Disc Log Reference: 011

Information Released under Environmental Information Regulations

Subject: Contrails

Date Released: 25/9/2013

Summary of request:
Could you please tell me the relative humidity percentage needed to form short lived contrails and the percentage needed to make those contrails persist in the sky for hours.

Information released:
Contrails are formed when hot aircraft exhaust emissions mix with cool, moist ambient air in the upper troposphere. Traditional forecasting methods for predicting the presence of contrails have used the tephigram, a tool for plotting the atmospheric temperature profile. Empirical evidence was used to add lines to the tephigram, known as MINTRA lines. Two lines were used to indicate the potential for short-lived and persistent contrails. Moving along the temperature profile vertically up through the atmosphere, the point at which the profile first crosses the MINTRA line indicates the base of the layer in which contrails may form. For the second MINTRA line, this similarly indicates the base at which persistent contrails may form. Continuing vertically up through the atmosphere, if the temperature profile recrosses the MINTRA lines then this indicates the levels above which contrails are not expected to form or persist. This method implicitly includes the effect of relative humidity, but is explicitly determined as a critical temperature as a function of pressure alone.

Research into contrail formation has further indicated that contrails form in air that is super-satured and that contrails can persist for several hours if the air is super-saturated with respect to ice (Haywood et al., 2009). This means that the relative humidity of the air is above 100% and so the presence of particles in the aircraft exhaust emissions immediately provides a source of condensation nuclei on which the water in the super-saturated air can condense and become visible. If the temperature is above a critical value, the condensation forms as ice crystals and it is these that are more likely to persist in the atmosphere.

The critical temperature for contrail formation is given by the Schmidt-Appleman criterion and depends on pressure, humidity and temperature, as well as engine characteristics (Radel and Shine, 2007).

Persistence of contrails is also strongly influenced by other factors, such as wind and wind shear at the level of the contrail formation. Strong winds will cause contrails to be rapidly displaced from the area of formation and gradually disperse. Wind shear can result in turbulence that disperses contrails rapidly.

So the answer to the question is that short-lived contrails tend to form in conditions of super-saturation (RH>100%) with respect to water and persistent contrails tend to form in conditions of super-saturation (RH>100%) with respect to ice.

References:
Haywood, J. M., R. P. Allan, J. Bornemann, P. M. Forster, P. N. Francis, S. Milton, G. Radel, A. Rap, K. P. Shine, and R. Thorpe (2009), A case study of the radiative forcing of persistent contrails evolving into contrail-induced cirrus, J. Geophys. Res., 114, D24201, doi:10.1029/2009JD012650.

Radel, G. and Shine, K.P. (2007), Evaluation of the use of radiosonde humidity data to predict the occurrence of persistent contrails, Q. J. R. Meteorol. Soc. 133: 1413–1423, DOI: 10.1002/qj.128