Australian Government
Civil Aviation Safety Authority

Advisory Circular

AC 139-05(0) **JUNE 2004**

GUIDELINES FOR CONDUCTING PLUME RISE ASSESSMENTS

CONTENTS

1. REFERENCES

- Manual of Standards Part 139 – Aerodromes, Chapter 10

2. PURPOSE

2.1 The purpose of this Advisory Circular (AC) is to provide guidance to aerodrome operators and persons involved in the design, construction and operation of facilities with exhaust plumes about the information required to assess the potential hazard from a plume rise to aircraft operations.

2.2 CASA has identified that there is a need to assess the potential hazards to aviation because the vertical velocity from gas efflux may cause airframe damage and/or affect the handling characteristics of an aircraft in flight.

2.3 The stability of an aircraft is especially critical during periods of high pilot workload, such as when the aircraft is being manoeuvred at low altitudes with flaps extended and/or gear down. Typically, this includes the initial take-off climb and the approach to land - when the aircraft is in the vicinity of an aerodrome.

2.4 In some cases, the high efflux temperature or velocity may cause air disturbance at higher altitudes. In this case, CASA also requires an assessment of the potential for the exhaust plume to affect the safe handling of aircraft in other phases of flight.

Advisory Circulars are intended to provide recommendations and guidance to illustrate a means but not necessarily the only means of complying with the Regulations, or to explain certain regulatory requirements by providing interpretative and explanatory material.

Where an AC is referred to in a 'Note' below the regulation, the AC remains as guidance material.

ACs should always be read in conjunction with the referenced regulations

3. STATUS OF THIS AC

3.1 This is the first AC on the subject of plume rise assessments.

4. BACKGROUND

4.1 Exhaust plumes can originate from any number of sources; chimneys; elevated smoke stacks at power generating stations; smelters; combustion sources; a flare created by an instantaneous release from pressurised gas systems all create exhaust plumes to one degree or another.

4.2 Aviation authorities have established that an exhaust plume with a vertical gust in excess of 4.3 metres/second (m/s) may cause damage to an aircraft airframe, or upset an aircraft when flying at low levels.

4.3 Low level flying operations are typically conducted during:

- approach, landing and take-off
- specialist flying activities such as, crop dusting, cattle mustering, pipeline inspection, power line inspections, fire-fighting, etc
- search and rescue operations
- military low-level manoeuvres

4.4 While approach, landing and take-off are normally conducted in the vicinity of an aerodrome, the other low level operations can be conducted anywhere across the country.

4.5 The risk posed by an exhaust plume to an aircraft during low level flight can be managed or reduced if information is available to pilots so that they can avoid the area of likely air disturbance.

4.6 As a result of this, CASA requires the proponent of a facility with an exhaust plume, which has an average vertical velocity exceeding the limiting value (4.3 m/s at the aerodrome Obstacle Limitation Surface (OLS) or at 110 metres above ground level anywhere else) to be assessed for the potential hazard to aircraft operations.

4.7 The stack itself may also need to be assessed and reported as a "tall structure" in accordance with the guidelines provided in AC 139-08.

5. THE ROLE OF THE PROPONENT

5.1 The proponent of a facility that creates an exhaust plume has a legal responsibility and a duty of care to provide details of the facility to CASA so that CASA and aerodrome owners can assess the potential hazards to aircraft safety.

5.2 Proponents of a facility to be located within 15 kilometres of an aerodrome, are to consult the aerodrome operator if that facility includes a combustion source which generates an exhaust plume which has a vertical velocity greater than 4.3 m/s at the height of the OLS.

5.3 Should an aircraft accident or incident be attributed to air turbulence created by a plume - the role of persons and/or organisations associated with the construction and operation of the facility would ultimately be examined by the courts.

5.4 In areas remote from an aerodrome, CASR Part 139 requires the proponent of such facilities to notify CASA if the exhaust plume would have a vertical velocity greater than 4.3 m/s at a height of 110 metres or more AGL.

6. THE ROLE OF THE AERODROME OPERATOR

6.1 CASR Part 139 requires aerodrome operators to notify CASA of any existing or potential obstacles, i.e. any object that infringes or will infringe the aerodrome OLS. This may include the area within 15 kilometres of the aerodrome.

6.2 The "obstacle" referred to in CASR Part 139 does not necessarily have to be a solid object like a building or stack. It can include gaseous efflux which is capable of physical definition or measurement.

6.3 For the purposes of CASR Part 139, the hazardous gaseous efflux is defined as the vertical and horizontal limits of the exhaust plume at which the average vertical velocity reduces to a value of 4.3 m/s.

6.4 Just like a physical penetration of the OLS, the aerodrome operator is required to notify CASA of the details of the exhaust plume, so that CASA can determine if it should be classified as a "hazardous object" under CASR Part 139.

6.5 In the vicinity of major capital city airports (and other leased Federal Airports) the *Airports (Protection of Airspace) Regulations* also apply. Under these regulations, the aerodrome operator has an obligation to notify the Department of Transport and Regional Services (DOTARS) of any potential infringement of the prescribed airspace established for the aerodrome. DOTARS has the power to prohibit, or limit, the erection of a facility with an exhaust plume, which has an average vertical velocity greater than 4.3 m/s at the lower limit of the prescribed airspace.

7. THE ROLE OF THE CIVIL AVIATION SAFETY AUTHORITY (CASA)

7.1 Where there is a potential to impact on aircraft safety, both structural and non-structural elements of a proposal will need to be assessed. This may happen concurrently, or may be undertaken separately where it is likely that the structural elmenent would be critical in it's own right.

7.2 When a proposed facility with potential efflux discharges is assessed for conformance under an aerodrome OLS or PANS-OPS surface, and the airspace is likely to be penetrated by the structure itself, technical details of the discharge rates need not be submitted with the initial notification to CASA and the aerodrome operator.

7.3 On the other hand, when a proposed facility is located under the OLS and PANS-OPS surfaces but its efflux discharges into the OLS or and PANS-OPS surfaces, then technical details of discharge rates etc. should be submitted in conjunction with height details to CASA and the aerodrome operator.

7.4 In areas remote from an aerodrome, when notified of a proposal that has an exhaust plume with a vertical velocity greater than 4.3 m/s **or** at a height of 110 metres or more above ground level, CASA will determine the effect on aircraft safety. In this case, CASA will assess whether or not the exhaust plume should be classified as a hazardous object under CASR Part 139.

7.5 In the case of a solid object, CASR Part 139 provides for its marking and/or lighting so that its shape is delineated and made visible to pilots operating at night, or in reduced visibility conditions. Since this is not feasible for an exhaust plume, CASA will be obliged to consider alternative measures to make sure that pilots are unlikely to encounter air turbulence resulting from vertical plume velocities in excess of 4.3 m/s. Such measures might include:

- amendment to an existing instrument approach and/or departure procedure
- declaration of a Danger Area centred on the source of the plume

7.6 In determining the need for a Danger Area, CASA will consider the severity and frequency of the risk posed to an aircraft which might fly through the plume. This assessment requires plume rise data to be provided as a probability distribution for the height and lateral limit of the critical vertical velocity.

7.7 Since plume rise and lateral dispersion are highly dependent on crosswind and the temperature differential between the plume and ambient air, this assessment requires the use of site specific metrological data throughout the full height of the plume.

8. APPLICATION FOR APPROVALS

8.1 The proponent of a development that will generate an exhaust plume, which may pose a risk to aircraft operations, must provide CASA with sufficient details to make a hazard assessment. The "Application for an Operational Assessment of a Proposed Plume Rise" form at Attachment B can be used for this purpose.

8.2 To date, proponents of these developments have used a number of models to estimate the likely rise and lateral dispersion of the exhaust plume. In the absence of reliable meteorological data, plume rise has often been assessed in still air conditions. Whilst this represents a worst case scenario, the probability of this occurrence in actual weather conditions at the development site is usually quite low.

8.3 Lateral dispersion may similarly have been misrepresented, because these models assume that wind conditions are constant with height. This has often led to an overly conservative estimate of aviation impacts, and in some cases unnecessary restrictions on aircraft operations or even the refusal of the proposal.

8.4 Earlier guidelines set by CASA required consideration of oxygen content and temperature gradient within the plume, however this is no longer the case. Plume assessments to date have demonstrated that temperature and oxygen content quickly regain their ambient levels well before the vertical velocity is reduced to the 4.3 m/s vertical gust threshold.

8.5 This AC sets out the minimum requirements, established by CASA, for the analysis of the vertical rise and dispersion of hot buoyant plumes, and the data presentation requirements for the hazard assessment of the risk posed to aircraft operations.

8.6 Exhaust plumes from minor industries would not normally require the sophistication of "The Air Pollution Model" analysis, as their plumes tend to dissipate within 10 m above the stack height. However, exhaust stacks located within the take-off and approach areas of an aerodrome, and in close proximity to a runway, would still need to be assessed. In this case, standard plume rise equations should be adequate.

9. THE USE OF DIFFERENT PLUME MODELS

9.1 Environmental regulatory authorities routinely require the modelling of plume dispersion from industrial sources as the means of predicting ground level concentrations of air pollutants. A range of software applications, such as "AUSPLUME" (Environment Protection Authority of Victoria) and the "ISC3" (Environment Protection Authority of the USA), have been developed for this purpose. These are relatively simple steady-state mathematical simulations, known as Gaussian plume models.

9.2 These air dispersion models typically incorporate a plume rise module, which calculates the height to which pollutants rise due to momentum and buoyancy. They also include a dispersion model which estimates how they spread as a function of wind speed and atmospheric stability.

9.3 These same models can provide the basis for estimating the potential effects on aviation, by predicting values of vertical velocity as a function of height and lateral dispersion of the plume.

9.4 These models use either ground level or near-surface wind speed data from sources such as an anemometer. In their simplest forms, they assume that wind speed remains constant with height, and there is no wind shear. A "worst case" **plume rise** is typically evaluated by assuming calm conditions while the "worst case" **lateral dispersion** is calculated by assuming that the maximum surface, or near-surface level, wind is constant throughout the height of the plume.

9.5 In reality wind speed and direction can vary considerably with height. As a result, some models attempt to simulate this situation by predicting increasing wind speeds with height, based on a simple power law relationship.

9.6 Since stack plumes may disperse at hundreds of metres above ground level, realistic modelling requires meaningful wind and temperature data throughout the height of the plume.

9.7 More advanced numerical models are now available that enable better representation of atmospheric processes using three-dimensional meteorological fields. Even so, their use has been limited because of the need for site specific meteorological observations.

9.8 The Air Pollution Model (TAPM) is a combined predictive meteorological module, and plume dispersion module, which provides a better alternative for realistic estimates of plume rise and lateral dispersion/displacement. This combination provides a three dimensional grid type simulation model which is most suited in estimating the frequencies of occurrences.

9.9 Where a stack is proposed in the vicinity of an aerodrome, additional meteorological data such as cloud cover and visibility can also assist in determining separate aviation impacts in visual or instrument meteorological conditions. This too can be provided by TAPM.

9.10 TAPM, run in **meteorology mode**, reliably simulates the complex three dimensional behaviour of the atmosphere and predicts site-specific hourly-averaged meteorological data. In the **plume rise mode**, TAPM analyses plume behaviour in the meteorological conditions which were likely to have been experienced at the site.

9.11 CASA considers that TAPM provides the ability for realistic plume modelling where there is no reliable meteorological data available from measurements/observations.

9.12 TAPM software was developed by the CSIRO in 1999 and TAPM v2.0 was released in April 2002. It predicts three-dimensional meteorology and air pollution concentrations.

9.13 TAPM solves approximations of the fundamental equations of the atmosphere to predict meteorology and pollutant concentrations, eliminating the need to have site-specific meteorological observations. Plume behaviour is in turn assessed by reference to the predicted meteorology.

9.14 The Plume Rise Module is used to account for plume momentum and buoyancy effects for point sources. This has been validated against the most commonly used mathematical equations for hot buoyant plumes in both calm and windy conditions. Plume rise is terminated when the plume dissipation rate decreases to ambient levels.

9.15 TAPM is supplied with databases of terrain, vegetation, soil type, sea-surface temperature, and synoptic or large scale meteorological analyses for the period 1997-2001. After the model has run, the user can process the output data in various ways through the interface and analyse the results.

9.16 The model output files include, general meteorology (as hourly averages) and final plume rise centreline heights for the point source(s).

9.17 Output meteorological files can be created in formats suitable for use directly with simpler dispersion models such as, AUSPLUME or ISC3, if required.

9.18 TAPM, in its proprietary form, is only able to model plumes originating from a point source. The algorithms may need to be modified by the user, or an alternative software application utilised, to simulate the plume rise from an area, a line or a volume source.

9.19 TAPM contains a buoyancy enhancement factor to handle overlapping plumes from multiple stacks. Alternatively, overlapped plumes can be modelled using another software, or empirical application, to determine resultant characteristics at the location where the plumes become fully merged. These merged plume characteristics can then be adopted as the source in the TAPM plume rise module.

10. WHAT INFORMATION NEEDS TO BE PROVIDED TO CASA?

10.1 Applicants for a hazard assessment must provide CASA with an electronic data file of all model simulations undertaken for the plume assessment. This will be retained for future reference and/or used for the purpose of a random compliance audit.

10.2 Summary findings suitable for use in the aeronautical assessment should be presented in a written Impact Assessment Report.

10.3 The Impact Assessment Report shall provide a probability distribution for the height and lateral limit of the plume vertical velocity of 4.3 m/s and, where applicable, the probability of activation and duration for each plume event associated with the combustion source(s).

10.4 Detailed guidelines for the use of TAPM and the provision of the data required by CASA for a hazard assessment are included at Attachment A.

10.5 The form to be completed when requesting an Operational Assessment of a Proposed Plume Rise is included on the CASA Forms for Advisory Circulars web page http://www.casa.gov.au/manuals/regulate/casr139/form1247.pdf.

11. WHO BEARS THE COST OF A HAZARD ASSESSMENT?

11.1 Proponents of a facility, which generates an exhaust plume with a vertical velocity greater than 4.3 m/s at the OLS for an aerodrome or greater than 110 metres above ground level, will be required to bear all costs associated with a hazard assessment.

11.2 In the case where the CASA determination requires amendment to Airservices Australia documentation, these costs will also be borne by the proponent.

12. FURTHER INFORMATION

12.1 Further information on plume rise assessments can be obtained from the aerodrome specialists in the Aerodrome Standards Section of CASA. You can contact them on 131 757.

12.2 A list of consultants who specialize in plume rise assessments can also be found on the CASA Web Site at http://www.casa.gov.au/aerodromes/info.htm.

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Attachment A

Using TAPM V2.0 for Plume Rise Assessments

Meteorological and Grid Related User Inputs

The meteorology and grid related model inputs should be the default TAPM inputs, except for the following:

- The modelling period should be a continuous period of at least 5 full years
- The entire horizontal grid domain should be a square region with 25 by 25 (or more) grid points, with a 30 km outer grid and two nested grids at 10 km and 3 km
- A further sub-3km nested grid may be added at the user's discretion provided it is not less than 800 m
- The horizontal domain should be less than 1000 km by 1000 km
- The number of vertical levels should be at least 25
- The grid centre coordinates should be as close to the plume source (or centroid of the sources) as allowed by the resolution of the user interface
- Terrain height database should be extracted from the AUSLIG 9 second DEM database for the region under consideration
- The user may input site-specific geographical data such as, monthly sea surface temperature, land use data and deep soil moisture content, provided it is objectively demonstrated that the data used is more appropriate than the default TAPM data for that region
- Monitored meteorological data may be assimilated into the model provided it is demonstrated to be of high quality and of the appropriate type (e.g. hourly averaged data)
- Users may select the "Rain Processes" option at their own discretion
- Users may select the "Prognostic Eddy Dissipation Rate" option at their own discretion

User Inputs for Single Point Source or Non-Merged Plumes

The guidelines for the point source specifications are as follows:

- The source position should be correctly located with respect to the grid centre
- Buoyancy enhancement should be set to 1

Merged Plumes or Non-Point Sources

TAPM v2.0 is not suitable for the determination of plume rise dynamics for plumes that merge significantly or for plumes that do not originate from point sources (such as a buoyant line source). For such sources, TAPM should be run in meteorology-only mode using appropriate input parameters as outlined in the "Meteorological and Grid Related User Inputs" section on the previous page. The resulting 5 full years of hourly averaged upper level meteorological data should be used in the solution of the TAPM plume rise equations that have been suitably modified by the user to account for the effect of height dependent plume merging or the non-point source nature of the emitted plume. Impact assessment reports must detail the equation modifications and provide appropriate justification for the methods used.

Data Analysis and Presentation

The analysis of plume rise dynamics, and upper level winds, should include data from every hour of the full 5 years of hours modelled. Analysis and presentation should comply with the following:

- Plume dynamics analysis should consider average plume velocities
- Horizontal displacement of the plume centreline, and plume spread about the centreline, should be evaluated as a function of height for each hour using the TAPM generated upper level meteorological wind speed and direction along with the calculated plume spread. Combining this with corresponding average vertical plume velocity (as a function of height for that hour) the regions of space for which all or part of the plume exceeds the critical velocity at any time within the modelled period should be determined. These horizontal regions should be plotted for at least 8 well-spaced heights above the ground ranging from the height of the point source to the maximum height at which the average vertical velocity reduces to the critical vertical plume velocity.
- Horizontal displacement of the plume centreline should be evaluated as a function of height for each hour using the TAPM generated upper level meteorological wind speed and direction. Combining this with corresponding peak vertical plume velocity as a function of height for that hour, the regions of space for which the centreline of the plume exceeds the critical velocity at any time within the modelled period may be determined. These horizontal regions should be plotted for at least 8 well-spaced heights above the ground ranging from the height of the point source, to the maximum height at which the peak vertical velocity falls to the critical vertical plume velocity.
- Wind speed cumulative frequency plots for at least 8 well-spaced heights ranging from the height of the point source to the maximum height at which the peak vertical velocity reduces to the critical vertical plume velocity should be generated and presented in graphical form in the impact assessment report.
- The percentage of the time that wind speeds are less than 0.1, 0.2, 0.3, 0.4 and 0.5 m/s, for at least 8 well-spaced separate heights ranging from the height of the point source to the maximum height at which the peak vertical velocity falls to the critical vertical plume velocity should be generated from TAPM's upper air meteorological data and presented in tabular form in the impact assessment report.

- The heights above the ground at which the average vertical velocity of the plume exceeds the critical vertical velocity for the following percentages of the time should be presented in tabular form in the impact assessment report: 100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1%, 0.5%, 0.3%, 0.2%, 0.1%, 0.05%.
- The maximum, minimum and average heights above the ground at which the average vertical plume velocities exceed the critical vertical velocity should be presented in tabular form in the impact assessment report.