CONFERENCE ON AVIATION AND ALTERNATIVE FUELS

Rio de Janeiro, Brazil, 16 to 18 November 2009

Agenda Item 1: Environmental sustainability and interdependencies

ADDITIONAL LOCAL AIR QUALTIY BENEFITS FROM SUSTAINABLE ALTERNATIVE FUELS FOR AIRCRAFT

(Presented by the Secretariat)

SUMMARY

While the primary benefit for developing sustainable alternative fuels for aircraft is their potential to reduce lifecycle greenhouse gas (GHG) emissions, the feedstocks envisioned to be used for these alternatives will result in fuels that are very low in sulphur. Reduction of the sulphur content of fuels has been a proven method to improve local air quality as a result of lower sulphur oxides (SO_x) and particulate matter (PM) emissions.

The conference is invited to approve the conclusions and recommendations in paragraphs 5 and 6.

1. INTRODUCTION

1.1 As explained in CAAF/09-IP/06, the use of sustainable alternative fuels offers the potential for a reduction in GHG emissions. Reducing the levels of sulphur in jet fuel may provide air quality benefits from reduced emissions of sulphur oxides (SO_x) and particulate matter (PM).

2. FUEL SULPHUR CONTENT

2.1 Removing sulphur from conventional jet fuel to produce a low sulphur jet fuel will significantly reduce PM and SO_x emissions from aircraft. Currently, jet fuel has a specification maximum of 3,000 ppm for sulphur; however, jet fuel in the market has a lower sulphur content. Worldwide surveys conducted during 2007 found that annual weighted average jet fuel sulphur content ranged from 321-800 ppm[1]. Hydrodesulphurization, which could be applied to remove the fuel sulphur, is a common process in petroleum refineries, and low sulphur diesel fuel is already widely used internationally. Low sulphur jet fuel has a sulphur content less than 15 ppm.

[1] Taylor, W. F., *Survey of Sulfur Levels in Commercial Jet Fuel*, CRC Aviation Research Committee of the Coordinating Research Council, February 2009, Alpharetta, GA

2.2 The reduction of emissions as a result of fuel sulphur removal has been demonstrated in cars, trucks, and other vehicles as the sulphur content of diesel fuel has been significantly reduced in several regions[2]. For example, the E.U., Japan, and U.S. have reduced the sulphur content of diesel fuel in recent years. With these changes SO_x emissions have been virtually eliminated, which, as will be explained in Paragraph 3, results in a significant reduction in secondary PM and volatile primary PM emissions.

2.3 The hydrodesulphurization process which is used to reduce the sulphur content of jet fuel does result in minor increases in refinery GHG emissions. Also, lower sulphur emissions at cruise altitudes may increase global warming impacts, since SO_x in the upper atmosphere reflects solar radiation, thus reducing overall radiative forcing. The interdependencies between air quality benefits and increased GHG emissions should therefore be considered when planning to reduce the sulphur content of conventional jet fuel.

3. PARTICULATE MATTER

3.1 Particulate matter (PM) from fuel combustion is a mixture of microscopic solids, liquid droplets, and particles with solid and liquid components suspended in air. Solid particles, such as soot or black carbon, are referred to as non-volatile particles. Volatile PM is comprised of inorganic acids (and their corresponding salts, such as nitrates and sulphates), and organic chemicals from incomplete fuel combustion.

3.2 PM is commonly classified according to particle size. Particles smaller than 2.5 micrometers, characterized as $PM_{2.5}$, are commonly referred to as fine particles. Aircraft emissions are comprised primarily of ultra fine ($<PM_{0.1}$) particles[3].

3.3 Fuel combustion also results in gaseous pollutant emissions, notably nitrogen oxides (NO_x), sulphur oxides (SO_x), as well as unburned hydrocarbons. These pollutants are referred to as secondary PM precursors because they are transformed in the atmosphere into aerosol PM. Secondary PM formation, which results from complex chemical reactions in the atmosphere and/or particle nucleation processes, can produce either new particles or add to existing particles. Examples of secondary particle formation include:

a) the conversion of sulphur dioxide (SO_2), which is produced by oxidation of the sulphur in fossil fuels, to sulphuric acid (H_2SO_4) vapour, which then forms droplets as the sulphuric acid condenses due to its low vapour pressure. The resulting sulphuric acid aerosol can further react with gaseous ammonia (NH_3), in the atmosphere to form various particles of sulphate salts (e.g., ammonium sulphate $(NH_4)_2SO_4$);

b) the conversion of nitrogen dioxide (NO_2) to nitric acid (HNO_3) vapour that interacts with PM in the atmosphere, and reacts further with ammonia to form ammonium nitrate (NH_4NO_3) particles; and

[2] U. S. Environmental Protection Agency, *National Clean Diesel Campaign*, http://www.epa.gov/otaq/diesel/index.htm, September 2009.

[3] Transportation Research Board of the National Academies, Airport Cooperative Research Program, *Research Needs Associated with Particulate Emissions at Airports*, ACRP Report 6, Washington, D.C. 2008.

c) reactions involving gaseous volatile organic compounds (VOC), yielding condensable organic compounds that can also contribute to atmospheric particles, forming secondary organic aerosol particles.

3.4 According to a recent analysis of the impacts of aviation emissions on human health[4], primary PM emissions are responsible for 13% of total PM impacts. Secondary PM is much more significant with sulphur-related PM emissions responsible for 33% and NO_x-related PM emissions responsible for 54%. With low sulphur jet fuel, SO_x emissions would be significantly reduced, which in turn would result in a significant reduction in secondary PM. Overall, volatile primary PM emissions are reduced due to reduced fuel sulphur content. Hydrodesulphurization causes other fuel modifications that also reduce non-volatile PM emissions.

3.5 Our present understanding of PM pollution is insufficient to fully evaluate the magnitude of health and environmental effects of exposure. However, indications are that the size of PM is a significant factor. Coarse particles can be inhaled but tend to remain in the nasal passage. Smaller particles are more likely to enter the respiratory system. Health studies have shown a significant association between exposure to fine and ultra fine particles and premature death from heart or lung disease. Fine and ultra fine particles also have been linked to effects such as cardiovascular symptoms, including cardiac arrhythmias and heart attacks, and respiratory symptoms such as asthma attacks and bronchitis. These effects can result in increased hospital admissions, emergency room visits, absences from school or work, and restricted activity days. Individuals that may be particularly sensitive to fine particle exposure include people with heart or lung disease, older adults, and children[5].

3.6 Standard setting organizations specify requirements that jet fuel must meet for physical properties, chemical content, contaminant limits, and overall performance requirements. To limit PM and SO_x fuel combustion emissions, fuel standards have maximum limits on the sulphur content of fuels. Annex 16 to the Convention on International Civil Aviation, Volume II (Aircraft Engine Emissions) does not set standards for these emissions in particular since they are primarily a result of the composition of the fuel rather than engine technology.

4. LOCAL AIR QUALITY BENEFITS

4.1 The feedstocks used to produce sustainable alternative fuels for aircraft do not contain sulphur, thus making these fuels inherently free of sulphur. Using these fuels results in the near total reduction of SO_x and primary PM emissions compared to conventional jet fuel. They also reduce secondary PM substantially.

5. CONCLUSIONS

5.1 The conference is invited to:

a) conclude that sustainable alternative fuels for aircraft may provide local air quality benefits in addition to their lifecycle GHG emissions benefits; and

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[4] Brunelle-Yeung , E., *The Impacts of Aviation Emissions on Human Health through Changes in Air Quality and UV Irradiance* **,** Thesis, Master of Science in Aeronautics and Astronautics, Massachusetts Institute of Technology, Boston, MA, May 2009.

[5] U. S. Environmental Protection Agency, *Review of the National Ambient Air Quality Standards for Particulate Matter; Policy Assessment of Scientific and Technical Information*, http://www.epa.gov/ttn/naaqs/standards/pm/data/pmstaffpaper_20051221.pdf, December 2005.

b) acknowledge the interdependencies between the removal of sulphur from conventional aviation fuels and the climate impacts of aircraft emissions;

6. RECOMMENDATIONS

6.1 The conference is invited to recommend that:

a) States take into account the local air quality benefits associated with the use of sustainable alternative fuels for aircraft when making policy decisions on their use; and

b) ICAO further explore the environmental benefits and trade-offs of alternative fuels with reference to local air quality.