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Australian Government
Civil Aviation Safety Authority

Advisory Circular

AC 139-05(0) OCTOBER 2003

GUIDELINES FOR PLUME RISE ASSESSMENTS

CONTENTS

1. REFERENCES

Regulations 139.350, 139.360 and 139.370 of the *Civil Aviation Safety Regulations 1998* (CASR)

Part 139-Aerodromes

2. PURPOSE

CASA has identified the need to assess the potential hazard to aviation where the vertical velocity from gas efflux may cause airframe damage and/or affect the handling characteristics of an aircraft in flight.

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

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

3. STATUS OF THIS ADVISORY CIRCULAR

This is the first Advisory Circular (AC) on the subject of plume rise assessments.

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

4. GENERAL

4.1 Airworthiness authorities have established that a vertical gust in excess of 4.3 metres/second (m/s) may cause airframe damage to an aircraft at critical stages of flight, e.g. when approaching to land with flaps extended.

4.2 CASA therefore requires that an exhaust plume which has an average vertical velocity exceeding the limiting gust value of 4.3 m/s at the aerodrome OLS or at 360 feet AGL to be assessed as a potential hazard to aircraft operations.

4.3 The exhaust plume typically originates from chimneys or elevated stacks at power generating stations, smelters and similar combustion sources or as a flare created by an instantaneous release from pressurised gas systems.

4.4 The purpose of this AC is to provide guidance for aerodrome operators and for persons involved in the design, construction and operation of such facilities about the information required to assess the potential hazard to aircraft operations.

5. WHY REPORT

5.1 The risk posed by an exhaust plume to aircraft safety during low level flying operations can be managed or mitigated if information is provided to pilots so that they can avoid the area of likely air disturbance.

5.2 Low level flying operations are typically conducted during:

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

5.3 While the first of these categories are normally conducted in the vicinity of an aerodrome, the other low level operations can be conducted anywhere across Australia.

5.4 The proponent of a facility which creates an exhaust plume has both a legal responsibility and a duty of care to provide details so that aviation authorities may assess the potential hazard to aircraft safety.

5.5 The stack itself may need to be reported as a “tall structure” in accordance with the guidelines provided in CAAP 89W-2(0).

5.6 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 the courts would examine operation of the facility.

6. AVIATION REGULATIONS

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 includes 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 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 OLS.

6.5 The aerodrome operator is 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.

6.6 In the vicinity of major capital city and other leased federal airports the *Airports (Protection of Airspace) Regulations* apply. Under these regulations, the aerodrome operator has 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.

6.7 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.

6.8 These measures allow CASA to assess whether the exhaust plume should be classified as a hazardous object under CASR Part 139.

7. HAZARDOUS OBJECT IDENTIFICATION

7.1 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.

7.2 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.

7.3 Such measures might include:

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

7.4 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.

7.5 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 because the critical plume rise velocity will exceed 4.3 m/s at the OLS associated with an aerodrome at or above 360 feet AGL, must provide CASA with sufficient details to make a hazard assessment.

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. While this represents a worst case possibility, 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.

8.4 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.

8.5 Earlier guidelines set by CASA required consideration of oxygen content and temperature gradient within the plume but 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.

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

8.7 Exhaust plumes from minor industries would not normally require the sophistication of The Air Pollution Model (TAPM) 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, and in close proximity to a runway would still need to be assessed. In this case, standard plume rise equations should provide adequate accuracy.

9. 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 (EPA Victoria) and ISC3 (USEPA), 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, and 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 estimation of potential aviation impacts by predicting values of vertical velocity as a function of height and lateral dispersion (or displacement) 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 form they assume that wind speed remains constant with height and there is no wind shear. A "worst case" plume rise scenario 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 the ground, 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 now provides a better alternative for realistic estimates of plume rise and lateral dispersion/displacement. The 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.

10. THE AIR POLLUTION MODEL (TAPM)

10.1 The 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.

10.2 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.

10.3 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.

10.4 Plume rise is terminated when the plume dissipation rate decreases to ambient levels.

10.5 TAPM is supplied with databases of terrain, vegetation and 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.

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

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

10.8 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, line or volume source.

10.9 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.

11. WHAT INFORMATION NEEDS TO BE PROVIDED?

11.1 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. Summary findings suitable for use in the aeronautical assessment should be presented in a written report.

11.2 This 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).

11.3 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.

12. WHO BEARS THE COST OF A HAZARD ASSESSMENT?

12.1 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 at 360 feet AGL will be required to bear all costs associated with a hazard assessment.

12.2 In cases where the CASA determination requires Airservices Australia to amend its internal procedures and/or amend information published for pilots in the AIP caused by the hazard, these costs will also be borne by the proponent.

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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 (above). 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.