# Shellharbour Airport Committee Report

## Risks to the Safety of Aviation of
## The Proposed Tallawarra B Open Cycle Gas Turbine

## and other
## Peaking Power Plants

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# Executive Summary

This report, provided by the Aircraft Owners and Pilots Association (AOPA) Australia, identifies serious threat to human life associated with the Peaking Power Plant proposed by the proponent for the circuit of Shellharbour Airport. The report goes on to describe the specifics of the threat, the details of how the threat has so far come to be unrecognised, and recommendations moving forward.

## Issue Statement

**Any form of peaking power plant will pose a serious and unavoidable risk to the safety of aviation within the circuit at Shellharbour Airport, along with potential risk to the general public residing within the vicinity of the Shellharbour Airport runway 34 circuit.**

**To fulfil the proponent's Duty of Care requirements, the proponent must conduct a technically rigorous and transparent plume assessment, using CASA and Shellharbour City Council endorsed critical factors with results validated against the available Bureau of Meteorology (BOM) airport site data.**

**It is CASA's responsibility to require that the anomalies identified in this AOPA report are rectified and that data more relevant to the types of aircraft placed at risk by the Tallawarra B plume be the focus of the Aeronautical Impact Assessment.**

## Issue Summary

It is unclear from the Proponent's Aeronautical Impact Report (062001-03), specifically what is being assessed, or how it has been assessed. The proponent's report lacks the rigour and transparency necessary to correctly assess the risk the proposed plume poses to the safety of aviation at Shellharbour Airport.

The key shortcomings are:

1. The Critical Plume Velocity used in the report has been calculated incorrectly and overlooks the role that Vertical Gusts play in safe flight conditions for General Aviation aircraft within the circuit. This is the most significant error in the report. The proponent's use of 6.1 m/s as the CPV does not take into account:
   a. The relevant aircraft type;
   b. the stage of flight of the aircraft, or;
   c. the location of the efflux as required by regulation 139.370(2) or AC 139-05(3) paras 2.1.4 and 2.1.5.

2. A plume vertical velocity of 6.2 m/s encountered by a Cessna 172N climbing out at best rate of climb speed and maximum take-off weight, will push the aircraft wings to the Critical Angle of Attack (AOA), causing the wings to lose lift and the aircraft to momentarily stop flying. By definition, this represents the onset of 'severe turbulence' for this aircraft type under these conditions. A Piper Archer II, a Foxbat and a Jabiru J160 will have their wings stalled by a 6.1 m/s gust. The Piper Archer II would likely be pushed to phase 2 flight, whilst the Foxbat and Jabiru j160 would likely both be pushed to phase 3 flight (into a spin). Recovery from a spin at or below circuit height of 1000 feet is not recoverable before flight into terrain, regardless of pilot experience. Such flight into terrain is usually fatal.

3. The proponent shows no evidence of the model output data being validated against data available from the relevant regulatory body, in this case the Bureau of Meteorology (BOM). The proponent's report confirms that ambient winds at Shellharbour Airport are less than 5 kts for 42.9% of the time. The lack of validation of plume rise output data used in the assessment against this BOM Shellharbour Airport data, questions the integrity of the conclusions drawn.

4. The Report's approach to risk analysis is insufficient for a potential impact of this calibre.

   a. Using 6.1 m/s as the CPV is akin to saying that Shellharbour Airport is only used by large passenger carrying jet aircraft cruising at altitude.

   b. Excluding 45 hours of the data of most risk to the aircraft concerned is not in accord with the model instruction manual, and is a statistically invalid approach to assessment.

   c. Comparing FlighAware tracked ADSB flights which are primarily Instrument Flight Procedure Flights (IFR) to at risk Visual Flight Procedure (VFR) flights, which fly totally different flight paths, is an invalid comparison.

   d. Comparing a hypothetical 20 hours per 5 day week of power plant operations, to 24 hours per day, 365 days per year of VFR flight movements is mathematically invalid. If all the flights occur at periods other than when the plant is operating, then there is zero risk. If the flights all happen while the plant is operating, the risk is significantly higher than stated.

5. The conclusions drawn in the proponent's report have not been reconciled with the technically valid conclusions drawn in the Jacobs Technical Memo, "*Plume Rise and Options to Reduce GT Exhaust Velocity and Temperature*", dated 31 August 2018. Jacobs confirms in the memo that exhaust plume rise is determined by two factors - momentum flux and buoyancy flux. The memo goes on to say *"after a distance of several diameters from the stack, buoyancy is the dominant factor. This is consistent with Plume Rise Theory."*
   The memo concludes: *"Based on the plume rise modelling undertaken as part of the initial assessment and for the options considered here, it is estimated that to achieve a plume velocity of 6.1 m/s at 1031 ft AMS an exhaust temperature of 400-430 deg C at an approximate stack flow of 1300 m3/s would be needed. None of the potential engineering solutions of GT alternatives outlined here can achieve these exhausts temperatures and flows."*

## Statement of recommendation

The specific recommendations from this report are:

1. CASA to determine the appropriate Critical Plume Velocity for the correct assessment of risk to the safety of aviation, taking into account the Visual Flight Rules (VFR) aircraft affected by the plume, their location in the circuit, and the aircraft aerodynamic situation.

2. CASA to determine the appropriate Critical Plume Height(s) for the assessment taking into account Visual Flight Rules (VFR) aircraft affected by the plume, their location in the circuit, and the aircraft aerodynamic situation

3. Energy Australia to present a transparent plume rise assessment with clarity of specifically what is being assessed, how it is being assessed, and all assumptions made.

4. Energy Australia to validate model output data used for the assessment, and report the accuracy of that data as part of the assessment.

5. Energy Australia to reconcile any difference between final assessment findings and those presented by Jacobs in their technical memo on peaking power plant engineering modifications.

6. Energy Australia to conduct a valid risk assessment.

# Contents:

# Report Body

## Introduction and Background Information

Aircraft Owners and Pilots Association (AOPA) Australia have an Australia Wide Airport Representative committee reporting to the CEO. The AOPA Shellharbour Airport Committee is part of that structure, voted by aircraft owners and pilots at Shellharbour Airport to represent them.

Energy Australia (the proponent) have conditional approval to build an Open Cycle Gas Turbine (OCGT) power generating plant within the circuit of Shellharbour Airport (YSHL), with the condition being that it does not pose a risk to the safety of aviation at YSHL. This report studies the risks caused by this proposed development, with particular reference to Aviation Projects Aeronautical Impact Assessment Report 062001-03 dated December 2019 (the proponent's report).

The Civil Aviation Safety Authority (CASA) is the Australian air safety regulator responsible for managing the aviation safety system. It is CASA's responsibility to work ON the system to ensure it is safe for pilots and others to work IN. It is specifically CASA's responsibility to ensure that the system of safety around aerodromes is safe for pilots and others to operate IN.

Aircraft fly because of the lift created by air passing over the wings. Lift is created when the wings form a small positive Angle of Attack (AOA) with the air they are passing through. The wings stall (stop creating lift) at what is called the Critical Angle of Attack (Critical AOA). For most general aviation (GA) aircraft, this critical AOA is approx. 16 degrees. The wings will always stall at the same Critical AOA regardless of the aircraft speed, power level, weight or orientation.

Aircraft have three basic phases of flight. The first is when the wings are creating lift. This is where all pilots spend most of their flying time. With the exception of aerobatic pilots, even multi thousand hour commercial pilots will have spent probably less than 1 or 2 hours total actual time outside this phase of flight. This is the phase of flight where the great majority of pilots develop their 'muscle memory' – where humans go when things go wrong - our automatic reflex.

The second phase of flight is at or around the critical angle of attack. Approaching the critical angle of attack, air starts to separate along the top of the wing and the wing starts to lose lift. It is an unfortunate fact that in phase two flight, everything the pilot has ingrained into muscle memory is wrong. In phase two flight, pulling the stick back to pull the nose up makes the nose go down further. Rolling the ailerons right to lift a 'dropped' left wing makes the left wing drop further. In phase 2 flight, the elevator and ailerons behave as though connected back-to-front. In phase two flight, muscle memory is a hindrance, not a help. The only time most pilots spend in phase 2 flight (other than aerobatic pilots), is during a very small part of their training, when conditions are benign, and the pilot is expecting the aircraft wings to stall.

The third phase of 'flight', is after the wings have fully stalled. If this third phase persists, the aircraft will enter a spin. If this third phase is entered whilst under full power at best rate of climb airspeed, Vy, there is a serious risk of the aircraft being "flick rolled" (auto-rotation at high roll rate), into a spin. It is highly unlikely a spin entered at circuit height (1000 feet) by a general aviation (GA) aircraft is recoverable before contacting terrain, regardless of pilot experience, and is usually fatal.

Worldwide, approximately 50% of all fatal GA accidents happen in the circuit. The aircraft are flying very close to the critical angle of attack, and at altitudes typically 1000 feet AGL (above ground level), or lower. It takes very little disruption to cause the aircraft under these conditions to move into phase two or phase three flight.

It is the responsibility of CASA to keep the airspace within the circuit of the aerodrome safe for pilots. Unfortunately, in Australia, we have a situation where CASA have the responsibility, but not always the authority, to ensure this occurs. In NSW, the NSW Department of Planning and Public Spaces has the authority, along with the Duty of Care, to over-ride CASA and approve this development, even if CASA formally deems the situation to create a hazard to the safety of aviation. CASA's only recourse then is to put in place ineffective administrative procedures to attempt to make the situation safe. It is then on the pilot's shoulders to worry about the plume along with everything else in the circuit.

The exhaust plume from an OCGT is invisible, and in the circuit, has sufficient vertical thrust to cause GA aircraft to enter phase two or phase three flight. In non-aviation language, placing an OCGT plume in the circuit of an aerodrome is akin to a company randomly placing black ice as a by-product on a road. Drivers understand the risk of black ice and would normally avoid situations under which it is likely to form. But, if a company was authorised to randomly place black ice on the road as a by-product under any and all weather conditions, because it was in the state's interest to do so, driving on that road would become very hazardous, regardless of how well the situation was modelled to 'prove' it is safe.  Placing a sign on the road to warn that black ice is a possibility does not make it safe. Reducing the speed limit, would not make it safe. It is the same for a pilot in the circuit encountering a vertical plume of sufficient velocity to stall the wings. Knowing about the plume does not make it safe.

The safest and most effective risk mitigation strategy is to remove the source of the risk. There are at least two ways to do this. The first is to construct a Combined Cycle Gas Turbine (CCGT) plant (these don't make 'black ice'). The second is to construct the Open Cycle Gas turbine (OCGT) plant elsewhere (where the 'black ice' by-product doesn't go on a road).

This committee supports both of those solutions. The CCGT plant is acceptable because it takes the raw plume from the OCGT plant and processes it to convert the energy in the plume into electricity. This renders the plume relatively harmless to aircraft within the vicinity of the plume. As an argument against building a CCGT unit, Energy Australia continues to claim that the CCGT unit takes too long to start up. For example, at the recent NSW RAPAC meeting, Energy Australia stated a CCGT unit can take up to 6 hours to start up (See NSW RAPAC Meeting 28 May 2019 minutes).

These comments by Energy Australia reference old technology (though still very reliable equipment and still currently available). GE, one of the manufacturers, on the other hand, says their modern HA CCGT units start up in less than 30 minutes. They are also capable of starting in less than 10 minutes in simple cycle mode, but this would defeat the purpose from an aviation safety perspective.

Apart from the extra capital cost and the time to install, the 7HA.01 430 MW CCGT plant operates at record-breaking levels from the perspective of efficiency and pollution performance. On the other hand, the Aeroderivative peaking plants currently being investigated by Energy Australia, pose a hazard to the safety of aviation and produce approximately 12 ½ times the pollution of the 7HA.01 CCGT unit.

Regarding alternative 2, Energy Australia had approval to also build an OCGT plant at Marulan, an option recently let lapse by Energy Australia. An Australian Financial Review interview (https://www.afr.com/companies/mining/energyaustralia-forges-ahead-with-400m-nsw-gas-plant-20180709-h12g9o) with Energy Australia's Mark Collette reveals:

*The Tallawarra B option was chosen ahead of building a generator of up to 700 MW at a new site in Marulan, which would have required investment in grid, gas and water connections that are already in place at the Wollongong site, which hosts EA's existing 430 MW Tallawarra generator.*

*"It's always a little bit tougher for 'greenfield' rather than 'brownfield' and as we've worked through options Tallawarra is first in line," Mr Collette said.*

Whatever is happening outside the normal CASA aeronautical impact process, the NSW Minister for Energy and the Environment presented the NSW Department of Planning, Industry and Environment document titled "NSW Electricity Strategy" on the morning of the most recent COAG Energy Minister's meeting. In this document, section 5 specifically states the need for a 320 MW gas peaking plant to be built at Tallawarra.
Energy Australia are now sufficiently emboldened to also be investigating building a series of Aeroderivative gas turbines, which were never approved, even conditionally. The Secretary's assessment report - Modification for extension of approval (07_0124 MOD 1) states in paragraph 2: (https://www.planningportal.nsw.gov.au/major-projects/project/16991)

***"PROPOSED MODIFICATION***
*Energy Australia is seeking to extend the approval lapse date of Tallawarra Stage B for an additional five years (i.e. 21 December 2015 to 21 December 2020) in order to complete the tendering, contracting, design, construction and commissioning for a combined cycle generator (refer to **Appendix A**)."*

Unfortunately Appendix A is nowhere to be found on the Department of Planning, Industry and Environment, NSW Planning Portal for Major Projects.

The assessment report goes on to say:

*"The proposed modification does not seek to change other aspects of the approved project, including the type and capacity of gas turbines, the maximum electricity generation rates, the construction of ancillary infrastructure or the utilisation of existing infrastructure"*
*"The Department considers that there is no increase in predicted environmental impacts beyond those that have already been assessed and approved. There are no proposed changes to the approved electricity generation rates, electricity generation methods or physical operation of the project."*

Energy Australia are however, investigating the potential installation of Aeroderivative gas turbines as an alternative in the proponent's Report. Aeroderivative Gas Turbines are low cost units based on aircraft jet engines. The Simple Cycle versions are relatively inefficient and relatively filthy environmentally with 12 ½ times the environmental impact of a CCGT unit. Fortunately, they come in 2 varieties, Simple Cycle and Combined Cycle. Unfortunately, Energy Australia are only investigating the Simple Cycle versions.

## FAA position on plumes within the vicinity of an airport

FAA memo Sept 24, 2015 titled
Technical Guidance and Assessment Tool for Evaluation of Thermal Exhaust Plume Impact on Airport Operations

*"After thorough analysis, the FAA has determined the overall risk associated with thermal exhaust plumes in causing a disruption of flight is low. However, the FAA has determined that thermal exhaust plumes in the vicinity of airports may pose a unique hazard to aircraft in critical phases of flight (particularly takeoff, landing and within the pattern) and therefore are incompatible with airport operations.*
*Flight within the airport traffic pattern, approach and departure corridors, and existing or planned flight procedures may be adversely affected by thermal exhaust plumes[1]. The FAA-sponsored research indicates that the plume size and severity of impact on flight can vary greatly depending on several factors at a site such as:*
*Stack size, number, and height; type of exhaust or effluent (e.g., coolant tower cloud, power plant smoke, etc.);*
*Proximity of stacks to the airport flight paths;*
*Temperature and vertical speed of the effluent;*
*Size and speed of aircraft encountering exhaust plumes; and*
*Local winds, ambient temperatures, stratification of the atmosphere at the plume site."*

## Technical Analysis:

The essence of any plume rise assessment distils to three critical factors. The relevance and quality of these three factors determine the usefulness or otherwise of the output data used to determine the risk to the safety of aviation of any proposed plume. These three factors are:

1. The Critical Plume Velocity (CPV)
2. The Critical Plume Height (CPH), and
3. The model used, including the quality and validity of its inputs, its setup and validation of its outputs against actual relevant results within the area under consideration.

AC 139-05 (3) para 2.1.2 states:

*" Part 139.370 of the Civil Aviation Safety Regulations 1988 (CASR) provides that CASA may determine that a gaseous efflux having a velocity in excess of 4.3 m/s is, or will be, a hazard to aircraft operations because of the velocity or location of the efflux."*

Para 2.1.4 states:

*"An exhaust plume of moderate or higher turbulence intensity has the potential to affect the safety of aircraft operations, such as in critical stages of flight (periods of high pilot workload) and low level flying operations."*

Para 2.1.5 states:

*"For example, a light aircraft in approach configuration is more likely to be affected by a plume rise than a heavy aircraft. …. "The potential hazards and risks posed by these plumes must be mitigated to ensure the safety of aircraft operations in the vicinity of the plume rise"*

This report will show that because the proposed location of the plume is within the circuit of Shellharbour Airport, and because of the mix of general aviation aircraft using Shellharbour Airport, even a CPV of 4.3 m/s poses a risk to the safety of aviation at Shellharbour Airport.

The appropriate CPV and CPH must relate to the situations in which the aircraft are exposed to the proposed exhaust plume. Terrain constraints dictate that circuits at Shellharbour Airport are flown to the north and east of the runways. This requires non-standard right hand circuits on runways 34 and 26. For noise abatement reasons, when weather doesn't dictate any particular runway to use, runway 34 is the preferred duty runway. Aircraft using runway 34 for departure, circuits, or other training activities are the aircraft most exposed to risk due to the proposed plume. The appropriate CPV and CPH would take these conditions into account.

CASA supports use of CRIRO's TAPM (The Air Pollution Model) for plume rise assessments in Australia. There have been concerns expressed in the literature, both in Australia and overseas, about the accuracy of the TAPM model. It is also understood that CSIRO no longer fully supports the TAPM model, and the report does not declare the relevance or impact of this.

More importantly, both CASA and the Bureau of Meteorology are clear that any individual derived vertical gust will have different effects on an aircraft depending on the aircraft size (weight), speed and configuration. This is ignored by the proponent, and derived gusts are applied as though the effect is the same for all aircraft regardless of size, configuration or any other consideration. The main impact of this in the way the assessment is conducted, is the CPV used.

A Cessna 172N was chosen for the CPV calculations presented in this report. The Cessna 172 is widely considered a 'typical' GA aircraft. It is, and has been, used for many years for both touring and training, under both Instrument Flight Rules (IFR) and Visual Flight Rules (VFR). The calculations show that a Cessna 172N departing runway 34 at Maximum Take Off Weight (MTOW) and best rate of climb (Vy), will be approaching the onset of severe turbulence for that aircraft under those conditions.

## Critical Plume Velocity

The MITRE Corporation in the US have shown through their work, that any given initial buoyancy flux from a stack, will subject different aircraft types to severe turbulence up to different altitudes relative to the aircraft's weight and aerodynamic characteristics. They show that a plume can be characterised by its initial buoyancy flux. The initial buoyancy flux for the Tallawarra B OCGT units (scenario 2, Jacobs 5 June 2018) is 3862 $m^4/s^3$. From the MITRE Corporation work, this level of buoyancy flux will present as severe turbulence for a Convair CV880-M (similar to a 737) below 1000 feet, but for a Navion GA aircraft (similar to a Cessna 172), that same plume would present as severe turbulence up to approximately 6000 feet.

The Bureau of Meteorology in their *Hazardous Weather Phenomena Windshear* document state:

> *"Wind shear is defined as a wind direction change over a vertical or horizontal distance."*
>
> *"Although wind shear may be present at all levels of the atmosphere, its occurrence in the lower levels is of particular importance to aircraft taking off and landing. During the climb-out and approach phase of flight, aircraft airspeed and height are near critical values, rendering aircraft especially susceptible to the adverse effects of wind shear. The response of aircraft to wind shear is extremely complex and depends on many factors including the type of aircraft, the phase of flight, the scale on which the wind shear operates relative to the size of the aircraft, and the intensity and duration of the wind shear encountered"*

A "Plane and Pilot" article titled "Understanding Maneuvering Speed – It isn't what you think", points out that design gust speeds refer to aircraft at maximum take-off weight (MTOW). The only aircraft operating within the circuit likely to be at MTOW are those aircraft departing to go enroute. It is common practice for all pilots to fly with fuel and aircraft loading for local and training flights much lighter than MTOW. Aircraft performance is usually significantly better with low loading. An aircraft lighter than MTOW is at risk of exceeding structural strength before stalling. This is relevant whether the flaps are retracted or extended.

Noel Kruse presents the simplest understanding of the effects of vertical gusts on aircraft and the determination of the appropriate CPV for any aircraft type under any conditions, in his educational "Fly Better" series.

Lesson 13, 'Aircraft Structural Limits', is the relevant lesson (particularly from page 266 onwards). See Appendix A.

Most aviation people would accept a Cessna 172 as a typical General Aviation (GA) and training aircraft across Australia. Whilst not an aerobatic aircraft, it is built to the Utility Category structural strength requirements (stressed to +4.4G), so it is stronger than 'Normal Category' aircraft (stressed to +3.8G).

The spreadsheet in Appendix B shows calculations done to identify the derived vertical gust necessary to cause a Cessna 172N aircraft to stall under relevant circumstances in the circuit.

The Cessna 172N has wings designed by the National Advisory Committee for Aeronautics (NACA). They are a NACA 2412 wing root airfoil with NACA 2412 mod wing tip airfoil. These wings have a critical AOA of 16 degrees (NACA Report 824, page 394).The Pilot Operating Handbook (POH) indicates the aircraft is designed to withstand a stress of +4.4G with clean stall speeds at maximum take-off weight (MTOW) of 47 Knots Indicated Airspeed (KIAS) (fwd) and 42 KIAS (aft). The POH stall speeds vary depending on whether the aircraft is loaded fully forward in the Centre of Gravity (CG) range, or fully aft. Calculations were done for both then averaged.

The scenarios modelled in the attached are as follows:

**Case 1**.

As a base case, the Cessna 172N was modelled cruising in clean configuration with wings level at MTOW and turbulence penetration speed. This case is more applicable for an assessment outside the vicinity of an aerodrome where the alerted pilot while cruising, reduced speed to turbulence penetration speed to avoid possible aircraft structural damage.

**Case 2**.

The aircraft climbing out at Vy, wings level with clean configuration and MTOW for crosswind departure.

**Case 3**.

The aircraft conducting a rate 1 turn downwind, clean configuration and MTOW.

The following principles are applied:

1. The wing only knows Angle of Attack (AOA)
2. The wing always stalls at the same AOA regardless of speed, power setting, or orientation of the aircraft
3. The derived vertical gust required to reach the wing's critical AOA and stall the wings represents, by definition, the onset of severe turbulence, for that aircraft, under those conditions
4. Applying the principles in the BOM Turbulence Intensity Table, the derived gust to produce the onset of moderate turbulence is half the derived gust to produce the onset of severe turbulence.

5. Applying the principles in AC139-05(3) (CASA's Advisory Circular on Plume Rise Assessment), the derived vertical gust to produce the onset of moderate turbulence is the CPV for this aircraft type under these conditions.

The calculated turbulence penetration speed used in the analysis was reduced by 10 KIAS based on the work of Barry Schiff in his book 'The Proficient Pilot' Volume 2, Chapter 4, 'Flying in Turbulence'.

Vo(rolling) is applied to the aircraft turning downwind based on the following quote from Noel Kruse's lesson on aircraft structural strength, annex B *"Turbulence, by its very nature, will rarely impose 'symmetrical G' on an aeroplane.* ***It*** *invariably imposes some degree of 'rolling G', but none of the gust response speeds, however they are calculated, consider 'rolling G' in the calculation! Further, upon encountering turbulence the pilot will probably attempt to maintain altitude and/or attitude by 'wrestling' with the aeroplane's controls, which means that he/she throws some manoeuvre loads into the 'mix' too!*

*The combination of gust induced 'rolling G' loads and pilot induced manoeuvre loads defies any sort of quick 'in flight' mental calculation, so if you encounter severe turbulence I suggest that you slow your aircraft to* ***Vo(rolling)*** *quickly."*

**Based on all the above, the calculated CPV for the Cessna 172N cruising at altitude at turbulence penetration speed in utility category, is 4.3 m/s.**

This CPV of course, is not relevant in the circuit. Since the critical aircraft/plume situation is climbing out runway 34, departing crosswind, or turning downwind for departure, circuits or other training activities. The relevant CPVs to look at here are climbing out clean, MTOW at Vy or Vroll if turning downwind.

For the Cessna 172N in utility category, these CPVs are:

- **Climbing out clean at Vy and MTOW – 3.3 m/s**
- **Using Vroll, turning downwind at MTOW – 2.6 m/s**

Critical Plume Velocities were calculated for several other aircraft using YSHL – see Appendix B.

## Summary of CPVs for various aircraft on climb-out, MTOW at Vy

| **Aircraft** | **CPV-MTOW Vy** (m/s) | **Wing stall Plume velocity - MTOW, Vy** | **CG loc** |
|---|---|---|---|
| Jabiru J160 | 1.3 | 2.7 | |
| Foxbat A22LS | 1.5 | 3.1 | |
| Piper Archer II | 2.6 | 5.2 | |
| Foxbat A22 | 2.8 | 5.7 | |
| C172N Utility Cat. | 3.1 | 6.2 | fwd CG |
| Sonex Aero V 80HP | 3.4 | 6.9 | |
| C 172N Utility Cat. | 3.5 | 7.1 | aft CG |
| VANs RV10 | 3.6 | 7.2 | |

| | | | |
|---|---|---|---|
| Jabiru J230 | 3.8 | 7.6 | |
| Pipistrel Alpha | 4.0 | 8.0 | |
| VANs RV7 | 4.6 | 9.2 | |
| J160 local practice | 2.7 | 5.5 | 80 kt<br>Climb out |

A 6.1 m/s vertical gust would present to a Cessna 172N climbing out crosswind as approaching severe turbulence. A Piper Archer II, a Foxbat and a Jabiru J160 will have their wings stalled by a 6.1 m/s gust. The Piper Archer II would likely be pushed to phase 2 flight, whilst the Foxbat and Jabiru j160 will both be pushed to phase 3 flight (into a spin).

For the Cessna 172N turning downwind at MTOW, the situation is quite complex, and the committee leave it to CASA and the proponent to calculate the appropriate CPV for that aircraft under those conditions.

Critical plume velocities have been calculated for a series of aircraft types using Shellharbour Airport. The are many aircraft that will have their wings stalled if impacted by a 6.1 m/s vertical gust while climbing out wings level at Vy and MTOW. (see appendix B)

It is inappropriate to use a Critical Plume Velocity of 6.1 m/s to assess the risk to the safety of aviation of the proposed plume at Tallawarra B due to the aircraft types and their energy state whilst manoeuvring in the circuit.

The above calculations assume the aircraft is operating at MTOW in clean configuration. Most aircraft departing with partial flaps have the gust strength of the aircraft halved. This is ignored at this stage, as has the effect of the plume on aircraft flying at less than MTOW.

AC 139-05(3) Plume Rise Assessment Process Step 3 indicates it is CASA's responsibility to determine the Critical Plume Velocity to be used in the Aeronautical Impact Assessment. Despite the fact that this plume rise assessment is well past step three, the proponent continues to insist on using 6.1 m/s as the Critical Plume Velocity.

The risk posed to the safety of aviation of aircraft using runway 34 by using a CPV of 6.1 m/s is hazardous, potentially fatally.

## Critical Plume Height

The Critical Plume Height (CPH) must be determined taking into account the situations where aircraft in the circuit are most at risk to plume rise from the proposal.

These situations occur for winds 5 - 10 knots and less from directions ranging from due west through north to due east, and for all winds less than 5 knots. Under these local conditions, runway 34 is the duty runway, and these are the conditions under which the plume rise will present the greatest risk to the safety of aviation.

Under these conditions, aircraft will climb to 500 feet minimum prior to turning crosswind to climb from 500 feet through to the downwind turn. Not all aircraft have sufficient power to attain

1000 feet prior to turning downwind, but it is reasonable to assume that the majority of aircraft will climb from 500 feet to 1000 feet then turn downwind.

A conservative assessment would see genuine sensitivity analyses done by the proponent from 500 feet to 1000 feet at ambient wind conditions of 5 to 10 knots with wind blowing from anywhere north of and including the east-west line and for all winds less than 5 knots.

AC 139-05(3) section 3, 'Plume Rise Assessment Process', indicates that it is CASA's responsibility to determine the CPH. It seems reasonable that there be two CPHs determined, one related to aircraft climbing out cross wind, and the second for aircraft turning downwind.

## CSIRO's 'The Air Pollution Model' (TAPM)

The following aspects of the TAPM model are of most concern related to the plume rise assessment within the circuit of Shellharbour Airport:

- The accuracy of the predicted spatial location of the plume.
- The accuracy of the predicted vertical penetration of the plume
- The prediction or otherwise of turbulent gusts associated with the plume
- Statistically invalid use of the model output data
- Lack of Model Validation.

## Predicted Spatial Location

The Tennessee Valley Authority (TVA) in the US have taken a significant number of actual power plant plume measurements across various of their power plants. (*ref: "Full-Scale Study of Plume Rise At Large Coal-Fired Electric Generating Stations" – Carpenter, Leavitt, Thomas, Frizzola and Smith – journal of the Air Pollution Control Association. Ref: Analysis of Plume Rise Data from Five TVA Steam Plants – Domenico Anfossi – 1985 American Meteorological Society*). TVA's purpose was to enable development of better predictive models so they could more adequately design stack heights to facilitate better dispersion of exhaust pollution.

The MITRE Corporation compared TAPM model outputs against actual results from three of those Tennessee Valley stacks and found that the TAPM model was consistently inaccurate in predicting the plume location by approximately 24%.

Peter Best et al in their paper "Aviation Safety and Buoyant Plumes", at the Newcastle Clean Air Conference 2003, point out in para 2.2, a shortcoming in the TAPM model where it *"assumes that the horizontal plume velocity instantaneously takes up the ambient horizontal velocity at stack height".* This assumption is very questionable for high velocity, high temperature buoyant plumes such as those from an OCGT generating plant.

A 24% level of uncertainty about the actual location of the plume in the circuit of Shellharbour Airport is significant.

Jacobs, wrote an email to CASA's Office of Airspace Regulation dated 9/10/2017 (Appendix 3) explaining differences in, and updating the then current plume rise numbers for the preferred scenario 2 – 2 off GE 9E.04 OCGT units. This email shows for scenario 2, using 99.9% culled data, that at 2200 feet AHD and 4.9 m/s plume velocity, the plume is displaced 2092 metres from the source with a diameter of 1100 metres. Whilst it is unclear from the proponent's report specifically what is being assessed, it is difficult to see based on Jacobs technical memo referenced elsewhere in this document that the plume characteristics will be significantly different from these numbers. This plume may well be a risk to IFR aircraft as well as VFR. The IFR risks are not addressed in this report.

## Vertical Penetration

The MITRE Corporation also conducted laboratory tests to help them choose between using the Jirka, Spillane and TAPM models for their plume rise assessment work. From that laboratory work they determined that the TAPM model "significantly understated the extent of the vertical penetration of the plume".

Peter Best et al, (paper as above), para 5 state: *"Meteorological inputs are critical for a reasonable treatment of risk, especially for near-calm conditions at stack-top and above. Unfortunately, it is these very conditions under which near-surface measurements…..with TAPM-like prediction methodologies are likely to be poor indicators of actual conditions"*

**Katestone,** in their 2003 Newcastle Clean Air Conference paper titled Aviation Safety and Buoyant Plumes state:

> *"Meteorological inputs are critical for a reasonable treatment of risk, especially for near calm conditions at stack top and above."*
>
> *"Recent project work near Williamtown Airport gave a comparison of 5 years of hourly results with available balloon and 30m tower measurements.*
> *The main conclusions were:*
> - *TAPM tends to underpredict the frequency of occurrence of very light winds (<1m/s) compared to tower observqtions (typically 1.2 – 3.5% compared to 5.7 – 14.9%)"*

**Pacific Environment Limited** B.FLT.0369 (Part E) Final Report states in the executive summary:

> *"It is therefore apparent that TAPM can predict meteorological parameters with an adequate degree of precision in certain instances"---- "it is, however, essential that the model be run on an adequate resolution to capture the local scale meteorology. In addition, the TAPM solution should be validated against concurrent observations for any observed meteorological data (eg Bureau of Meteorology) station within the TAPM domain. This validation will provide a measure of accuracy of model prediction at the location."*

The effect of under predicting calm or near calm conditions means the model predicts higher winds than actual. Predicted higher winds lead to predicted lower plume intensity. The model also assumes that the plume instantaneously takes up the horizontal component of the predicted ambient wind. This also lessens the model predicted plume intensity.

Rather than making the model grid spacings as fine as necessary to ensure the model produced predicted ambient winds that correlate with actual, the proponent has historically been using coarser grid spacings than the TAPM model default settings. It is unclear from the current report what grid spacings have been used for this current assessment.

Hence we now have a proposed ‘actual’ plume that is likely to be significantly more penetrative than predicted, with a 24% level of uncertainty of its actual location, within the circuit of Shellharbour Airport.

## Turbulent Gusts

There is a significant volume of work in the literature regarding turbulent gusts, also known as eddies, willie willies, etc., and the effect of these on aircraft stability and loss of control accidents.

The TAPM model V4 has the option of controlling the choice of turbulence scheme the model uses, with the default being the TKE-EPS-EDMF scheme. AC 139-05(3) and the proponent are both silent on this matter. If the TAPM model has the ability to predict turbulence associated with the plume, this aspect should be understood and applied as relevant.

## Model Validation

All of the above uncertainty can be clarified to one degree or another through model validation. Model validation is standard technical practice for such an assessment. Validating the TAPM model output data used for the assessment with concurrent BOM actual data at the airport would provide a much needed measure of accuracy of the model prediction.

The Aviation Projects Aeronautical Impact Assessment 062001-03 states in para 5.8, page 27:

> *“Analysis of Bureau of Meteorology Aerodrome Climatological Summary Model D for Albion Park (Wollongong Airport) – YWOL revealed that the wind is less than 5 kt for approximately 42.9% of the time.”*

It is well known that the risk to the safety of aviation presented by the plume is most significant for winds at or below 5 kts, which, according to the proponent’s report, is 42.9% of the time. With ambient winds less than 5 kts, the duty runway is runway 34 at Shellharbour Airport for noise abatement reasons, placing the aircraft climbing out crosswind, then turning downwind, in direct contact with the plume.

It is fundamental that the proponent be required to validate the output data presented in the assessment with the actual BOM reported wind conditions at Shellharbour Airport. Any prediction of overall stronger ambient winds, by definition, reduces the predicted plume intensity, thereby understating the actual risk to the safety of aviation.

## Misapplication of Model Data - Use of only 99.9% of the output data:

The only legitimate source of information on how to setup, operate and use the TAPM V4 model, is the TAPM V4 User Manual by Peter Hurley, CSIRO Marine and Atmospheric Research Internal Report No. 5, October 2008. An alternative to this might be formal advice from CSIRO with such a guideline. The first use of 99.9% data was the 2010 Ambidji plume rise assessment. The prior report used 100% of the data.

Nowhere in the TAPM V4 manual is there any suggestion that culling the output data will gain a more representative result of anything. Excluding the 0.1% of outlying data is statistically invalid. The only reason to remove this data is to reduce the reported maximum plume penetration, the reported maximum heights of plume velocity at 4.3 m/s and 6.1 m/s, and the reported proportion of time the plume exceeds 4.3 m/s and 6.1 m/s at 1000 feet and 1500 feet.

This data culling across the 5 years analysed removes 45 hours of the most critical data related to the hazard presented to the safety of aviation in the circuit. It removes the 'outlier' vertical height data reached by the plume. (These 45 hours also represent the 45 hours of maximum plume vertical velocity at 1000 feet and 1500 feet).

The appropriateness or otherwise of this approach can be verified by validating the percentage of time the 'culled' output data shows the ambient winds to be less than 5 kts compared to the 42.9% of time reported by the proponent's report. The stronger the model predicts the winds to be, the lower the model predicts the risk to the safety of aviation to be, because stronger winds disperse the plume more quickly.

AC 139-05(03) also contains no advice to adopt such a practice.

## Risk Assessment:

1. An adequate risk assessment cannot be done at 6.1 m/s for Shellharbour Airport. This is akin to saying that Shellharbour Airport is only used by large passenger carrying jet aircraft cruising at altitude.
2. Any risk analysis that excludes 45 hours of the data of most risk to the aircraft concerned is not a risk analysis, and does not constitute an aeronautical impact assessment.
3. FlighAware tracked flights are ADS-B flights. Almost all ADS-B flights belong to IFR equipped aircraft. IFR flight paths do not mirror VFR flight paths. The IFR aircraft flying over the plume would have been flying VFR because IFR flight paths do not track over the plume. Most of these particular ADS-B flights would belong to Skydive Australia aircraft departing and returning VFR. The risk to the safety of aviation is primarily to VFR flights. The risk analysis must focus on the remainder of the annual movements at YSHL that are VFR, not the FlightAware flights that are primarily IFR.
4. If the risk analysis is to be done on 20 hours per week of power plant operations, the plume rise data and aircraft movement data must mirror those operating hours, otherwise the analysis is invalid. If all the flights occur at periods other than when the plant is operating, then there is zero risk. If the flights all happen while the plant is operating, the risk is significantly higher than stated. This approach taken in the report is mathematically invalid.

# Summary and Conclusions

Energy Australia have a Duty of Care to ensure the Tallawarra B development does not pose a risk to the safety of aviation. Unfortunately, the Aviation Projects Aeronautical Impact Assessment Tallawarra B OCGT report 062001-03 lacks the rigour and transparency necessary to correctly assess the risk to the safety of aviation of the VFR aircraft using Shellharbour Airport.

The use of 6.1 m/s as the Critical Plume Velocity demonstrates at best, a lack of understanding of the effect vertical gusts have on General Aviation Visual Flight Rules (VFR) aircraft. The use of 6.1 m/s is not only incorrect, it poses a very real and significant risk to the safety of VFR aircraft using Shellharbour Airport.

The culling of 45 hours of critical data from the model output is mathematically invalid, is not supported by the TAPM owner's manual , and it is not supported by AC139-05(3). This is a practice adopted purely to reduce the model reported intensity of the plume, and is poor practice.

The Risk Analysis within the report is flawed from more than one perspective, and is commented on within the report.

The proponent's report has not been validated against the relevant BOM history of data at Shellharbour Airport. Plume intensity is at its greatest with ambient winds below 5 kts, which the proponent's report confirms is 42.9% of the time.

The proponent's report has not been reconciled against the Jacobs Technical Memo on engineering modifications to peaking power plants (*Plume Rise and Options to Reduce GT Exhaust Velocity and Temperature, dated 31 August 2018).*

It is CASA's responsibility to set the Critical Plume Velocity and Critical Plume Height, taking into account paras 2.1.2, 2.1.4 and 2.1.5 in AC 139-05(3).

CASA has a Duty of Care to ensure the proponent applies due diligence and transparency in conducting this Aeronautical Impact Assessment.

# Recommendations:

1. CASA to determine the appropriate Critical Plume Velocity for the correct assessment of risk to the safety of aviation, taking into account the Visual Flight Rules (VFR) aircraft affected by the plume, their location in the circuit, and the aircraft aerodynamic situation.

2. CASA to determine the appropriate Critical Plume Height(s) for the assessment taking into account Visual Flight Rules (VFR) aircraft affected by the plume, their location in the circuit, and the aircraft aerodynamic situation

3. Energy Australia to present a transparent plume rise assessment with clarity of specifically what is being assessed, how it is being assessed, and all assumptions made.

4. Energy Australia to validate model output data used for the assessment, and report the accuracy of that data as part of the assessment.

5. Energy Australia to reconcile any difference between final assessment findings and those presented by Jacobs in their technical memo on peaking power plant engineering modifications.

6. Energy Australia to conduct a valid risk assessment.

John Cleary
Chairman, AOPA Shellharbour Airport Committee.

Relevant bio

B Sc (tech)
Australian Advanced Aerobatic Champion 1996
Retired Chairman Australian Historical Flying Museum
Founding President Illawarra Flyers
Retired President BHP Steel Coated Products

January 20, 2020

Appendices A to E attached

**Glossary of Terms:**

| | |
|---|---|
| 7HA.01 | GE's heavy duty gas turbine (https://www.ge.com/power/gas/gas-turbines/7ha) |
| AC 139-05(3) | CASA's advisory circular for conducting plume rise assessments |
| Aeroderivative gas turbine | Gas turbine electricity generators based on aviation jet engines (https://www.ge.com/power/services/aeroderivative-gas-turbines) |
| aft | towards the rear |
| AOA | Angle of Attack |
| Critical AOA | The angle of attack at which the aircraft wings stall<br>stall = lose lift causing the aircraft to stop flying<br>Separation can start to occur over a range of about 2 to 4 degrees of AOA prior to the critical AOA. At the beginning, the airflow separation is toward the trailing edge (back edge) of the wing and this separation point moves progressively forward as the AOA increases further. |
| AOPA | Aircraft Owners and Pilots Association |
| BOM | Bureau of Meteorology |
| CASA | Civil Aviation Safety Authority |
| CASR | Civil Aviation Safety Regulations |
| CCGT | Combined Cycle Gas Turbine |
| Convair CV880-M | An American narrow-body four-engined jet airliner |
| CPH | Critical Plume Height - the height used for the plume assessment |
| CPV | Critical Plume Velocity - the plume velocity used for the assessment |
| CSIRO | The Commonwealth Scientific and Industrial Research Organisation |
| fwd | Forward - towards the front |
| G loading | Aircraft load factors are traditionally referred to as G, because of the relation between load factor and apparent acceleration of gravity felt on board the aircraft.<br>G loading increases as the square of the speed<br>A plume vertical gust causes causes the wings to generate more lift than is required to keep the aircraft flying in equilibrium. The wings generate lift and centripital force which causes the aeroplane to accelerate, which in turn causes an apparent increase in the weight of the aeroplane via the centrifugal force. This acceleration is expressed in terms of G<br>The amount of lift that can be developed by a particular wing when set at its critical AOA will depend on its airspeed |
| GA | General Aviation |
| GE | *General Electric* is an American multinational conglomerate |
| IFR | Instrument Flight Rules |
| m/s | metres per second (a measure of velocity or speed) |
| MTOW | Maximum Take off Weight |
| NACA | The National Advisory Committee for Aeronautics (US) |
| Navion GA Aircraft | North American Aviation four place retractable cross country private |

| | |
|---|---|
| | aircraft |
| OCGT | Open Cycle Gas Turbine |
| POH | Pilot Operating Handbook |
| RAPAC | Regional Airspace Proceedures Advisory Committee |
| TAPM | CSIRO's "The Air Pollution Model" |
| TVA | Tennessee Valley Authority - a federally owned corporation in the US |
| VFR | Visual Flight Rules |
| Vo | Operating manoeuvring speed. It is the stall speed at the design airframe G limit. Vo = Vs root Gdesign limit<br>Below Vo, the aircraft will stall before exceeding the aircraft G limit<br>Above Vo, the airframe will be exposed to forces above the design limit prior to the wings stalling |
| Vo(rolling) | Vo(rolling) is a 'rule of thumb' reduction in maximum indicated airspeed to cater for a pilot fully deflecting the controls with the aircraft under load, eg encounter a plume gust while turning downwind.<br>During the turn to downwind, it is likely one wing will stall before the other. This creates different lift and drag on each wing, causing the aircraft to both roll and yaw, leading to autorotation or an incipient spin. |
| Vs | The indicated airspeed at which the aircraft in 'clean' configuration and maximum take-off weight, with idle power setting, will reach the critical angle of attack whilst maintaining straight and level flight. Vary any of these and the indicated airspeed at the stall varies.<br>New stall speed = Vs mutiplied by the square root of the load factor |
| Vsm | Velocity stall manoeuvre. This is the velocity required to stall the wings with the aircraft at that particular G loading<br>The stall acts as a sort of safety valve or safety net which prevents too much lift and therefore too much G being developed at a particular airspeed<br>The velocity of the stall in a manoeuvre (Vsm) equals the velocity of the stall at 1G (Vs), multiplied by the square root of the manoeuvring G (at MTOW).<br>Vsm = Vs root G or, G = (Vsm/Vs)squared |
| Vy | Aircraft best rate of climb indicated airspeed |
| YSHL | Shellharbour Airport |

**Appendices (Attachments):**

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| A2 | | Various aircraft Vy, MTOW CPV Calculations |
| B 1 | | Noel Kruse – Fly Better Lesson 13 |
| B2 | | Barry Schiff – Flying in Turbulence |
| B3 | | Gary Deck – Plane and Pilot article – Understanding Maneuvring Speed |
| C | | Relevant Accident/Incident References |
| C1 | | California Pilots Association Report |
| D | | Relevant Scholarly Works References |
| E | | Other References |