliner. Each Saturday he gives you a 'behind the cockpit door' insight to life in the flight deck.