COMMITTEE ON AVIATION ENVIRONMENTAL PROTECTION

SIXTH MEETING

Montreal, 2 to 12 February 2004

Agenda Item 1: Review of proposals relating to aircraft engine emissions, including the amendment of Annex 16, Volume II

NO_x STRINGENCY CONSIDERATIONS

(Presented by ICCAIA)

SUMMARY

The FESG economic analysis does not seem to support the economic reasonableness of increased stringency at this time, but ICCAIA accepts that it might be reasonable to increase NO_x stringency enough to encourage market-driven incorporation of the best proven low NO_x combustor technology in current and near term products. If CAEP members decide that a new NO_x standard is appropriate, the most reasonable and timely approach would be a stringency increase of 10%, becoming effective in 2008. An increase of 15% could be a disincentive to make near term improvements in current products. It would be less cost effective, entail higher risks of failure, and in some cases require manufacturers to incorporate technology that has not yet been proven.

Action by the CAEP is in paragraph 2.

1. TECHNOLOGY STATUS

1.1 As indicated in CAEP/6-WP/4, while no revolutionary technologies have been developed since CAEP/4, there has been continued evolutionary technology progress to further optimize rich-burn combustors based on an increasing body of design experience and the development and application of improved analytical design tools.

1.2 Recent new engine designs have been certificated with NO_x margins from 7 to 30% relative to the CAEP/4 standard that is effective as of January 2004. These results have shown that while the

CAEP/4 standard can be met with significant margin in some engine applications, it is particularly challenging for new engines in the highest range of thrust and pressure ratio. For example, the highest thrust engine in the WG3 Current Production database (CAEP/6-WP/5), which was certificated in 2000, has only 7% margin to CAEP/4. The engine uses a rich dome dual annular combustor with the latest low NO_x features. The high engine pressure ratio and bypass ratio that make the engines in this class exceptionally fuel efficient and quiet also make the task of reducing NO_x most challenging. Other new high pressure-ratio engines are also close to the CAEP/4 requirement as evidenced by CAEP/6-WP/5 (production database).

2. POTENTIAL BENEFIT OF INCREASED STRINGENCY BASED ON EVOLUTIONARY TECHNOLOGY

2.1 Although recent technology progress has not been revolutionary, a modest increase in NO_x stringency might provide significant environmental benefit because it would create a market incentive for manufacturers to further develop and incorporate the best in proven low emissions features into newly manufactured engines. For example, the WG3 Current Production database (CAEP/6-WP/5) shows that 33% of current production engine models would fail to meet a 10% reduction in NO_x relative to the CAEP/4 standard. By comparison, only 16 to 17% of engine models then in production failed previous increases in stringency at CAEP/2 and CAEP/4. Those figures only consider the number of engine models affected. In fact, in following a family plan, nearly 50% of the individual engines that are currently manufactured would be affected because the highest thrust models of the most popular engine families (e.g. CFM56 and V2500) have less than 10% margin to the CAEP/4 standard.

2.2 CAEP/6-WP/4 points out that driven by market pressures, manufacturers have been proactive in addressing future standards through introduction of proven technology. As an example, even though there is not a formal production cut-off requirement for the CAEP/4 standard that takes effect in 2004, there is only one current engine model in production that will not meet CAEP/4. All of the other affected models have either ceased production, or have been modified to meet the new standard.

3. ACCELERATING STRINGENCY TO INCREASE ENVIRONMENTAL BENEFITS

3.1 As summarized in Figure 1, FESG cost-benefit analysis shows that the benefits of a 10% increase in stringency effective in 2008 are as great as those of a 25% increase effective in 2012. A 10% increase in stringency is close to the best capability demonstrated with current combustor technology over the whole range of engine thrust and pressure ratio. The earliest practical implementation date is 2008, recognizing that manufacturers require at least three years lead time prior to engine certification for engine development. Thus, a near term 10% NO_x stringency increase is more beneficial than a larger long term NO_x stringency increase, and is consistent with the ICAO principles of technological feasibility and environmental benefit.

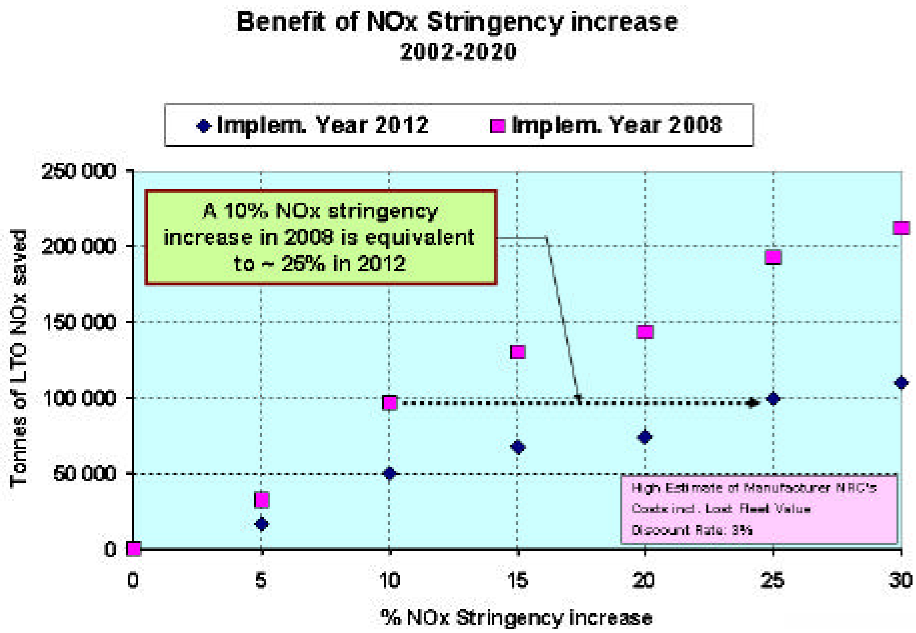

Figure 1. Benefits of stringency options

4. SETTING A SAFE STRINGENCY LEVEL TO MAXIMIZE ENVIRONMENTAL RETURN ON INVESTMENT

4.1 As summarized in Figure 2, the greatest benefit per unit cost is achieved with a 10% increase in stringency, whether the stringency is effective in 2008 or 2012. Even though benefits may increase at a higher stringency level, cost will be substantially increased at 15% or more because of the need to develop new, unproven technology for some applications; but there are risks. A review of Tables 4.1 in the FESG report on the "Economic Analysis of NO_x Emissions Stringency Options" (CAEP/6-IP/13) indicates that at a stringency level of 15% a large percentage of in-production engines, many incorporating best available technology, will need to be modified with "newer", not yet certified technology (TL5a), or in some instances require technology well beyond current best practice (TL5b). Since these technologies are unproven, manufacturers may need to reduce flight worthiness margins relative to the required operating envelope to achieve NO_x emissions requirements. Additionally, as described in the Emissions Workshop presented to the CAEP Steering Group, higher NO_x stringency levels could also lead to tradeoffs for increased CO, HC and CO_2. Because of the expense, reduced margins and potential tradeoffs, there will be less incentive for manufacturers to incorporate low NO_x features in current products if stringency of 15% or above is adopted. Thus, 10% is the most economically reasonable option under consideration.

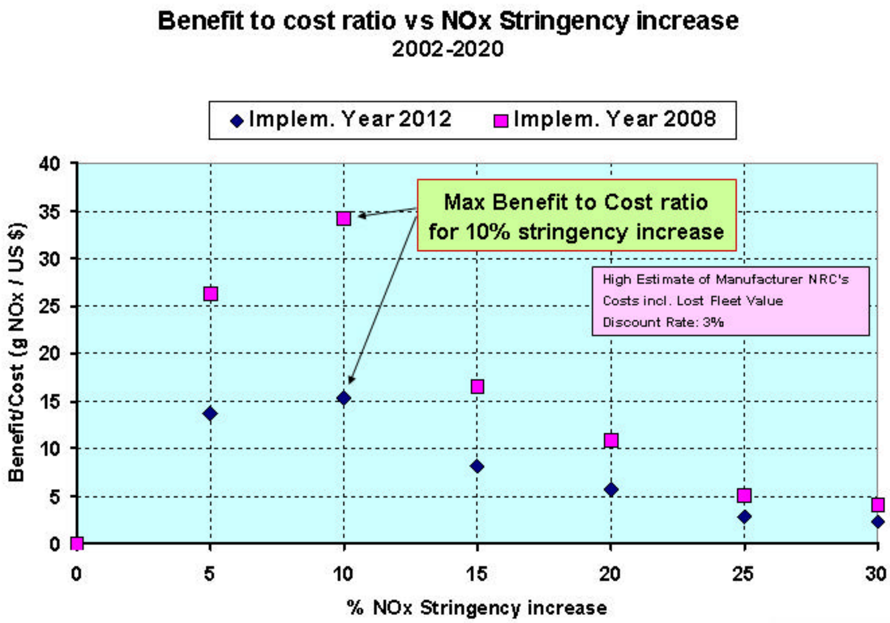

Figure 2. NO_x stringency increase

5. THE HIGH COST OF REDUCING AVIATION EMISSIONS

5.1 Based on the FESG analysis (CAEP/6-IP/13), even with the assumption that there is no loss in fleet value, and using low estimates of manufacturer non-recurring costs, the marginal cost to reduce NO_x is estimated to exceed $20,000/tonne. This is significantly more expensive than typical costs in other industries.

6. MANAGING FUTURE EMISSION TECHNOLOGIES

6.1 Revolutionary technologies employing lean direct injection (LDI), lean pre-mixed pre-vaporized (LPP) and optimized rich-quench-lean (RQL) are under development within the manufacturers and within the research establishments. These technologies are not currently at a sufficiently high level of readiness to guarantee success in near term products, and therefore compliance dates assumed by FESG might be overoptimistic. Additionally, trade-offs must be kept in mind when assessing new standards based on future technological developments. It should be remembered that introduction of DAC II combustors in the CFM56 engines was done at the expense of increased fuel burn/CO_2, CO, HC, reduced combustor life and airstart altitude. Development progress on these technologies will be tracked under the proposed long term technological goals review process (CAEP/6-IP/4), and when airworthiness has successfully been demonstrated, these technologies can serve as the basis for future increases in NO_x stringency. Certification standards impact products entering service and these products must be flight-worthy. Thus, these standards cannot be based on research goals. This point was recognized by Working Group 3 in developing the following assumption in support of the FESG analysis of NO_x stringency options:

> "In the context of technology for improved technology performance to be used as part of the basis for ICAO standard setting, technological feasibility refers to any technology, demonstrated to be safe and airworthy, and available for application over a sufficient range of newly certificated aircraft".

6.2 Given the challenge of meeting the recently implemented CAEP/4 standard and the evolutionary nature of recent technology progress, there is no technical justification for a large reduction in the ICAO NO_x standard at this time. Technology development in order to attain the higher stringency levels is the subject of long-term technology goals. An unintended consequence of setting standards beyond the reach of current and near-term technologies could be the disincentive to make interim solutions.

7. ACTION BY THE CAEP

7.1 If CAEP members decide that a new NO_x standard is appropriate, the most reasonable and timely approach would be a stringency increase of 10%, becoming effective in 2008.

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