9√P AND ALL THAT

by Ian Wigmore

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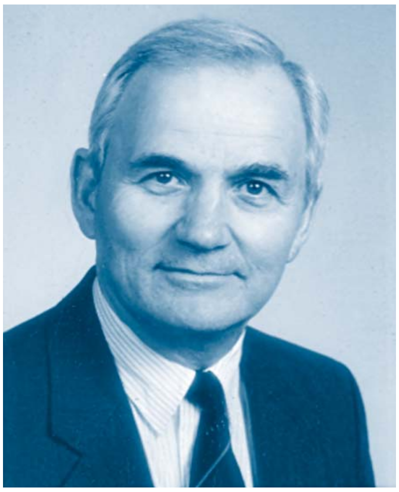

9√P- what is that all about? Well, you shall see. This is a story about a Boeing 747 that overran the runway in Bangkok in 1999 - and 9√P was very much a factor in that accident.

First, a few facts about wet runways - especially the sort that have standing water on them. The presence of water on the runway affects the friction between the tyres and the runway, reducing the braking action. The brakes don't work as well even if the runway is only damp, but the reduction in braking action if the runway is wet is considerable; in fact pilots have to take this into account when calculating critical take-off and landing data.

Take-off and landing performance is calculated taking into account the runway surface conditions, which are defined in JAR-OPS 1.480 as follows:

Contaminated runway. A runway is considered to be contaminated when more than 25% of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by the following:

1. Surface water more than 3 mm (0·125 in) deep, or by slush, or loose snow, equivalent to more than 3 mm (0·125 in) of water;
2. Snow which has been compressed into a solid mass which resists further compression and will hold together or break into lumps if picked up (compacted snow); or
3. Ice, including wet ice.

Wet runway. A runway is considered wet when the runway surface is covered with water, or equivalent, less than specified above or when there is sufficient moisture on the runway surface to cause it to appear reflective, but without significant areas of standing water.

Damp runway. A runway is considered damp when the surface is not dry, but when the moisture on it does not give it a shiny appearance.

Dry runway. A dry runway is one which is neither wet nor contaminated, and includes those paved runways which have been specially prepared with grooves or porous pavement and maintained to retain 'effectively dry' braking action even when moisture is present.

I expect you know about aquaplaning - or hydroplaning as it is also known; after all, it applies just as much to driving a car as to landing an aeroplane. Aquaplaning is a generic term covering different aspects of an aircraft sliding over a wet surface. In case you are a little rusty, here are a few facts:

- **Viscous aquaplaning** refers to the reduced friction coefficient that occurs due to a thin film of water on the runway acting as a lubricant. It can occur on damp to contaminated runways, and at speeds down to low taxi speeds. It is most severe on runways with a smooth texture.

- **Reverted-rubber aquaplaning** occurs when a wheel 'locks up' (or stops rotating) and is dragged across a wet surface, generating steam. The steam pressure lifts the tyre off the runway surface. Heat from the steam causes the rubber to revert to its unvulcanised state, leaving a black, gummy deposit of reverted rubber on the tyre. This type of aquaplaning can occur at any speed above about 20 kts and results in friction levels equivalent to an icy runway.

- **Dynamic aquaplaning** occurs when the tyre is lifted off the runway surface by water pressure and acts like a water ski. It requires surface water depth greater than tyre-tread depth and sufficient ground speed to prevent the water escaping from the tyre's contact patch or footprint. Under these conditions, the tyre is wholly or partly buoyed off the pavement by hydrodynamic force and results in a substantial loss of tyre friction. Dynamic aquaplaning can occur in depths of water as little as 3 mm. This is the type of aquaplaning we shall talk about in the rest of the article.

- If the tyre has deep tread, or if the runway is grooved, this will help shed the water from beneath the tyre, providing good friction with the runway surface even in wet conditions, but if there is not much tread on the tyre the water has nowhere to go.

- The likelihood of dynamic aquaplaning increases with speed and with the depth of the water. Low tyre pressure also increases the risk for aquaplaning. This is where $9\sqrt{P}$ comes in, because someone has worked out that aquaplaning is likely to take place at speeds (in knots) above this figure, where P is the pressure of the tyre in pounds/square inch. In fact, aquaplaning can take place at speeds as low as $7.7\sqrt{P}$[5]: that's the speed at which aquaplaning commences; once it has begun, it may continue at much lower speeds. So if the pressure in your car tyres is 36 psi, then aquaplaning is possible at speeds above 46kts (about 86 km/hr), and on a plane like a Boeing 747 with tyre pressures of 210 pounds/square inch, the aquaplaning speed is about 111kts.

Now to our story. This concerns a Boeing 747 landing at Bangkok, Thailand. The official report has 186 pages and contains much important information. In this article I have concentrated on the bits about wet runways and aquaplaning and left the rest for you to read. The full report may be viewed at http://www.atsb.gov.au/publications/investigation_reports/1999/AAIR/aair199904538.aspx or a good summary by the Flight Safety Foundation is at http://www.flightsafety.org/ap/ap_june01.pdf .

On 23 September 1999, a Boeing 747-400 aircraft, Qantas One, was on a scheduled passenger flight to Bangkok carrying 391 passengers, 16 cabin crew, and three flight crew (captain, first officer and second officer). The first officer was the handling pilot (Pilot Flying) for the flight.

Before commencing descent, the crew obtained the Bangkok Airport weather information. The wind was from 240 degrees at 10kts, and visibility was 9 km. It was raining at the airport and there were thunderstorms in the area.

At about 2216 local time Qantas One commenced descent from FL350. At 2219 the crew were advised that they would be landing on runway 21L, behind a Thai International Airbus A330. The crew briefed for the approach and appropriate selections were made on the auto-brake system. At some point after this another Boeing 747 - Qantas 15 - was vectored ahead of Qantas One, although the crew were not informed of this.

The auto-brake system allows the pilots to select a rate of deceleration appropriate for their landing conditions. The actual rate of deceleration is monitored after touch-down and brake pressure is automatically applied to maintain the selected deceleration rate. For the auto-brake system to operate, engine power must be at idle within 3 seconds of touch-down, but manual braking is available if this limit is exceeded. The aircraft was also fitted with an anti-skid system, which works in a similar way to a car's ABS system.

At 2226 ATC advised that there was heavy rain at the airport, but the visibility from the control tower was 4 km. The crew were not concerned about the weather at this stage of the approach. Rain and thunderstorms were common events at Bangkok and it was still about 20 minutes before landing. The visibility was well within the first officer's limits (1500 m).

At 2233 the crew completed the approach checklist. The planned landing configuration was flaps 25 with a final approach speed of 154kts. They changed frequency to Bangkok Arrivals, descended to 2500 ft and proceeded towards the runway final approach path. At 2236 they were informed that there was heavy rain over the airport. Two minutes later, the flight was cleared for an ILS/DME approach to runway 21L.

[5] According to the accident report.

http://www.atsb.gov.au/publications/investigation_reports/1999/AAIR/aair199904538.aspx
http://www.flightsafety.org/ap/ap_june01.pdf

Between 2237 and 2239, the second officer obtained Information Tango. This included information from the routine weather observation taken at 2230, including the fact that there was a thunderstorm situated over the airfield. It also stated that tower and ground controller training was in progress.

At 2239 the captain informed the crew that he could see the thunderstorm cloud overhead the airport. After they had turned inbound he had a clear view of the runway environment. They were not in cloud at that point and there was no rain; however the storm cell over the airport was clearly visible and was also evident on the flight deck weather radar display. Such conditions were a common occurrence in Bangkok and other tropical locations and the crew were conscious of the possibility of turbulence, wind shear and reduced visibility.

Over the next three minutes the first officer began to slow the aircraft down using speed brakes to assist in this. At about the same time a special weather observation was taken: the visibility was now 1500 m and the runway visual range (RVR) was 750 m. The arrivals controller did not advise the crew of this, nor did he tell them that the ATIS information had changed.

At 2242 Qantas One began to descend on the glide-slope. The crew were told to contact Bangkok Tower when they reached the final approach point (about 4.1 nm from touchdown). Shortly afterwards Qantas 15 informed Tower that they were going around, but the crew of Qantas One did not hear this transmission as they had not yet reached the final approach point, nor did the controller inform them of this. The primary reason for the go-around was loss of visual reference in heavy rain.

At 2243 the landing gear was extended and shortly afterwards, when the aircraft was at 1900 ft and 165kts, flap 25 was selected. As they reported at the final approach point the controller advised 'caution runway wet and braking action reported by Airbus Three (the Thai aircraft) is good'. And cleared Qantas One to land. The crew assumed that the Airbus mentioned by the tower was the immediately preceding aircraft and considered that they had no reason to think the runway conditions were not appropriate for landing. At this stage the crew had not flown through any rain. The crew completed the landing checklist and configured the aircraft for landing.

At 2245 the speed was still 166kts and the first officer commented that the aircraft 'doesn't want to slow down'. Although still above the target speed, the speed was still decreasing. The engine power had been reduced to below the normal setting but the first officer did not want to reduce it further. The captain was aware that the speed was a little high but thought the situation was under control. Shortly afterwards, light rain was encountered and the windscreen wipers were selected 'On'.

From 2246 onwards the rain became heavy. The approach and runway lights were now only visible for brief intervals as the windscreen wiper blades passed across the screen. The first and second officer later said that the rain was the heaviest either of them had ever experienced during an approach.

Passing 140 ft the speed had increased to 170kts and the rate of descent was 600 ft/min. The aircraft began to deviate above the ILS glide-slope. The captain commented 'you're getting high now'. He later reported that he had noticed the rate of descent had decreased after they hit the heavy rain. The captain said 'you happy?' and the first officer replied 'ah, yes'.

They were still high and fast as the aircraft crossed the runway threshold. The captain said 'get it down, get it down, come on, you're starting your flare'. The first officer began to retard the thrust levers in preparation for landing. At 10 ft and 157kts the captain instructed the first officer to go around. The first officer manually advanced the thrust levers but did not activate the 'TO/GA (takeoff/go around) function, which automatically advances the engine power to the correct setting.

A few seconds later the aircraft touched down at 156kts, one third of the way along the runway, 636 m beyond the ideal touchdown point. At the same moment the rain intensity decreased and the captain could see the length of the runway. He assessed that there was sufficient runway remaining to stop and cancelled the go-around by retarding the thrust levers, without saying anything. This resulted in confusion amongst the other pilots, and contributed to the crew not selecting (or noticing the absence of) reverse thrust during the landing roll.

Unfortunately, the captain accidentally failed to retard the No 1 thrust lever. This had two serious effects:

1. Automatic spoiler deployment was delayed, and,

2. Because more than 3 seconds elapsed before all engines were selected to idle, the auto-brake system did not activate (although manual braking was applied).

Due to these and other factors, the aircraft's speed did not decrease below the touchdown speed (154 kts) until the aircraft was halfway down the runway.

The aircraft overran the runway end at 96kts and entered the stop-way. At 79kts it collided with the ILS localiser antenna about 100 m beyond the end of the stop-way. It continued for a further 100 m through very wet boggy soil before coming to a stop.

The aircraft sustained substantial damage during the overrun. The collision with the ILS localiser antenna initiated the collapse of the nose and the right wing landing gear. Loss of the right wing landing gear caused the aircraft to adopt a slight right wing low attitude, allowing the right inboard engine nacelle, and then the right outboard engine nacelle, to contact the ground as the aircraft slowed. No significant injuries occurred during the landing or subsequent precautionary disembarkation.

The investigation established that, during the landing roll, the aircraft tyres aquaplaned on the water-affected runway. This limited the effectiveness of the wheel brakes to about one third of that for a dry runway. In such conditions and without reverse thrust, there was no prospect of the crew stopping the aircraft in the runway distance remaining after touchdown.

EDITORIAL COMMENT

Well, the airline and the pilots certainly learned a lot from this accident, but you may be asking yourself if they received all the help they deserved. If I had been flying that 747, I think I would have liked to be told that the weather conditions had deteriorated severely, to the extent that the aircraft ahead of me had elected to fly a go-around. And I might have been happier if controller training had not been in progress in these difficult conditions.

What do you think? Your comments would be most welcome.