How Not to Start a New Millenium!

By Richard Yates FRAeS

Introduction

Richard Yates began a 20-year career in the Royal Air Force in 1967. Initially engaged as an Air Defence radar operator, he was commissioned in 1972 and trained as a navigator. Posted to Nimrods in 1974, Richard spent the rest of his RAF service as a 'Cold War warrior' specialising in anti-submarine warfare, surface surveillance and search and rescue. As well as serving in many parts of the UK, his RAF career included a year in Bahrain (1969-70) and just over 3 years based in Malta on Nimrods (1974-78).

On leaving the RAF in 1987, Richard joined the UK CAA where he became involved in the development of pan-European aviation safety regulations. Seconded to the Joint Aviation Authorities in 1992 as the Operations Director and based in The Netherlands, he led the development of the JAR-OPS operational regulations which, as EU-OPS, is the set of requirements that now apply to all European Air Operator Certificate holders.

In October 1998 Richard joined the Civil Aviation Safety Authority's executive team for three years following which he established his own consulting business in late-2001, focussing on safety management and, particularly, Fatigue Risk Management Systems.

Richard Yates joined the RAeS as a Fellow in 2002; he is currently a member of the Melbourne Branch committee.

Overview

In late-1999, with the end of the last century and the second millennium fast approaching, the only potential fly in the ointment that any of us had in mind was something that became known as the 'millennium bug'. I had joined the Civil Aviation Safety Authority (CASA) some fourteen months previously having moved to Australia from Europe when I was appointed Assistant Director, Aviation Safety Standards.

Like many other entities in the world at that time, CASA and the aviation industry had been making preparations for the millennium bug. It was feared that this widely-anticipated affliction could cause all manner of problems with computer systems the world over as the clocks ticked past midnight on New Year's Eve and the year 2000 began. Much effort went into a variety of contingency plans to address potential problems in the event that things did not go smoothly as the world moved into the Millennium Year 2000 (MY2K).

Thankfully, the widespread concern about the transition to MY2K was unfounded and the global computer glitches that had been expected did not materialise. Little did I realise however that the Authority and the Australian General Aviation industry were about to be confronted with an unforeseen crisis of a completely different kind.

Just a few days before Christmas we received reports of what appeared to be fuel contamination associated with Mobil 100/130 Avgas. It rapidly became apparent that we had a serious problem on our hands which required some drastic actions to be taken. This unprecedented event caused a lot of heartache and distress for a great many people, particularly the operators of piston-engined general aviation aircraft who were directly affected.

It is now a little over 20 years ago since what became known as 'The Mobil fuel contamination crisis' occurred. Having been intimately involved in managing the fuel contamination crisis at CASA, I felt it might be worthwhile to put my personal recollections

The Mobil refinery at Altona

of this event on the record. The opportunity to share my story was provided by the initiative of the RAeS Melbourne Branch to post some 'Member Stories' on the RAeS website.

First Signs

The first I remember hearing about the problem was on 22 December 1999 when reports came in to CASA's Head Office in Canberra about two engine failure incidents that had occurred the previous day at Moorabbin, a busy GA aerodrome in Victoria near Melbourne. The first incident involved a student pilot who was making his final solo flight in a Cessna 150, prior to undertaking his general flying progress test. Shortly after take-off, just eighty feet above the ground, everything went quiet; having practised a number of engine failures during his training to date, this young pilot had to deal with the real thing. He had learned his lessons well and, closing the throttle, he lowered the nose and carried out a successful forced landing back on the remaining runway. Soon after landing the engine started again and the student pilot taxied the aeroplane back to where he had started from. The second engine failure occurred soon afterwards, when another aircraft was starting its take-off roll; the take-off was aborted.

I learned subsequently that a few days previously (16 December) a Bankstown-based aircraft fuel system overhaul business had reported to Mobil that a black substance had been found in a number of fuel boost pumps. The pumps concerned had been clogged by the black substance and failed as a result. On 17 December, Mobil's agent at Moorabbin reported to the company that black deposits had been found in some piston-engined aircraft fuel systems. Samples of the contaminant were tested by Mobil and internal discussions took place, including with a senior company chemist in the US.

Returning to the engine failures, it was soon determined that both of the aircraft affected were using Mobil fuel and this led Mobil to quarantine their 100/300 Avgas supplies at Moorabbin airport straight away. Immediate and detailed investigation of the two engine failures revealed that the fuel systems of both aircraft were contaminated in the same way.

The contamination appeared as a sticky black/brown coloured substance (similar in appearance and consistency to Vegemite) which blocked the fine brass mesh in fuel filters very effectively. This gunk-like substance was also found to have accumulated on other brass components in the fuel systems; it also caused sticking carburettor needles. At this early stage nobody had any idea what this 'Vegemite-like' substance might be, how it came to be present and how best to get rid of it. The Avgas in the contaminated aircraft had been produced at the Mobil fuel refinery at Altona to the south west of Melbourne, some of it was also distributed by Air BP.

Having received the reports of the engine failures and possible fuel contamination on 22 December, CASA issued an urgent Notice to Airmen (NOTAM) to alert general aviation operators in Victoria about possible fuel contamination. We also issued a Media Release giving an "Aviation Fuel Warning" and Mobil decided to quarantine further fuel supplies at Essendon.

At this relatively early stage in the crisis, the only common factor wherever contamination had been detected appeared to be Mobil's 100/130 Avgas. While it was believed to be due to something in the fuel supplied, nobody was

able to identify what was causing the problem or why. To make matters worse, we didn't know how widely the fuel from the suspect batch had been distributed nor by what means. The other significant unknown was how many aircraft had been refueled with some of the suspect fuel. There were intense discussions with Mobil following which the company quarantined its fuel supplies at all locations and issued a Media Release on "Avgas quality concerns". At the same time of course, the jungle telegraph was also running hot.

The Regulatory Response Begins

Because of the growing uncertainty and concern, CASA issued an Airworthiness Directive (AD/GENERAL/77) on Christmas Eve requiring all aircraft operators who had uplifted any Mobil 100/130 Avgas since 23 November to check their aircraft fuel systems. This AD required that if evidence of fuel contamination was found, it was to be reported and all affected elements of the fuel system were to be cleaned before further flight. Distribution of such an important AD the day before Christmas was a challenge to say the least. A Media Release was issued advising of the requirement for a "Mandatory inspection for fuel contamination and the AD was published on CASA's website mid-morning; it was also distributed via the Aircraft Owners and Operators Organisation (AOPA) fax broadcast system. Hard copy was put into the regular mail system, Australia Post having advised that nothing would be gained by Express Post due to the time of year – Happy Christmas!

On 29 December we amended AD/GENERAL/77 for clarification; Mobil established an Aviation Hotline on the same day. Mobil Australia had also sought assistance from their US colleagues and some petro-chemists were flown out to Melbourne between Christmas and the New Year to try and identify the cause of the contamination problem.

It was perhaps fortunate in one sense that the fuel contamination crisis occurred when it did because it coincided with the habitually quieter time over the Christmas/New Year holiday period. Nonetheless, there was increasingly widespread, and totally understandable, anxiety and concern in the General Aviation industry about the potential effects of the fuel contamination in terms of possible damage to fuel systems and engines and, naturally, the potential business consequences. This became all the more clear when we learned that the industry was starting to raise questions about compensation.

At the same time, reports started coming in of aircraft that had been found to be contaminated in areas other than Victoria, but principally in the east of the country. CASA offices around Australia started making enquiries to identify all of the locations that had taken delivery of any quantity of the suspect fuel so that we could try and get a sense of the magnitude of the problem. At CASA's Head Office we formed a group of airworthiness and maintenance specialists that I chaired which met every morning to review the latest actions and information received in the preceding 24 hours.

Although CASA had been having extensive discussions with Mobil since the outset, the first face-to-face meeting with company representatives in Canberra did not take place until 6 January. This was the day when we learned from Mobil that the contamination was due to the presence in the fuel of a primary amine: Ethylenediamine, known as EDA for short. We were informed that EDA was the additive used by Mobil to neutralise the sulphuric acid used earlier in their Avgas refining process. Mobil representatives told us that the problem had been caused by the mechanical failure of a component known as a 'scrubber pump' at their Altona refinery. Post-refining testing of the suspect batch had indicated that the level of acidity present in the fuel at the end of the process was unacceptably high. As I recall, this led to an increased quantity of EDA being added to the refined petroleum product in order to neutralise the acid. My understanding was that when functioning normally, the 'scrubber pump' added an appropriately measured amount of EDA such that the acid was neutralised without there being any residual EDA in the end product. Unfortunately, the amount of EDA added following the pump's failure was more than required so the fuel was, in effect, 'EDA rich' and that, as it turned out, was the problem.

Mobil also explained that they had developed a sophisticated test a few days earlier to identify the presence of EDA in a fuel sample using Nuclear Magnetic Resonance (NMR). However, this test required special facilities so Mobil were trying to develop a less sophisticated test that could be used in the field.

We had heard two days previously that there appeared to be no problem with the suspect fuel until it came into contact with brass and Mobil made it clear that the fuel had complied with all international specifications at every check. However, the excess EDA in the fuel unfortunately caused a chemical reaction when it came into contact with brass. We learned that EDA has a marked affinity for copper and it was the reaction with the copper in the brass components that gave rise to the black, sticky contaminant. So while Mobil had confirmed that EDA was causing the contamination, they confessed that no one had yet worked out how to deal with the problem. Mobil also made us aware that EDA reacts with carbon dioxide to form a carbamate of EDA and that (significantly as it turned out), in addition to having a liking for copper, EDA also had a great affinity for water.

Later the same day, the Mobil representatives were meeting with CASA technical staff, when one of the Mobil reps received a report of two apparent cases of re-contamination. Two aircraft at Moorabbin that had been found to be contaminated previously, then cleaned in accordance with AD/GENERAL/77 and refuelled, were displaying signs of repeat contamination with identical symptoms.

We still did not know how widespread the problem was and we sought information on the distribution of contaminated fuel from Mobil and Air BP, the latter being the biggest purchaser of Avgas 100/130 in eastern Australia. (At the time Air BP produced its own Avgas 100/130 in Western Australia.)

In view of the apparent onset of a continuing problem, we released a NOTAM on 7 January warning operators of the latest developments and advising the need to exercise caution. The NOTAM also required aircraft found to have been affected earlier to be inspected again before each flight.

At the same time as distribution of the Avgas was being followed up, NOTAMs issued etc., we contacted a number of Civil Aviation Authorities around the world, and the International Civil Aviation Organisation in Montreal to see whether anyone had any experience of the problem we were dealing with – they hadn't. I also got in touch with a number of my former colleagues in various authorities and industry organisations in Europe and the USA to seek their views and/or any ideas they may have on how to decontaminate affected aircraft. Because nobody had experienced anything like this particular problem before, all that they could do was to wish us luck!

On top of all of the above, reports started coming in about a clear substance that had also been found to be contaminating fuel systems; this was believed to have been the result of EDA's reaction with carbon dioxide.

What Next?

It will be clear from the story so far that we were faced with a number of unknowns and uncertainties. We didn't know the size of the problem – as in how many aircraft were affected – nor did we know how widespread the problem might be geographically. To answer these two questions, we needed a practical test to indicate whether or not fuel was contaminated but we didn't have one. We also knew that whenever we were able to identify all of the contaminated aircraft and fuel supplies, an effective decontamination procedure would have to be developed and implemented. It is no exaggeration to say that the situation appeared to be deteriorating by the day.

By definition, one of the primary responsibilities of a safety regulatory body such as CASA is to safeguard people and property. Because of the potential risk of more engine failures due to the contaminated fuel, we obviously had to be extremely cautious. In the circumstances, it seemed to me that until, or unless, we knew a good deal more, there was only one course of action open to us. I therefore made what I look back on as one of the more significant decisions I have taken in my life; namely, the grounding of all aircraft that may have uplifted suspect fuel. I don't know the exact number of aircraft that were grounded but thousands were involved – I can recall numbers ranging from 3,200 to 5,000 and have seen suggestions that the number was closer to 7,000. Whatever the actual figure, it will be clear that a great many aircraft, owners and operators were badly affected.

The grounding of affected aircraft came into effect on 10 January 2000 when I signed a second Airworthiness Directive (AD/GENERAL/78); this AD also cancelled the earlier AD/GENERAL/77. CASA also established a 1-800 Hotline number for people in the industry to call with queries/concerns over the contamination problem. In addition, information was disseminated via CASA's website and updated whenever fresh information came to hand.

From the cover of Flight Safety Australia – March/ April 2000

We were notified of possible contamination in Darwin associated with fuel that had been transported there in drums. We also learned subsequently that contaminated drum stock had been transported to a variety of remote locations but, thankfully, it had all been quarantined. As it turned out, only one contaminated drum 'got out'; the single aircraft that was refuelled from it was found to be contaminated.

As mentioned above, we had to try and establish which aircraft had been contaminated and which ones were 'clean'. To this end, some sort of simple, practical and reliable test was required that could be carried out easily in the field. The EDA contamination 'epicentre' appeared to be in Victoria and while EDA-type contamination had been found further afield, it often seemed that the further the fuel had been transported, the less contaminated it became.

Fuel distribution tracing also revealed one seemingly inexplicable situation relating to a batch of contaminated fuel that had been loaded into an oil tanker and transported by sea to Queensland. This vessel was at sea when the cause of the fuel contamination had been identified so on arrival fuel samples from the tanker were tested for the presence of EDA. Mysteriously, when the fuel from the tanker was tested, it was found that no EDA was present but the reason why was unknown.

In addition to finding a simple means of testing for the presence of EDA, it was also necessary to work out how to clean the fuel systems in aircraft that had been contaminated. In other words, a safe and effective method of decontamination also had to be found.

We had learned by now that EDA comes in 3 forms:

- The liquid form used by Mobil in the refining process;
- The copper 'chelate' (black sticky) form; and
- The carbamate (white/clear) form.

As mentioned, we had also learned that in all its forms, EDA was very fond of water in which it would dissolve readily.

The two weeks between 10 and 23 January 2000, following the grounding of all affected aircraft, was a period of frantic and frenetic activity. As discussed, a suitable field test had to be identified and Mobil had been working for some time on such a method, other than the NMR test. The company had managed to develop a prototype but we felt that before the Authority could require operators and maintenance organisations to use such a test, it needed to be validated by an independent, petro-chemical expert.

Following a number of enquiries, CASA was extremely fortunate to find, and engage the services of, the late Professor David Trimm. When he moved to Australia in 1979, David Trimm had been appointed the Professor of Chemical Technology at the University of NSW. David's move to Australia followed three years at the University of Trondheim in Norway where he was the Professor of Petrochemistry. Born and educated in the UK, David had lectured on Catalysis in the Department of Chemical Engineering and Chemical Technology at Imperial College, London. As such, David was highly qualified to assist us and he enjoyed an impressive international reputation; he was also a delightful person to work with.

Professor David Trimm in the lab

On 18 January David Trimm observed a practical application of the proposed field test developed by Mobil during a trial at Bankstown. The test appeared to detect the black 'gunk'

satisfactorily but Professor Trimm felt that it was not conclusive and noted that the reported white contaminant had not yet been identified. David advised that while he was basically comfortable with the test itself, until the white contaminant had been analysed and identified, aircraft should remain grounded.

We had started drafting Airworthiness Directives on how aircraft should be decontaminated and this led to much discussion. On 19 January, CASA technical staff had a very productive meeting with a number of CAR 35 engineers and Mobil representatives aimed at exploring possible ways of safely decontaminating aircraft and returning them to service. In view of EDA's affinity for water, it became clear that H_2O was the best means of getting rid of all traces of EDA in an aircraft that had tested positive. That said, the notion of flushing aircraft fuel tanks and fuel system components with water inevitably caused some surprise for many people to say the least. However, we concluded that there should not be a difficulty with introducing water into fuel systems provided that it was removed properly. The means of getting rid of residual water once it had been drained from an aircraft's tanks and fuel system was to then flush with isopropyl alcohol. Many valuable inputs emerged during our deliberations which were incorporated in the draft ADs.

Over the next few days, Professor Trimm, Mobil and the Defence Science and Technology Organisation received samples of the white contaminant for analysis, the incidence of which appeared to be far lower than the black 'gunk'. Initial indications were that the white material contained a number of oxides and hydroxides and when checking aluminium oxide/hydroxide it appeared that high concentrations of EDA could have an effect on aluminium. It was concluded however that successful decontamination to remove the EDA should address this concern.

A further meeting involving CASA technical staff, a CAR 35 engineer and representatives from a number of maintenance organisations and operators took place at Moorabbin on 22 January. The draft ADs were again discussed in detail with further refinements being agreed. All industry engineering representatives present re-affirmed that the introduction of water into fuel systems was acceptable.

In the meantime, following acceptance of the test by David Trimm, and while all this activity had been going on, Mobil had been busy procuring the equipment necessary to make up hundreds of test kits for distribution to the industry. It was obviously important that the field test should be carried out in as consistent a manner as possible so at the same time as test kits were being procured, an accompanying procedure was developed together with an instructional video. Each test kit package comprised the test materials required, the test procedure and the video.

Coming Out the Other End

Following two weeks of sustained effort, a final field trial using the proposed test kit and the draft procedure was successfully conducted at Bankstown on Sunday 23 January. Later the same day we were able to issue AD/GENERAL/79 which required the field test to be carried out on all aircraft that may have uplifted suspect fuel. Aircraft that tested positive would then have to be decontaminated while those aircraft that tested negative, thereby being found to be uncontaminated, could be returned to service. As testing got underway, the early results indicated a high proportion of positive results.

Two further ADs covering decontamination were issued on 24 January, one for 'simple' fuel systems and the other for aircraft having 'complex' systems; these were:

- AD/GENERAL/80 which applied to aircraft classified as having simple fuel systems; this procedure could be undertaken by a Licensed Aircraft Maintenance Engineer.
- AD/GENERAL/81 was applicable to aircraft with 'complex' fuel systems. This required a separate decontamination procedure to be developed for each type of aircraft and approved by an industry engineer who held an appropriate CASA delegation.

In summary, there were four ways of dealing with the decontamination problem, either:

- AD 80 for 'simple' systems;
- AD 81 for 'complex' systems;
- A decontamination method approved by the aircraft/engine manufacturer; or
- Replacement of the entire fuel system.

As well as draining the whole fuel system when there was physical evidence of contamination and/or a fuel sample from an aircraft tested positive for EDA, because of the 'leaching' effect of EDA on copper-based alloys, all brass components had to be inspected. Very fine

items such as sintered filter elements had to be scrapped and drawn brass items were to be replaced if damaged. The whole system then had to be filled with water, particular care being taken with bladder-type fuel tanks because the flexible, fabric-like material such tanks were made of could 'hide' small quantities of fluid in folds and creases. When tanks had been filled with water the aircraft had to be rocked and agitated to ensure, to the extent possible, that the water would get into every nook and cranny. The water was drained from the system which was then flushed with isopropyl alcohol to get rid of any residual water. Once this step had been completed, the aircraft was filled with 'clean' fuel and left to settle for a period after which a further EDA test was carried out. If the test result was negative the aircraft could be returned to service once all affected components had been cleaned or replaced as necessary. In the event of a positive test result indicating that EDA was still present, the whole process had to be repeated until a negative test result was achieved.

On 25 January, the day after the decontamination ADs were issued, the first successfully decontaminated aircraft was airborne. However, it took some time before things started to improve significantly because, unfortunately (and almost inevitably in the circumstances, particularly the short timeframe), there were some teething problems and Mobil had experienced some difficulties with the test kits that they had undertaken to provide. The company had hoped to have a large number of kits available on 24 January but in the event there were only 4 and these were in Melbourne. In large part, this difficulty was because some of the kit contents had to be sourced from overseas and although the items had arrived in Australia, there was a delay due to customs clearance.

Thankfully the difficulties with the test kits were soon overcome and the majority of affected aircraft were tested, decontaminated when required and returned to service. There were a few owners/operators who would not put water in their aircraft but over time the concerns were resolved and general aviation activity eventually returned to normal.

Loose Ends

Mobil was of course extremely busy while the crisis was ongoing and during its aftermath, as were CASA and many in the industry.

The company issued a number of Press Releases in the form of numbered 'Avgas bulletins' which covered such issues as:

- The quarantining of fuel supplies at different locations
- The establishment of a Mobil Aviation customer hotline
- The provision of "Financial hardship Support for Avgas Customers"
- Paying "for Aircraft Fuel System Cleaning"; and
- A business loss compensation program

The consequences of the Mobil fuel contamination crisis were far-reaching. Many aircraft owners and operators suffered financially due to the various costs involved in testing for EDA, decontaminating affected aircraft and the rectification and replacement of affected parts. Maintenance organisations, as well as many owners and operators, also suffered a substantial loss of business while aircraft were grounded. Mobil had accepted responsibility and developed schemes for compensation, there was also talk of a possible class action but I am not aware of the outcome of any such proceedings.

The mystery of the oil tanker that had been loaded with contaminated fuel in Melbourne which was found to be no longer contaminated when it was unloaded in Queensland was solved eventually. Apparently water was present in the bottom of the tanker's tanks which attracted, and consequently removed, the EDA from the Avgas being transported. In effect, it was the state of the tanker itself that resulted in the removal of the EDA from the load of Avgas.

As well as coping with the many unknowns along the way, another unknown was what the long-term effects might be on aircraft fuel systems if they had been contaminated by EDA. It was therefore important to monitor what happened to those aircraft that had been decontaminated. I understand that loss assessors who went around the country discovered some problems such as fuel selector valves corroding and sticking and there were some cases of failure in fuel transmitters and with elastomer products. I still do not know whether EDA contributed to these issues in some way or whether it was simply that these items had not been inspected for some time. I believe Mobil also initiated a study by a firm in the USA to examine the possible long term effects of EDA.

Lessons Learned

The EDA contamination crisis taught us several valuable lessons about the way in which such a crisis should be handled, including:

- Communication – It is essential to communicate clearly, openly, honestly and frequently with all of the affected stakeholders so that everyone involved knows what is going on;
- Communication mechanisms - Identify and use every possible means of communication. The world was a somewhat different place 20 years ago but the CASA website in particular came into its own;
- Collaboration - Complex problems demand complex solutions and great benefit can be derived from involving industry stakeholders. I would be the first to acknowledge how beneficial it was to work with industry representatives throughout, particularly when developing the decontamination processes and procedures;
- Timing – One rarely has the opportunity to control the timing of events in a crisis but our experience would dictate that late in the day on Christmas Eve is not a good time to try and contact a large number of operators.
- Minimise contamination risk - If your business is refining oil into petroleum, don't use EDA in the process.

The Mobil fuel contamination crisis was unique and unprecedented and it is to be hoped that the industry never has to cope with fuel contamination in the future; nor would I wish to repeat the experience of managing the crisis. It was demanding and challenging for all concerned and many of those involved had to take some tough decisions. I believe that we handled the situation as well as we were able to and, above all, I am thankful that there were no accidents, injuries or fatalities due to fuel being contaminated by the dreaded EDA.

Notes:

1. Mobil ceased 100/130 Avgas production within a year or so of the fuel contamination episode. At that time, Mobil, Shell and BP produced Avgas but today the only producer in Australia is Viva Energy.

2. The Australian Transport Safety Bureau initiated a major safety deficiency investigation into the circumstances of the contamination episode. Their report entitled 'Systemic Investigation into Fuel Contamination' (https://www.atsb.gov.au/media/33960/sir200103_001.pdf) was released in March 2001.