Doc 10012, CAEP/9

INTERNATIONAL CIVIL
AVIATION ORGANIZATION

COMMITTEE ON AVIATION ENVIRONMENTAL PROTECTION

NINTH MEETING

Montréal, 4–15 February 2013

REPORT

Approved by the Committee on Aviation Environmental Protection and published by decision of the Council.

The views expressed in this report should be taken as advice of a body of experts to the Council but not as representing the views of the Organization.

The Supplement to the report indicates the action taken on the report by the Council.

MONTRÉAL 2013

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INTERNATIONAL CIVIL AVIATION ORGANIZATION

NINTH MEETING OF THE
COMMITTEE ON AVIATION ENVIRONMENTAL PROTECTION (CAEP)

Montréal, 4 to 15 February 2013

SUPPLEMENT NO. 1

1. The Council, at the sixth meeting of its 199th Session on 31 May 2013, took action on the recommendations of the ninth meeting of the Committee on Aviation Environmental Protection (CAEP/9), as set forth hereunder.

2. RECOMMENDATIONS FOR AMENDMENT OF STANDARDS AND RECOMMENDED PRACTICES AND PROCEDURES (RSPP)

2.1 Recommendation 2/1, page 2-4
Recommendation 3/1, page 3-4
Recommendation 3/5, page 3-14
Recommendation 3/8, page 3-21

2.2 The Council noted that the Air Navigation Commission had made a preliminary review of the above recommendations and agreed that they should be referred to Contracting States and international organizations. Following receipt of comments, the Commission will conduct a detailed review and will then present its recommendations for action to the Council.

3. RECOMMENDATIONS OTHER THAN FOR STANDARDS AND RECOMMENDED PRACTICES AND PROCEDURES

3.1 The Secretary General will arrange for any follow-up action in respect of all approved recommendations as indicated in the action taken hereunder.

Report Reference		Action by Council (C) or Air Navigation Commission (ANC)	Recommendation Title and Action Taken
Recommendation No.	Page No.		
1/1	1-14	C	**Acceptance of the Traffic and Fleet Forecasts** Approved the recommendation and requested the Secretary General to take the necessary action.
2/2	2-7	C	**Amendments to the Environmental Technical Manual — Volume II** Approved the recommendation and requested the Secretary General to take the necessary action.
2/3	2-12	C	**Publication of the CO_2 Standard Certification Requirement as an ICAO Circular** Approved the recommendation and requested the Secretary General to take the necessary action.
2/4	2-19	C	**Publication of a new ICAO Manual on operational opportunities to reduce fuel burn and emissions** Approved the recommendation and requested the Secretary General to take the necessary action.
2/5	2-20	C	**Publication of a new ICAO manual on Environmental Assessment Guidance for Proposed Air Traffic Management Operational Changes** Approved the recommendation and requested the Secretary General to take the necessary action.
2/6	2-22	C	**Publication of the "Independent Experts Operational Goals Group (IEOGG) report on mid-term and long-term operational goals for fuel** Approved the recommendation and requested the Secretary General to take the necessary action.

Report Reference		Action by Council (C) or Air Navigation Commission (ANC)	Recommendation Title and Action Taken
Recommendation No.	Page No.		
2/7	2-24	C	**Environmental Benefits from Aviation System Block Upgrades (ASBUs)** Approved the recommendation and requested the Secretary General to take the necessary action.
3/2	3-4	C	**Publication of the Environmental Technical Manual, Volume I — *Aircraft Noise*** Approved the recommendation and requested the Secretary General to take the necessary action.
3/3	3-8	C	**Acceptance of the CAEP/9 noise technology goals** Approved the recommendation and requested the Secretary General to take the necessary action.
3/4	3-8	C	**Publication of the report of the second Noise Technology Independent Expert Panel** Approved the recommendation and requested the Secretary General to take the necessary action.
3/6	3-14	ANC	**Consideration of Amendments to Annex 1** Approved the recommendation and requested the Secretary General to take the necessary action.
3/7	3-14	ANC	**Consideration of Amendments to Annexes 1, 6, 7 and 8** Approved the recommendation and requested the Secretary General to take the necessary action.

Report Reference		Action by Council (C) or Air Navigation Commission (ANC)	Recommendation Title and Action Taken
Recommendation No.	Page No.		
3/9	3-21	C	**Refrain from the introduction of operational restrictions** Approved the recommendation and requested the Secretary General to take the necessary action.
5/1	5-3	C	**Revised CAEP work programme** Approved the recommendation and requested the Secretary General to take the necessary action.

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REPORT OF THE NINTH MEETING OF THE COMMITTEE ON AVIATION ENVIRONMENTAL PROTECTION (CAEP) (2013)

LETTER OF TRANSMITTAL

To: President of the Council

From: Chairman, Committee on Aviation Environmental Protection (CAEP) (2013)

I have the honour to submit the report of the ninth meeting of the Committee on Aviation Environmental Protection (CAEP) which was held in Montréal, from 4 to 15 February 2013.

Chairman

Montréal, 15 February 2013

LIST OF RECOMMENDATIONS*

* Recommendations annotated "RSPP" relate to proposals for amendment of Standards, Recommended Practices and Procedures for Air Navigation Services or guidance material in an Annex.

COMMITTEE ON AVIATION ENVIRONMENTAL PROTECTION (CAEP)

NINTH MEETING

Montréal, 4 to 15 February 2013

HISTORY OF THE MEETING

1. DURATION

1.1 The ninth meeting of the Committee on Aviation Environmental Protection (CAEP) was opened by the First Vice President of the Council of ICAO, in Montreal, at 0930 hours on 4 February 2013. The meeting ended on 15 February 2013.

2. ATTENDANCE

2.1 The meeting was attended by members and observers nominated by 28 Member States and 9 international organizations, as well as by advisers and others as shown in the list below:

Members	Advisers	State
C. Fernández	G. Hernán	Argentina
S. Rosengren	T. Rees	Australia
J. Silveira	A. Filizola R. Da Silva	Brazil
G. Bourgeois	W. Bailey S. McKibbon Y. Cousineau F. Viele S. Mallet T. McDonald A. Simpson L. Aalders B. Mehta S. Rogers S. Sankey	Canada
L. Xiao Jie M. Xiaoning Ma (Alternate)	Ma Xiaoning Ning S. Yang S. Wai Ip	China
H. Eladawy	A. Abdel Ghafar	Egypt

Members	Advisers	State
P. Langumier	J.-P. Dufour B. Hamon B. Adoléhoumé A. Malige	France
F. Pleines-Schmidt	J. Bode F. Wetzel	Germany
L. Gupta	I. Chakraborty	India
D. Ercolani (Alternate) F. Sepe (Alternate)	F. Sepe	Italy
Y. Ishii	H. Yoshimura T. Ishii H. Ishii H. Fujiwara S. Machida H. Ohtake K. Funabiki T. Hosokawa H. Moriai	Japan
M. Lunter		Netherlands
T. Reklewski		Poland
Y. Khaletskiy (Alternate)	A. Mirzoyan V. Kopiev O. Kartyshev N. Malokova	Russian Federation
T. Kah Han	K. Teoh K.Wei Jie S. Leman Z.X.Chan	Singapore
S. Mugeri		South Africa
A. Benito (Alternate)		Spain
K. Keldusild	M. Johansson M. Hankanen T. Sjöberg	Sweden

Members	Advisers	State
U. Ziegler C. Marthe (Alternate)	T. Rindlisbacher	Switzerland
O. Zaporozhets	O. Grasko S. Boichenko C. Mykola	Ukraine
A. Simmons R. Worth (Alternate)	R. Worth D. Rhodes D. Lee R. Clarkson I. Jopson	United Kingdom
L. Maurice	C. Holsclaw K. Welsh J. Marks J. Skalecky J. Hileman G. Fleming M. Samulski R. Iovinelli D. Huff L. Brown	United States

Observers	Advisers	State/Organization
V. Filippou		Greece
Y. Gona	R. Bagus Riyono I. Septiana Sari E. Prihadi E. Emrizal M. Rozetta	Indonesia
S. Scott		New Zealand
T. Kråkenes	J.E. Ditlevsen	Norway
Ö. Sariünal	A. Kisacik S. Albuz	Turkey
M. Al Balooshi	D. Wong	United Arab Emirates

Observers	Advisers	State/Organization
X. Oh	E. Fleuti E. Leavitt K. Preston R. McGill P. Marx C. Damar	ACI
E. Hoeven		CANSO
T. Fenoulhet	W. Franken S. Arrowsmith I. de Lepinay H. Pulles A. Watt T. Elliff C. Eyers	EU
A. Hardeman M. Comber (Alternate)	R. Brown D. Anvid D. Jensen A. Rode D. Plumb N. Young T. Pohle A. J. Singletary M. Adam T. Roetger R. Andrezej	IATA
G. Visèle	R. Lapointe R. Stratton L. Knaapen G. Malaval B. Parry C. Etter D. Brown R. Dudebout E. Cotti	IBAC

Observers	Advisers	State/Organization
P. Madden	J. Bonnet	ICCAIA
	E. Jacobs	
	D. Sepulveda	
	C. Baltas	
	L. Gray	
	K. McCaldon	
	T. Percheron	
	J. Yu	
	T. Oishi	
	K. Iijima	
	A. Bonnet	
	C. Grandi	
	A. Rizzi	
	G. Freire	
	M. Heijl	
	D. Collin	
	O. Penanhoat	
	F. Couillard	
	J.-M. Boiteux	
	H. Gagnon	
	M. Huising	
	D. Lye	
	D. Allyn	
	B. Solaimani	
	P. Bendana	
	L. Riegle	
	A.Kempton	
	O. Husse	
	D. Carnelly	
	M. Vanova	
	K. Goddard	
	P. Lempereur	
	T. Nowaczyk	
	P. de Saint Aulaire	
	M. Majjigi	
	J. Brieger	
T. Johnson	D. Rutherford	ICSA
D. Rutherford (Alternate)	B. Hemmings	
B. Hemmings (Alternate)	M. Zeinali	
R. Brons	K. Hurst	IFALPA
	A. du Bedat	
	C. Couchman	
B. Hackmann (Alternate)		UNFCCC

The meeting was also attended by:

W. M. Vojvodic Vargas, Alternate Representative of Peru on the Council of ICAO
M. Rodmell, Representative of United Kingdom on the Council of ICAO
H. Puempel, Chief, Aeronautical Meteorology Division, WMO

3. OFFICERS AND SECRETARIAT

3.1 Dr. U. Ziegler (Switzerland) was elected Chairman of the meeting and Mr. G. Bourgeois (Canada) was elected Vice-Chairman of the meeting. The Secretary of the meeting was Ms. J. Hupe, assisted by Dr. N. Dickson, Ms. B. Ferrier, Mr. C. Mustapha, Mr. P. Novelli, Mr. T. Tanaka and Mr. T. Thrasher of the Environment Branch, Air Transport Bureau. Also participating in the meeting were Ms. G. Resiak, of the Economic Analyses and Policy Section, Air Transport Bureau; Mr. A. Coutu, Mr. H. Defalque, Mr. M. Fox, Mr. V. Maiolla, Mr. S. da Silva and Mr. G. Ville of the Air Navigation Bureau; and Mr. A. Opolot and Mr. C. Petras of the Legal Bureau.

4. LANGUAGES OF THE MEETING

4.1 Interpretation and translation were provided in Arabic, Chinese, English, French, Russian and Spanish.

5. AGENDA OF THE MEETING

5.1 The Council approved the following agenda for the meeting:

Agenda Item 1: Review of the assessments of the present and future impact of aircraft noise and engine emissions;

Agenda Item 2: Review of technical proposals relating to aircraft engine emissions;

Agenda Item 3: Review of technical proposals relating to aircraft noise;

Agenda Item 4: Alternative fuels

Agenda Item 5: Future work.

6. TERMS OF REFERENCE OF CAEP

6.1 To undertake specific studies, as approved by the Council, related to control of aircraft noise and gaseous emissions from aircraft engines.

6.2 In its work the Committee shall take into account the following:

a) effectiveness and reliability of certification schemes from the viewpoint of technical feasibility, economic reasonableness and environmental benefit to be achieved;

b) developments in other associated fields, e.g. land use planning, noise abatement operating procedures, emission control through operational practices, etc.;

c) international and national programmes of research into control of aircraft noise and control of gaseous emissions from aircraft engines; and

d) the potential interdependence of measures taken to control noise and to control engine emissions.

7. CAEP/9 WORK PROGRAMME

7.1 The Committee's work programme for this cycle was agreed during the CAEP/8 meeting and adjusted during the subsequent Steering Group meetings to accommodate the requests of the 37th Session of the ICAO Assembly. The following tables reflect the updated work programme:

Table 1. CAEP/9 Working Group 1 (Noise Technical) Work programme

Project Number	Short Title	Description
N.01.01	COORDINATION: Technology, operations and goals coordination	Coordinate with other working group Rapporteurs on interdependencies related to technology, operational issues, and goals as well as harmonizing the goal setting process.
N.01.02	COORDINATION: Databases coordination	Coordinate with other working group Rapporteurs on interdependencies related to management and update of noise and emissions databases.
N.01.03	COORDINATION: Environ-mental impacts coordination	Coordinate with other working group Rapporteurs on interdependencies related to environmental impacts, including stringency.
N.01.04	COORDINATION: SST coordination	Coordinate with other working group Rapporteurs on programmes for development of both noise and emissions SARPs for future supersonic aeroplanes.
N.02	Technical issues	Maintain and update Annex 16 V olume I and ETM Volume I.
N.03	NoisedB	Ensure process integrity and data currency of the ICAO noise certification database.
N.04.01	TECHNOLOGY: Monitor research	Monitor and report on the various national and international research programme goals and milestones.
N.04.02	TECHNOLOGY: Technology goals bench-marking	Review progress towards achievement of Technology Goals recommended by IEs for 2018 and 2028.
N.04.03	TECHNOLOGY: new technology	Using the IE process conduct review of new technological advances (e.g. open rotor, geared turbofan, blended wing body, etc.).
N.04.04	TECHNOLOGY: Liaise with other IERs	Build upon work done for other IE reviews.
N.04.05	TECHNOLOGY: IER alignment	Develop common approach on " Realization Factor" and uncertainty estimation for goal setting as well as align goal dates (2020 and 2030).

Project Number	Short Title	Description
N.05.01	SUPERSONIC: SST standards	Investigate adoption of current subsonic noise rules for supersonic Standards and make recommendations as appropriate.
N.05.02	SUPERSONIC: SST monitoring	Monitor, and report on, status of SST projects and expectations for their operation (nature, frequency etc.).
N.05.03	SUPERSONIC: Sonic boom research monitoring	Monitor and report on research to characterize, quantify and measure (including metric) sonic boom signatures and their acceptability while also assisting in promoting and defining such research. Assess the extent of knowledge on sonic boom and decide if it is appropriate to consider drafting Standards for sonic boom.
N.06.01	STANDARDS: Stringency option development	Review and analyze certification noise levels for subsonic jet and heavy propeller-driven aeroplanes. This work will include review of BP database application and content. Based on the analysis, develop a range of stringency options up to 10-12 dB cumulative margin relative to Chapter 4. The stringency options should take into account the margins at each of the 3 c ertification points. The stringency options shall apply to new aircraft types only, starting 1 Jan 2017 to 1 Jan 2020. No phase out of aircraft should be considered as part of the options investigated. The options considered for the analysis should anticipate more information on new technologies by the end of the CAEP/9 cycle. Other options can be considered following SG1 based on data availability. Any subsequent recommendation should not preclude low carbon technology such as the open rotor.
N.06.02	STANDARDS: Interdependencies	Coordinate with WG3 to assess interdependency effects of noise stringency options with respect to CO_2/fuel burn and NOx.
N.06.03	STANDARDS: Interdependencies	Respond to WG3 requests to assess interdependency effects of CO_2 emissions stringency options with respect to noise.
N.06.04	STANDARDS: Growth and replacement database	Review and update the Growth and Replacement (G&R) database for stringency analysis by MDG and FESG. Coordinate with WG3 to ensure consistency in assumptions. (Dec 2011 deliverable to MDG will include updates on project airplanes that changed to in-production and addition of new project airplanes where available as well as including seat class update).
N.06.05	STANDARDS: emerging technologies	Review data on emerging technologies.
N.06.06	STANDARDS: Open rotor	Investigate methodologies for noise certification of aircraft with new engine concepts such as open-rotor, etc.

Project Number	Short Title	Description
N.06.07	STANDARDS: Input for low mass analysis	Investigate a structural change to the relevant noise limits in the mass range below 10,000 kg (i.e. amending the lower (flat) portion of the limit) according to the 'double knee' approach. In particular: - Verify completeness of the G&R database for light aeroplanes, - Define the lower 'knee point' MTOM, - Define the slope of the lower sloped portion, and - Coordinate with MDG and FESG in evaluating the workload associated with incorporating a structural change to the limits.
N.06.08	STANDARDS: Low mass structure change	Propose a change to the structure of the relevant noise limits for low mass aeroplanes in combination with the already approved stringency options. (It is assumed that the results of the cost/effectiveness analyses on this issue by MDG and FESG will be included in their main report).
N.06.09	STANDARDS: Noise reduction technologies	If needed, report on potential for using ANDES beyond 2 dB for in production aircraft and up to 1 dB for project aircraft. If requested by FESG and MDG in order to resolve lack of compliant aircraft in certain seat classes at higher stringency scenarios.
N.06.10	STANDARDS: Unintended mission change	Support MDG and FESG in addressing unintended changes of mission (range, seating capacity) or propulsion format.
N.06.11	STANDARDS: Production rates	Support MDG and FESG in assessing the feasibility of production rates required for various higher stringency scenarios, including special considerations for project aircraft certification, production and delivery.
N.06.12	STANDARDS: Cost impact to in-production airplanes	Support FESG in analyzing the cost impact due to in-production aircraft failing various stringency scenarios.

Table 2. Working Group 2 (Operations) Work Programme

Project Number	Short Title	Description
O.01.01	Independent Expert Operational Goals review	Using the IE process, carry out a robust Air Traffic Operational review (as outlined Appendix H), and make recommendations for operational goals for noise and fuel burn in the mid-term (10 years) and the long term (20 years), using information and results from the limited CAEP/8 review, following a process similar to those of WG1 and 3, and addressing issues identified at SG/2009 and in the CAEP/8 IE report.
O.01.02	Independent Expert Operational Goals review (Action Plan)	Develop an action plan and schedule (based on CAEP/8 Report, Appendix H) for addressing issues raised by CAEP/SG and IEs, and conducting a more robust IE process.

Project Number	Short Title	Description
O.01.03	Independent Expert Operational Goals review (Report)	Facilitate an IE review including: a) Generate the guidance, information and material needed for the IE process; b) Hold a workshop and the IE Review; c) Hold follow-on meetings and regular telecons with the IEs to facilitate IE assessment and formulation of findings and report. This could involve providing additional information to the IEs. This task will include harmonising the processes and planning (e.g. base year) for operational goal setting with other IE processes to the extent possible. Coordination with WG3 ad-hoc group on CASFE (E.04) on metrics for operational goals.
O.02.01	Operational Opportunities to reduce fuel burn and emissions GM (Initial Chapters)	Refine the 4 draft chapters submitted to CAEP/8 (Chapter 2 - Airport Operations, Chapter 6 - Air Traffic Management, Chapter 7 - Non-Revenue Flying, and Chapter 12 - The Effect of Load Factor on Fuel Efficiency) to address outstanding comments and ensure the documents are harmonized with other ICAO provisions and industry best practices.
O.02.02	Operational Opportunities to reduce fuel burn and emissions GM (Completion)	Complete updates to the Circular 303 guidance material initially via the ad hoc group approach utilized at the end of the CAEP/8 work cycle. This task will include informally briefing the ANC on progress.
O.03.01	CNS/ATM Environmental Assessment High-Level Principles (Program Plan)	Draft a Program Plan to develop CNS/ATM environmental assessment guidance material. The plan should include compiling information on environmental assessment current best practices and identifying high-level principles to inform States, airports, ANSPs, and others.
O.03.02	CNS/ATM Environmental Assessment High-Level Principles (Guidance)	Develop CNS/ATM environmental assessment guidance material by compiling information on environmental assessment current best practices and identifying high-level principles to inform States, airports, ANSPs, and others. The task will be focused in scope on environmental impacts assessment (including both engine emissions and noise) related to proposed operational procedures changes, airspace redesigns, and other similar operational aspects. a) The task will develop approach/methodology and metrics coherently, rather than treating them as separate guidance tasks as in CAEP/8; b) The principles must be high-level and flexible to account for state-specific requirements and needs with respect to methodologies and metrics; c) The best practices should be requested directly from ANSPs and others as appropriate for use in developing the guidance material; d) The high-level principles will seek to identify information to populate proposed metrics and/or to validate or apply assessment methodologies.

Project Number	Short Title	Description
O.04	Task Coordination	The "operations" tasks will be coordinated within CAEP as necessary (e.g. WG1, WG3, MDG, FESG), Secretariat, external expert groups (e.g. CANSO), and external international initiatives (e.g. AIRE, ASPIRE). Liaisons from these groups will be encouraged to participate.

Table 3. Working Group 3 (Emissions Technical) Work Programme

Project Number	Short Title	Description
E.01	Interdependencies	Coordinate with other working group Rapporteurs on interdependencies related to (a) technology, operational issues and goals (b) management and update of noise and emissions databases (c) environmental impacts (d) SARPs for future SST aircraft.
E.02	Technology Goal: Fuel Burn	Using the IE process, carry out a Fuel Burn Improvement Technology review and make recommendations for technology goals and any necessary metric for timelines to be consistent with other working groups and UNFCCC.
E.03	Technology Goal: NOx	Dependent on de monstrable need and available resources, using the IE process, review progress towards achievement of NOx Technology Goals already set for 2016 and 2026; and, if requested, make recommendations for technology goals for timelines to be consistent with other working groups and UNFCCC.
E.04	Fuel Efficiency metrics (Fleet level)	Continue scoping and development of fuel/CO_2 efficiency metrics for specific application to CAEP work, including business aircraft, including the GIACC "Net CO_2 Intensity Metric" and the CASFE metric.
E.05	Alternative fuels & emissions	Examine and report on the emissions consequences resulting from the use of alternative fuels for aviation [both 'drop-in' replacements and 'non-drop-in']. Does not include lifecycle CO_2 emissions.
E.06	Fuel composition & emissions	Monitor trends in aviation kerosene fuel supply composition and assess consequences for emissions.
E.07	Technology advances	Provide assessment of advances in aircraft and engine design technologies for subsonic aircraft and the degree to which these technologies could influence gaseous emissions, smoke, particulate matter and fuel consumption; including the potential benefits and trade-offs amongst various emissions and noise, the likely timescales for introduction.

Project Number	Short Title	Description
E.08.01	CO_2 - Emission Standard (aircraft)	Conduct broad analysis to develop metric and methodology for a certification requirement pertaining to an aircraft CO_2 emissions standard. Plans for future work to develop the Standard: •2nd half Nov. – CO2TG progress telecom with CAEP Members; • Feb. WG3 Meeting – Metric System decision; • 2nd half Feb. – CO2TG progress telecom with CAEP Members.
E.08.02	CO_2 - Emission Standard(aircraft)	Develop s tringency proposals, including technology responses, regulatory levels and applicability and dates for evaluation of cost effectiveness and market impacts by FESG and MDG.
E.08.03	CO_2 - Emission Standard (aircraft)	Recommend an aircraft CO_2 emissions standard including applicability.
E.09	Interdependencies	Coordinate with WG1 to assess interdependency effects of CO_2 emissions stringency options with respect to noise.
E.10	Interdependencies	Respond to WG1 requests to assess interdependency effects of noise stringency options with respect to CO_2/fuel burn and NOx.
E.11	Annex 16, Vol. II maintenance	Maintain Annex 16, Volume II, taking account of updates to SAE-E31 documentation.
E.12	ETM maintenance	Maintain the emissions Environmental Technical Manual.
E.13	Emissions Database maintenance	Maintain the ICAO engine emissions certification databank.
E.14	G&R database maintenance	Review and update a "Growth & Replacement" database in order to support development of models used to populate future fleets and the replacement of retired aircraft. Coordinate with noise group to ensure consistency in assumptions.
E.15.01	NOx cruise - Climb relationship	Review the LTO NOx - cruise climb NOx relationship for staged combustion technologies, to quantify control of mission emissions of NOx, and identify any methodology issues with respect to the correlation between LTO and climb/cruise.
E.15.02		In addition monitor the need for the possible further development of the LTO NOx - cruise climb relationship for other future engine technologies to quantify control of mission emissions of NOx.
E.16	Certification Requirements - SST	Review and revise as appropriate the existing methodology and requirements for supersonic aircraft engine certification.
E.17	Certification requirements - new engine concepts	Develop methodologies for emissions certification of new engine concepts such as open-rotor, etc.

Project Number	Short Title	Description
E.18.01	PM - Non-volatile	Evaluate and document sampling and measurement methodologies for aircraft engine non-volatile PM emissions. Note input from SAE-E31.
E.18.02		Develop an aircraft engine based metric and methodology for application as a non-volatile PM emissions certification requirement for new engine types.
E.19	PM - volatiles	Evaluate and document sampling and measurement techniques to characterise the formation of volatile PM; Note input from SAE-E31.

Table 4. Forecasting and Economic Analysis Support Group (FESG) Work Programme

Project Number	Short Title	Description
F.01	Review of Economic Models	Review of economic models as needed for the CAEP/9 analyses.
F.02	Cost-effectiveness analysis of potential noise stringency options	Conduct the cost-effectiveness analysis of potential noise stringency options under consideration for CAEP/9 (including impacts on passengers, airports, airlines, etc.) as directed by SG2. In addition, conduct sensitivity analyses to assess the potential impacts (including fleet asset value) of the announcement date of a new standard (taking into account the applicability date) given the proximity of the adoption of two consecutive standards. Work in coordination with WG1, WG3 and MDG to: i. Assess the extent to which the fleet evolution process employed in the noise stringency analysis may have resulted in an unintended mission change by quantifying the payload/range capacity provided by seat class, route and stringency scenario and compare results to the FESG CAEP/8 route-specific forecasted demand. ii. Re-examine the applicability of the fuel burn scaling factor by modelling full flight fuel burn. iii. Assess the production rates required to provide the project and in-production aircraft projected for the stringency scenarios. iv. Develop and test a fleet evolution process that constrains the available fleet within reasonable production rates. v. Investigate and address the equal market share assumption using a market driven process that provides the most cost

Project Number	Short Title	Description
		effective aircraft that meets the FESG CAEP/8 forecasted demand. vi. Produce a new baseline projection of the fleet and the fuel burn to 2036 that incorporates the adjustments identified above.
F.03	Cost-effectiveness analysis of potential CO_2 policy options	Cost-effectiveness analysis of potential CO_2 policy options under consideration for CAEP/9.
F.04	Review of FESG CAEP/8 forecast	Conduct a comparison of the CAEP/8 forecast with actual data.
F.05	Assessment of the potential impact of constraints	Conduct a study on the potential impact of constraints on forecasting results.
F.06	Traffic and fleet Forecasts	Traffic and fleet forecasts in support to the CAEP/10 analyses. To be developed by route groups for both passenger and cargo services, over an overall time horizon of 30 years (from 2010 to 2040). New retirement curves for passenger and cargo aircraft as well as traffic projections to 2050 are to be included. Sensitivity analyses are required conducted around both the passenger and cargo traffic forecasts to generate low and high scenarios of growth. A forecast for aircraft with less than 20 seats should also be developed (for business jets only).

Table 5. Modelling And Databases Group (MDG) Work Programme

Item Number	Short Title	Description
M.01	Interdependencies	Coordinate with other working group Rapporteurs on interdependencies related to technology, operational issues, goals, environmental impacts and management and update of noise and emissions databases.
M.02	Noise Stringency	Conduct policy option analyses of the environmental benefits and interdependencies of a potential noise stringency as directed by CAEP and SG.
M.03	CO_2 Standard	Coordinate with other working groups with regard to preparing for policy option analyses of the environmental benefits and interdependencies of a potential CO2 standard as directed by CAEP and SG.
M.04	ICAO Environmental Goals Assessment	To support ICAO Environmental Goals and HLM Recommendation 9, conduct an updated GHG assessment, for the baseline case (both 2005 and 2006) and forecasts, and for various cases which consider technology and operational improvements. Assemble available data on alternative fuels life cycle for consideration in the CAEP/9 assessment.

Item Number	Short Title	Description
M.05	Model and database management	Model and Database management. Maintain version control of models and databases to be used in support of specific CAEP analyses. Determine if updates to models or databases require a re-evaluation. Model evaluation may now include dispersion and consideration of particulate matter.
M.06	Summarize Capabilities	If new models are introduced to support CAEP/9, continue the candidate model evaluation process initiated in the previous work program, which calls for sensitivity tests, comparisons with "gold standard data, and sample problems. Refine the process as appropriate on the basis of relevant criteria, to better inform CAEP which tools are sufficiently robust, rigorous and transparent, and appropriate for which analysis, and why there might be differences in modelling results.
M.07	Updated Databases	Working with the appropriate working groups, develop updated databases, as required.
M.08	Document 9911	Review and update ICAO Document 9911, as appropriate.
M.09	Fuel Burn Reporting	Seek to improve modelling and State reporting of fuel burn data by conducting a comparative assessment of modelled and reported data, as reported data becomes available.
M.10	CAEP Support	Provide support to CAEP Secretariat in dissemination of MDG results.
M.11	LAQ Guidance	Finalize the mitigation and interdependencies chapters of the air quality guidance manual.

Table 6. Impacts and Science Group (ISG) Work Programme

Project number	Short Title	Description
I.01.01	Coordination (internal group)	Coordination on activities.
I.01.02	Coordination (internal ICAO)	Coordination with other WGs, TFs, RFPs, etc. Rapporteurs and Secretariat on activities.
I.01.03	Coordination (external)	Consultation with experts from external agencies (e.g. WHO, WMO, IPCC, UNFCCC, etc.).
I.02.01	Group task development	Review CAEP work programme and identify critical science needs.
I.02.02	Group task development	Review with co-rapporteurs on implementation possibilities arising from Impacts Workshop
I.02.03	Group task development	Development of TORs, modus operandi to clearly define the scope of the work programme of the ISG.
I.03.01	Climate context (CO_2)	Development of underlying science thinking on a viation within context of UNFCCC discussions and other national/regional climate initiatives to inform ICAO-CAEP.
I.03.02	Climate context (non-CO_2)	Coordination of non-CO_2 issues for consensus science to inform ICAO-CAEP.

Project number	Short Title	Description
I.03.03	Local and surface air quality context	Development of thinking on aviation impacts and relevance to CAEP activities.
I.03.04	Noise context	Development of thinking on aviation impacts and relevance to CAEP activities.
I.03.05	Interdependencies context	Development of thinking on aviation impacts and relevance to CAEP activities.
I.04.01	Monitoring, Reporting, and Verification (MRV)	Review IPCC guidance to identify appropriate standard methodologies to measure/estimate, monitor and verify global GHG emissions from international aviation. Define the scope and resources necessary for a task that would propose methodologies and a mechanism to carry out such measurement/estimation, monitoring, and verification.

Table 7. Aviation Carbon Calculator Support Group (ACCS) Work Programme

Project number	Short Title	Description
C.01	ICAO Fuel Consumption Form	Provide CAEP comment and recommendations on the proposed fuel data collection form.
C.02	Enhancements to passenger Carbon Calculator	Refine the methodology and database associated with the passenger Calculator by: (a) updating the current database; (b) updating the methodology and underlying data sources using flight level global emissions inventories generated by AEDT/SAGE, AEM III, Aero 2k and FAST; and (c) transiting from modelled to measured values using measured fuel consumption data at the city pair level from industry bodies.
C.03	Estimating CO_2 emissions from air freight	Develop *Frequently Asked Questions* text for the ICAO website, on the difficulties of accurately estimating the CO_2 emissions attributable to air freight at this time. As a next step, develop a set of non-binding guidelines to enable interested parties to develop a carbon calculator methodology for belly freight.
C.04	Explore ways to collect data on offsetting and its use	Report on ways in which ICAO could collect data on the quantity of offsetting associated with air travel and how such data would be used by ICAO.
C.05	Offset Accounting Methodology	Develop a methodology to estimate the amount of emissions on an airport-pair basis that would have been offset by the operator as the result of exceeding their emissions allowances within a cap and trade system or other offsetting schemes.

8. WORKING ARRANGEMENTS

8.1 The Technical Committee met as a single body, with informal meetings convened as required. Discussions in the main meeting were conducted in Arabic, Chinese, English, French, Russian and Spanish. Some working papers were presented in English only. Papers were available electronically on the CAEP secure web site; no hard copies were provided to participants with the exception of the draft report for approval of the meeting. The report was issued in Arabic, Chinese, English, French, Russian and Spanish.

9. OPENING REMARKS BY THE FIRST VICE PRESIDENT OF THE ICAO COUNCIL

Good morning ladies and gentlemen. In the absence of the President of the Council, I have the honour as First Vice President of the Council and, on behalf of the Council, and the Secretary General of ICAO, to welcome you to the Ninth Meeting of the Committee on Aviation Environmental Protection (CAEP).

In opening this meeting my thoughts turn to how essential the work of CAEP is in meeting ICAO's environmental objectives, with a view to minimising the effects of global civil aviation on the environment. At each CAEP meeting, we need to develop new SARPs and guidance that will allow aviation to further:

- limit or reduce the number of people affected by significant aircraft noise;
- limit or reduce the impact of aircraft engine emissions on local air quality; and
- limit or reduce the impact of aviation greenhouse gas emissions on the global climate.

The global importance of environmental protection has grown immensely over recent decades, and with it, the significance and relevance of the work of CAEP.

The track record of the CAEP is impressive to say the least. CAEP has provided ICAO with excellent technical information, which has allowed global agreements to be made on real and comprehensive environmental solutions and, over the years, the depth and scope of your technical advice have proven essential in facilitating political decisions. As a world leading expert forum, CAEP continues to deliver and ICAO has come to expect only the best technical output from CAEP.

This CAEP/9 meeting brings together a significant body of work from the past three years including crucial advances in aircraft noise and emissions technical subject areas. At this meeting the CAEP will discuss options for a further reduction in the ICAO noise Standard, to which you have invested a significant amount of resources. This technical effort has required experts in the CAEP to overcome important modelling challenges, and for this dedication and skill you should be commended. These efforts have resulted in several noise stringency options being offered for the consideration of this meeting. Your decisions on a future noise Standard will affect generations to come and I wish you every success in coming to a comprehensive and robust outcome.

On technology and operations, in the past, your work on the establishment of mid and long-term goals for technological improvements in noise, NOx, and fuel-burn reduction has been crucial in supporting of the Standard setting and policy process. I have been made aware of the excellent work during this CAEP cycle of the Noise Independent Experts and the Operational Goals group. The outcome of these two groups will be reported to this CAEP meeting and will help policy makers by bringing state-of-the-art information upon which to base their policy decisions.

It is pleasing to see t hat the CAEP has made progress in developing the new ICAO CO_2 Standard, particularly given the significant technical challenges. Your work will form the basis of the new ICAO Annex 16, Volume III, and I know the Council looks forward to receiving the details on this in the near future. I understand that the development of the CO_2 metric system and certification procedures was no small task, and I know the all-important certification requirement for the CO_2 Standard will be presented for the consideration of this meeting. In order to finalise Annex 16, Volume III, I urge you to come together on the remaining issues as expeditiously as possible in an effort to deliver the ICAO CO_2 Standard to the international community as soon as possible. The world is certainly watching.

The ICAO CO_2 Standard will form part of a basket of measures, which includes, among others, operational improvements, Market-based Measures (MBMs) and sustainable alternative fuels to achieve ICAO's global aspirational goals, to reduce the impact of international civil aviation on climate change.

As you may be aware, following the agreement of the Council last November, a high level group of seventeen senior governments officials was established in order to develop policy recommendations on the elements of the upcoming 38th Assembly Resolution on international aviation and climate change.

I would like to draw your attention that, at the second meeting of the high-level group just held last week, the group acknowledged the key importance of work being undertaken by CAEP on technological and operational measures, and welcomed the progress of CAEP in the development of Standards and guidance material. The high-level group also recognized the current efforts of CAEP to update the CO_2 trends assessment by estimating the contribution of various categories of mitigation measures, and the CAEP trends will be used for discussion by the group on global aspirational goals. I understand that the trends assessment will be discussed during this meeting and the Council looks forward to hearing the results in the near future. The high level group also undertook substantial discussion around the possible means to enhance the reporting of data on the ongoing efforts of offsetting carbon emissions and the projected use of sustainable alternative fuels.

CAEP has played an important role in assisting with State action plan development. This has included assisting in the development of guidance material for planning of State action plans and supporting hands on training workshops on CO_2 emissions reduction activities. The CAEP should be commended for its continuous and excellent support on this issue, which allows ICAO to supply up to date and relevant assistance to States.

Overall, the technical basis you have laid in so many environmental areas – and will continue to build upon at this CAEP meeting – will go towards the achievement of ICAO's environmental objectives. We will need all possible measures to address aviation impacts, and it is important that CAEP continue to work on all fronts exploring the technical feasibility, potential environmental benefits and economic reasonableness of the options, and of course the interrelationships and trade-offs among them.

The discussion on environmental issues is always high paced, and as we move forward, it is clear that ICAO and CAEP must find dynamic ways of working in order to respond to the global community's need for technically robust environmental solutions.

As we begin our discussions in the CAEP/9 meeting, it is clear that your cooperation will be key in enabling ICAO to offer environmental solutions in a demanding international climate, which will have a lasting impact for decades to come. I'd like to offer my thanks to all of you for your dedication, support and technical excellence. I wish you a very productive meeting and I look forward to hearing about the outcome.

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GENERAL

During this segment the meeting reviewed reports by the Secretariat on main developments and activities carried out during this CAEP cycle. Information was provided on membership changes within the CAEP, the CAEP directives, the follow up of outcomes of the 37th ICAO Assembly and developments in ICAO, and developments in other UN bodies.

1. MEMBERSHIP AND PARTICIPATION IN CAEP ACTIVITIES

1.1 CAEP currently has 23 members and 16 observers, from States and international organizations. Since the 2012 Steering Group meeting, the UK, EU, Turkey and CANSO each nominated new representatives, which were subsequently approved by the Council of ICAO. In addition, the representative of ACAC is currently awaiting a formal nomination. The ICAO Council also approved a new observer State nomination from the UAE. Nigeria and WMO have lost their member and observer status respectively.

2. CAEP DIRECTIVES

2.1 In response to a request of the ICAO Council, specific directives for CAEP were developed. These directives were considered by the Council during its 189th and 193rd sessions. The full text of the CAEP directives were approved by the Council in June 2011.

2.2 The directives are in response to various comments made by the Council in relation to the working arrangements of CAEP. In particular, the directives: clarify the nomination process for CAEP members and observers; request a commitment of their contributions to a full CAEP cycle; set criteria for members and observers concerning the loss of their status as such, should they fail to contribute to the work of CAEP; allow the temporary nomination of alternates for CAEP members and observers to participate on their behalf during a specific meeting; and set the maximum number of CAEP observers from non-governmental organizations to seven.

2.3 Information on the CAEP directives was presented to the 2011 Steering Group meeting.

3. DEVELOPMENTS IN OTHER UN BODIES

3.1 UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

3.1.1 In order to follow up on the decisions made by the 17th Session of the Conference of the Parties to the UNFCCC, held in Durban, South Africa (COP17/CMP7) in December 2011, two UNFCCC climate change conferences were held in May 2012 in Bonn, Germany and in August 2012 in Bangkok, Thailand, prior to the UNFCCC Doha conference (COP18/CMP8), held from 26 November to 8 December 2012 in Doha, Qatar.

3.1.2 The Doha conference adopted a series of decisions referred to as the “Doha Climate Gateway”, which includes agreement on the second commitment period for the Kyoto Protocol from 2013 to 2020, as well as an elaboration of the work plan for the Ad-hoc Working Group on the Durban Platform (ADP) process, towards the adoption of a legally binding agreement on climate change by 2015 and its implementation from 2020. However, no decision was taken on how to address emissions from international aviation.

3.1.3 The Conference also decided to extend the work programme on long-term climate finance for one year up to the end of 2013, to further analyse options for the mobilization of USD 100 billion per year by 2020.

3.1.4 Under the ADP process, two streams of work were undertaken: 1) elaboration of the ADP work plan; and 2) consideration of the options and ways for increasing the levels of ambition to close the emissions gap between the current pledges of Parties and the reduction levels required to achieve the 2˚C target. During the Bangkok conference, ICAO presented the recent developments and on-going initiatives in responding to the actions requested by ICAO Assembly Resolution A37-19, including the activities to estimate the impacts of various mitigation measures (CO_2 trends assessment), which will serve as a technically sound basis for further discussions to review and explore global aspirational goals. Several Parties identified further progress of work under ICAO and IMO as one of the complementary initiatives for increasing the level of ambition.

3.1.5 During the Council Session held in November 2012, it was stressed that ICAO needs to communicate its position to other relevant UN bodies and international organizations and to showcase developments that demonstrate the commitment of ICAO to tackling climate change. With respect to the mobilization of revenue for climate finance and the use of international aviation as a potential source of such revenue being discussed under the UNFCCC process, the Council reiterated the need for ICAO and its Member States to continue to clearly express concern on this issue through the UNFCCC process.

3.1.6 ICAO will continue to cooperate with the UNFCCC process by providing perspectives on issues related to international aviation and climate finance to ensure that developments at ICAO are recognized and that international aviation is not singled out as a source of revenue for climate finance in a disproportional manner. ICAO also needs to closely follow-up if, and how, the issues related to international aviation would be addressed by the ADP process. The next major UNFCCC conference, COP19, will be held from 11 to 22 November 2013 in Warsaw, Poland.

3.2 **RIO+20 CONFERENCE**

3.2.1 The UN Conference on Sustainable Development (UNCSD, also known as the Rio+20 Conference) was held in Rio de Janeiro, Brazil, from 20 to 22 June 2012. Among the seven themes of the Conference, renewable energy, and in particular sustainable alternative fuels for aviation, was the most relevant theme for ICAO. At the Conference, ICAO demonstrated, in close cooperation with partners from the aviation industry, the global reality of sustainable alternative fuels for aviation through a series of four connecting flights from Montréal to Rio de Janeiro, which were all powered by sustainable alternative fuels. An ICAO report that summarizes this initiative: “Flightpath to a Sustainable Future”, is available on the ICAO public website (www.icao.int/env).

3.2.2 Following the outcome of the Rio+20 Conference, the UN Secretary-General issued an implementation framework, which maps the updates of all the major initiatives and actions related to the outcome of the Rio+20 Conference in various areas, such as energy and sustainable transport. ICAO will continue to update the UN Secretariat on new initiatives and partnerships that will be launched in response to the Rio+20 outcome document and follow-up process.

3.3 INTERNATIONAL MARITIME ORGANIZATION (IMO)

3.3.1 At the 63rd meeting of the Maritime Environmental Protection Committee (MEPC63) in March 2012, IMO agreed on the technical guidelines to support the implementation of technical and operational measures for international shipping adopted by MEPC62 in July 2011. MEPC63 also discussed a draft Resolution on Technical Cooperation and Transfer of Technology that would facilitate the implementation of technical and operational measures through the provision of assistance to States. Due to divergent views expressed by States on the need to reflect the principles of the UNFCCC and to include financial assistance, MEPC63 did not adopt the draft Resolution.

3.3.2 Regarding market-based measures (MBMs), MEPC63 did not agree on the possible narrowing-down of ten proposals for a global MBM for international shipping, to be used for further evaluation. The Chair of MEPC63 suggested the establishment of a Steering Committee and a list of criteria by which further evaluation of the proposals would be undertaken. Various views were expressed by States, mainly on the working method of the Steering Committee. MEPC63 decided that further discussions would take place at MEPC64 in October 2012.

3.3.3 The discussion at MEPC64 focussed on the draft Resolution on Technical Cooperation and Transfer of Technology. Divergent views continued to be expressed by States and the MEPC did not adopt the draft Resolution. This subject will continue to be discussed at MEPC65 in May 2013. Due to time constraints, the MEPC agreed to postpone further discussion on MBMs for international shipping.

3.4 UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP) ENVIRONMENTAL MANAGEMENT GROUP (EMG)

3.4.1 ICAO, along with other UN agencies, continued its cooperation with the UN Environment Management Group (EMG) chaired by the UN Environment Programme (UNEP). This group includes senior officials responsible for the environmental programmes in different organizations and was established in order to coordinate environmental issues throughout the UN system.

3.4.2 ICAO has contributed to the EMG working groups on Rio+20, green economy, and sustainability management. Regarding the work on sustainability management, ICAO has provided UN organizations with assistance and training on the use of its Carbon Emissions Calculator. In addition, the ICAO Green Meetings Calculator was used by the EMG working group on sustainability management.

3.5 Discussions and Conclusions

3.5.1 The meeting thanked the Secretary for the good work of ICAO in cooperating with other UN bodies and for keeping CAEP informed of the relevant on-going discussions within other UN bodies. CAEP encouraged the active participation of States' representatives and their technical experts in the UNFCCC process. The meeting will consider the support required for liaison activities held in cooperation with other UN bodies during its discussion on future work.

4. DEVELOPMENTS IN ICAO

4.1 FOLLOW-UP OF ACTIONS REQUESTED BY THE 37TH ICAO ASSEMBLY

States' Action Plans and Assistance to States

4.1.1 Following the seven hands-on training workshops for States' action plans held in 2011 and 2012, the Secretariat has continued to support States in the development and submission of action plans to ICAO by contacting individual States, by providing specific tools, information and guidance material, and in developing an interactive website to facilitate the preparation and submission of action plans.

4.1.2 By the end of January 2013, 57 ICAO Member States, representing approximately 77 per cent of global international air traffic have developed and submitted their action plans to ICAO. Information and data contained in the action plans submitted by States are being compiled and the areas of implementation support and assistance needs are being identified.

4.1.3 The ICAO "Assistance for Action – Aviation and Climate Change" Seminar, held in collaboration with the ICAO Technical Cooperation Bureau (TCB), was held from 23 to 24 October 2012 at ICAO Headquarters in Montreal, Canada. The objective was to share information with States and other stakeholders on the assistance needed to implement actions to address CO_2 emissions, including the identification of potential sources for assistance, as well as possible processes and mechanisms under ICAO to facilitate assistance provision.

Sustainable Alternative Fuels for Aviation

4.1.4 The Secretariat has continued its efforts to promote and further facilitate the development and deployment of sustainable alternative fuels for aviation, through the convening of the ICAO Aviation and Sustainable Alternative Fuels (SUSTAF) Workshop in October 2011. A summary of this workshop is available at www.icao.int/sustaf.

4.1.5 Building on the outcomes of the SUSTAF Workshop in 2011 and on the discussions of the 194th Session of the ICAO Council, the Sustainable Alternative Fuels for Aviation Expert Group (SUSTAF) was established in June 2012 to develop recommendations to further facilitate the development and deployment of sustainable alternative fuels for aviation, building upon the existing policies and measures, current initiatives and best practices being undertaken by States and organizations.

4.1.6 The Expert Group has focused its work on analysing the possible options to overcome the near-term challenges attendant to the deployment of sustainable alternative fuels in aviation, as well as to address the sustainability of these fuels. The group agreed that the priority is to set policies toward the creation of a long term stable market perspective in order to attract investments in the production of alternative fuels for aviation. Supporting research in processes technology and feedstock production also appears as key to decreasing production costs and meeting price parity with conventional jet fuel. Committing to the sustainable deployment of the fuels is a major request, for which States can build on the basis of existing principles and approaches.

Market-based Measures

4.1.7 The 37th ICAO Assembly agreed on a number of actions for market-based measures including the development of a framework, the elaboration of the guiding principles adopted by the ICAO

Assembly, analysis of a *de minimis* threshold, the exploration of a global MBM scheme, and collection of information on the volume of offsets. The elaboration of the guiding principles was undertaken as part of the development of evaluation criteria used to explore the feasibility of options for a g lobal MBM scheme. Numerous options were assessed; previous work on MBMs, including CAEP research, was collated and quantitative modelling analysis was undertaken. As a result of this analysis, the number of options under consideration was reduced, and the analysis of applying a *de minimis* threshold showed that market distortions could be significant. In the immediate term, offsets were found to be in oversupply in the carbon market and expected to remain so for the foreseeable future.

4.1.8 Three options for a global MBM scheme were identified for further consideration by the 196th session of Council in June 2012. In the subsequent 197th Council Session, the results of the qualitative and quantitative analyses were presented, demonstrating that all three options are technically feasible and have the capacity to contribute to achieving ICAO's environmental goals. Further work will continue both on the evaluation of the options for a global MBM scheme and on the development of the framework.

4.1.9 Development of specific ICAO guidance material on issues such as the distribution of emission obligations and data management/monitoring review and verification (MRV) could build on the technical work previously developed by CAEP. In light of the continuing work on the technical elements of the global MBM scheme, and work previously contributed by CAEP, the work programme of the CAEP/10 cycle could include tasks in support of the development of MBMs.

Global Aspirational Goals

4.1.10 The Secretariat has continued to work with CAEP to update the CO_2 trends assessment by estimating the contribution of various categories of mitigation measures (aircraft-related technology development; improved air traffic management and infrastructure use; more efficient operations; and alternative fuels) in order to measure current, and estimate future progress toward the achievement of global aspirational goals.

4.1.11 To quantify the progress achieved to date, the Secretariat has been working to estimate and verify the global fuel consumption from international aviation and tonne kilometres performed for 2010 and 2011, using the responses being received by the ICAO statistical forms including the new Form M, Fuel Consumption and Traffic — International and Total Services, Commercial Air Carriers. Fuel and traffic data that were not reported to ICAO are being estimated. This analysis directly supports the request of the 37th Session of the ICAO Assembly for the Council to regularly report CO_2 emissions from international aviation to the UNFCCC process. The methodologies used for estimating fuel consumption and results generated by the Secretariat will be reviewed by CAEP.

4.1.12 The Secretariat has worked to compile and interpret data contained in States' action plans to determine a global figure which will be integrated with the CAEP (2010 to 2050) CO_2 trends assessment. This will support the review by the Council of the medium-term global aspirational goal and exploration of a long-term global aspirational goal for international aviation.

4.2 HIGH-LEVEL GROUP ON INTERNATIONAL AVIATION AND CLIMATE CHANGE

4.2.1 Following the decision of the Council at its 197th Session, the High-level Group on International Aviation and Climate Change (HGCC), composed of 17 s enior government officials nominated by their administrations, was established to develop policy recommendations regarding the elements for the 38th Assembly Resolution on international aviation and climate change, including on:

global aspirational goals; technological and operational measures; sustainable alternative fuels for aviation; market-based measures; States' action plans; and assistance to States.

4.2.2 The HGCC held two meetings in December 2012 and January 2013, respectively. The third meeting is scheduled from 25 to 27 March 2013. Progress of work by the HGCC will be reported to the Council for its consideration of a proposal for the 38th Assembly Resolution on international aviation and climate change, for submission to the 38th Session of the Assembly in September 2013.

4.3 OTHER DEVELOPMENTS

Aviation System Block Upgrades (ASBU)

4.3.1 The need to quantify the environmental benefits of implementing Aviation System Block Upgrades (ASBU) was presented to the 2012 Steering Group, and a CAEP group was formed to determine the requirements of an environmental benefits analysis task. MDG and ASBU experts have progressed this task and details are presented in section 2.9.

ICAO Fuel Savings and Estimation Tool (IFSET)

4.3.2 The ICAO Fuel Saving and Estimation Tool (IFSET) has been developed to assist States with the estimation of fuel savings from the implementation of operational measures. State Letter 2012/4 was issued to inform States of its availability. MDG conducted a review of the IFEST and the results were presented at the 2012 Steering Group meeting. The IFSET tool has been used by the Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar (ASECNA) to quantify the fuel savings that have occurred due to ATM and navigational improvements that have taken place in the airspace covered by ASECNA. This work is expected to facilitate the task of CAEP in the area of trends assessment and in estimating future progress toward the achievement of global aspirational goals.

ICAO Secretariat work on the CO_2 Standard

4.3.3 The ICAO Secretariat provided the ANC with an informal briefing on the development of CO_2 Metric System which will underpin the CO_2 Standard. This aimed to enhance the understanding of the ANC regarding the nature and components of the future CO_2 Standard. This built on a long standing effort of updating an ANC CO_2 Standard ad-hoc group on the progress of the CO_2 Standard development over the past two years.

4.3.4 Following a request from the 2012 Steering Group, the ICAO Secretariat developed a CO_2 Metric System Fact Sheet which aimed to communicate the progress on the CO_2 Standard to those outside the ICAO processes. The CO_2 Metric System Fact Sheet can be found at http://www.icao.int/Newsroom/Pages/new-progress-on-aircraft-CO2-standard.aspx.

4.4 Discussions and Conclusions

4.4.1 A member highlighted the importance of a careful CAEP review of the trends prior to their external communication. The meeting recognized the expertise available within the Secretariat and thanked them for their significant efforts. The meeting deferred comments and discussion on alternative fuels, including SUSTAF, to Agenda Item 4. The meeting will consider the work of the Secretariat during its discussion on future work.

5. VOLUNTARY MEASURES

5.1 A member presented on behalf of the Focal Point on Voluntary Measures (FPVM) on recent voluntary measures work. Voluntary measures are one of the market-based measures, aimed at reducing climate impact caused by greenhouse gases (GHG) emitted from the aviation sector. CAEP developed the template for voluntary agreements between the aviation sector and public organizations, which is available on the ICAO website. The FPVM has been collecting information and providing feedback to States and the aviation community, with the aim of wider dissemination of such activities.

5.2 On 2 December 2009, States were requested to provide information, and since then the FPVM received 56 responses, which is more than five times as many as those reported at CAEP/7. The FPVM also received two responses updating information on voluntary measures. The member also went into detail on the dissemination of information, which included a description of the public web platform that collects and shares information on various voluntary activities across States. The member emphasized that it is essential to work on this web platform continuously in order to encourage entities to initiate or improve environmental activities and actively communicate their achievements to ICAO. This will positively impact the leadership of ICAO to address global climate change.

5.3 Discussions and Conclusions

5.3.1 The meeting thanked Japan for its continued support as the FPVM with members reaffirming the value of voluntary measures in their States and the value of having the information available through the ICAO website. The Secretariat explained that action plans and the list of voluntary measures are complimentary, noting that while not all stakeholders are in a position to submit action plans, anyone can submit a voluntary measure. The meeting supported the recommendation from the FPVM to make the process of submitting voluntary measures more user-friendly. An observer noted the opportunity to align the format of the questions to support compatibility between the action plan and voluntary measures processes. The Secretariat agreed to continue working closely with the FPVM on this initiative.

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Agenda Item 1: Review of the assessments of the present and future impact of aircraft noise and engine emissions

1.1 COORDINATION BETWEEN WORKING GROUPS

1.1.1 Due to the substantial resource demands and complexity of the CAEP/9 Work Programme, and the numerous cross-cutting issues between the various CAEP working groups, the groups took deliberate action to ensure sufficient coordination. This included frequent reviews of activities that required coordination and jointly reporting on those activities to each of the Steering Group meetings. Six tasks required multi-group coordination with the noise stringency assessment, fuel trends assessment, and CO_2-related activities requiring coordination among the most groups. This level of coordination proved to be an effective means of advancing the work.

Discussion and Conclusions

1.1.2 The meeting thanked the Co-Rapporteurs for their effective, necessary, coordination throughout the CAEP work programme. The meeting recognized that even closer coordination between MDG and FESG is needed in support of the CO_2 Standard analysis work. The meeting will consider ways to streamline and coordinate the meeting schedule to reduce meeting travel demands on the working group members and the resources required during its discussion on future work. The Secretary also urged that very large attendance at some working group meetings have posed challenges in advancing the work and in the ability for some States to host the meetings.

1.1.3 Regarding the particulate matter (PM) modelling challenges ahead, the MDG Co-Rapporteur shared a concern about the amount of work remaining particularly given the future large commitment required for the CO_2 Standard modelling. The Co-Rapporteur added that, from a technical perspective, the PM modelling is currently based on a statistical relationship between smoke number and PM, stating that there is much work ahead before a robust analysis can be performed.

1.2 REPORT OF THE MDG

1.2.1 The Co-Rapporteurs of MDG presented the group's report on activities since CAEP/8. Many of MDG's tasks were primarily related to policy option analyses, model and database management, and model evaluation. The work related to the policy option analysis of noise stringency is discussed in section 3.7 and work related to the analyses in support of the development of a CO_2 Standard is discussed in section 2.6. It was explained that significant work remains in order to develop a robust methodology for modeling particulate matter emissions (also see paragraph 1.1.3).

1.2.2 Work related to model and database management focused primarily on managing/developing the models and databases supporting the noise stringency assessment, with considerations toward an updated fuel trends assessment and CO_2-related activities to begin early in the CAEP/10 work cycle. A related element of the model and database management task was the archiving of supporting databases and assessment-related input/output data. MDG and the ICAO Secretariat are working closely to complete the archiving process associated with the noise stringency assessment.

1.2.3 MDG maintains a global database of civil aircraft movements known as the Common Operations Database (COD). This database is compiled on an annual basis primarily using data from EUROCONTROL and FAA/Volpe Center which together constitutes around 70-80 per cent of civil aviation flights in the world and is a key element of the FESG forecasting activities, MDG trends assessments, and policy option analyses. The remaining flights are identified from published timetable data, which is known from past analysis within MDG to have many shortfalls. MDG presented a list of States from which operations data would greatly improve this important database for MDG.

1.2.4 MDG continued the candidate model evaluation process initiated in the previous work program, which calls for sensitivity tests, comparisons with "gold standard data", and sample problems. It further requires MDG to refine the process as appropriate on the basis of relevant criteria, to better inform CAEP which tools are sufficiently robust, rigorous and transparent, and appropriate for which analysis, and why there might be differences in modelling results. MDG has completed the evaluation of one new model during the CAEP/9 work cycle, the Russian Federation's PEGAS local air quality model. PEGAS has been found to be satisfactory to support CAEP analyses. In addition, MDG is currently evaluating four models, as follows: (1) the Ukraine's PolEmiCa local air quality model; (2) the Ukraine's IsoBella noise model; (3) the Russian Federation's AcousticLab noise model; and Japan's JCAB noise model. Also covered under this task was MDG's review of the ICAO IFSET model. A summary of models and databases evaluated for CAEP/9 is contained in the Appendix.

1.2.5 The MDG Co-Rapporteurs presented the approach being taken to develop an updated fuel trends assessment. This assessment will include modeled fuel burn for 2006, 2010, 2020, 2030 and 2040, as well as an extension to 2050. It is planned that the 2006 results will be based on the CAEP/9, results while new modeled results will be computed for a 2010 baseline, based on an updated Common Operations Database. Computed results for 2020, 2030 and 2040 will rely on the new FESG forecast, while the 2050 results will be based on an extension of the fuel burn computed in the earlier years. It is anticipated that modeled results will be available from three tools as follows: (1) FAA's Aviation Environmental Design Tool (AEDT); (2) EUROCONTROL's Advanced Emissions Model (AEM); and Manchester Metropolitan University's FAST. The modelling will consider the following:

a) Aircraft-related Technology Improvements

b) Operational Improvements, both those related to improved ATM and more efficient infrastructure use; and

c) Net Life Cycle CO_2, related to alternative fuels relative to a petroleum baseline

It is anticipated that results will be provided separately for total global fuel use, international aviation, as well as domestic aviation. For international aviation, the graphics will also include ICAO's 2 per cent efficiency goal as well as how these measures compare with a carbon neutral growth target relative to 2020. The Co-Rapporteurs emphasized that the agreement on the alternative fuels assumptions is a challenging task.

Discussion and Conclusions

1.2.6 The meeting thanked MDG for their work. The chairman called to the attention of the meeting the conclusions of the comparison of the COD with ICAO-collected statistics: with the COD and the operations data reported to ICAO through the Statistical reporting forms being derived from independent data sources, they appear to be complementary. Improving the operational data coverage in the COD will help to improve the forecasts developed by FESG and the trends generated by MDG based on the COD and the forecasts. Similarly, where the COD offers improved coverage over the data reported to ICAO, an opportunity exists to improve the Secretariat's statistics with the potential in the future to harmonize the data used for both purposes.

1.2.7 The meeting stressed that an update to the COD to include broader coverage of both radar-based operations and trajectory data is of critical importance for all analyses. The members from

Argentina and Australia indicated that they are actively working to provide MDG with data to supplement the COD.

1.2.8 The Secretary stressed the importance of the MDG trends to support on-going discussions. To be useful, the results must be robust, but also communicated in a way that is easy to understand by a policy-making audience. This view was supported by the meeting, with members highlighting the importance of allowing enough time to conduct a careful and thorough review of the results, and it was highlighted that there are insufficient resources to conduct the full analysis more than once. The meeting also recommended that the communication format for the trends be vetted externally in parallel with the generation of the results to help communication to a non-technical audience.

1.2.9 The Secretary expressed concern over the maintenance, ownership and access to databases and models created and used by CAEP, and asked the meeting whether a more robust procedure is required. The Secretary also informed that the emissions databank had changed custodian from the UK to EASA, and this move had not been endorsed by CAEP. An observer highlighted that its ability to provide the fleet-wide noise and emissions database into CAEP depended on having effective use restrictions. The meeting noted that the management of databases should be treated in a delicate manner, and the data provided are of differing levels of sensitivity and have different use restrictions. Furthermore, regarding the ICAO emissions databank, an observer stated that during discussions in Working Group 3, views were expressed that certification authorities were in the best position to maintain these databases. The chairman asked that the Secretariat prepare a flimsy to be discussed that outlines the concerns over the current process with recommendations for a way forward on this issue.

1.2.10 Following the presentation by the ICAO Secretariat on a proposed way forward regarding database maintenance, ownership, and access the meeting encouraged the ICAO Secretariat to establish agreements regarding the maintenance of the ICAO NoisedB and the ICAO Aircraft Engine Emissions Databank with the States involved. The meeting also noted that the non-disclosure agreements in place between manufacturers and airworthiness authorities facilitate access by the latter to proprietary performance data that can be used to validate the data submitted for the ICAO databanks. Some members noted that new proposals regarding the management of databases would have significant implications and expressed the need to better understand and more carefully consider potential alternatives.

1.2.11 The meeting asked the Secretariat, working with States and an observer, to make a proposal for managing databases and models developed for the work of CAEP to be presented to the first Steering Group meeting of the CAEP/10 cycle. The presentation should help the Committee to better understand the challenges associated with transparency, ownership, access, and maintenance of the databases and models. It should also consider the needs of the contributors to the models and databases as well as the CAEP working groups.

1.3 **REPORT OF THE FESG**

1.3.1 The Co-Rapporteurs of the Forecast and Economic Analysis Support Group (FESG) presented the group's report. The work programme of the FESG for CAEP/9 was originally established at CAEP/8 and was subsequently amended during the cycle to reflect guidance provided by the Steering Group and to add new tasks. The FESG established two Task Groups to perform the tasks on its work programme for CAEP/9: the Forecast Task Group (FTG) and the Stringency Task Group (STG).

1.3.2 **Review of the Economic Models (Tasks F.01 and F.05)**

1.3.2.1 The FESG FTG continued the review of the global constrained forecasting model being developed by the German Aerospace Centre (DLR) for potential use in the assessment of the potential impact of constraints.

1.3.3 **Cost-effectiveness analysis of potential noise stringency options (Task F.02)**

1.3.3.1 The economic assessment of the noise stringency options under consideration for CAEP/9 was performed by the FESG Stringency Task Group (STG).

1.3.4 **Cost-effectiveness analysis of potential CO2 policy options (Task F.03)**

1.3.4.1 As the potential CO_2 policy options are still to be defined by WG3, no work has been initiated on the economic analysis since CAEP/8. The FESG has contributed to the work of the WMF Liaison Group (WG1-WG3-MDG-FESG) and the preparation of the CO_2 sample problem.

1.3.5 **Review of the FESG CAEP/8 forecast (Task F.04)**

1.3.5.1 A review of the CAEP/8 forecast was completed that compared the forecasting results with actual data. The objective of this task was to determine whether or not, in light of the events that occurred since the end of 2007, the FESG central forecast would remain the most likely scenario to be used in support to the CAEP/9-related work requiring the forecast (or should the low scenario of growth be used instead). The main conclusions of the review were that while for passenger services, traffic levels are expected to remain closer to the FESG CAEP/8 central forecast over the forecast time horizon, for cargo services, they are more likely to be closer to the low scenario of growth developed by the FESG. The CAEP/9 related analyses requiring the forecast took into consideration these conclusions

1.3.6 **Traffic and fleet forecasts (Task F.06)**

1.3.6.1 The FESG has completed the development of new traffic and fleet forecasts in support of the CAEP/10 analyses. The forecasts were developed by (32) route groups for both passenger and cargo services, over an overall time horizon of 30 years (from 2010 to 2040). New retirement curves have been developed (for passenger and cargo aircraft) as well as traffic projections to 2050. Sensitivity analyses were conducted around both the passenger and cargo traffic forecasts to generate low and high scenarios of growth. A forecast for aircraft with less than 20 seats has also been developed (for business jets only).

1.3.6.2 The Common Operations Database (COD) was used for the first time as the main source for the baseline operations and the current FESG consensus-based forecasting approach (complemented with additional adjustments and/or analyses specially designed to address issues that may arise) was used to develop the forecasts.

1.3.6.3 The FESG CAEP/9 forecast was developed in the wake of an exceptional economic downturn which has had a global impact. Oil and fuel have also sustained unusually high prices for an extended period. These events are likely to affect the global outlook for a number of years and will continue to be a source of downward risk on the future evolution of air traffic. The FESG CAEP/9 central forecast remains the most likely scenario. In terms of alternatives, the FESG CAEP/9 low scenario of growth is viewed to be a more plausible alternative than the high scenario of growth.

1.3.6.4 The total international and domestic passenger traffic forecasts are presented in Table 1, expressed in terms of average annual growth rate, and in Table 2, in revenue passenger-kilometres. In the most likely scenario (central forecast), the world passenger traffic, expressed in revenue passenger-kilometres, is expected to grow at the average annual growth rate of 4.9 per cent over the forecast period and at 4.0 per cent over the extension period. These growth rates fall to 4.2 per cent and 3.4 per cent respectively under the low scenario (pessimistic) and increase to 5.7 and 4.6 per cent respectively under the high scenario (optimistic).

1.3.6.5 The total cargo international and domestic traffic forecasts are presented in Table 3, expressed in terms of average annual growth rate, and in Table 4, in revenue tonne-kilometres. In the most likely scenario (central forecast), the world cargo traffic, expressed in revenue tonne-kilometres, is expected to grow at the average annual growth rate of 5.2 per cent over the forecast period and at 4.6 per cent over the extension period. These growth rates fall to 4.5 per cent and 4.2 per cent respectively under the low scenario (pessimistic) and increase to 5.6 and 4.6 per cent respectively under the high scenario (optimistic).

1.3.6.6 The combined passenger and cargo international and domestic traffic forecasts are presented in Table 5, expressed in terms of average annual growth rate, and in Table 6, in revenue tonne-kilometres. In the most likely scenario (central forecast), the world combined passenger and cargo traffic, expressed in revenue tonne-kilometres, is expected to grow at the average annual growth rate of 5.0 per cent over the forecast period and at 4.2 per cent over the extension period. These growth rates fall to 4.3 per cent and 3.7 per cent respectively under the low scenario (pessimistic) and increase to 5.7 and 4.6 per cent respectively under the high scenario (optimistic).

1.3.6.7 Tables 7 and 8 illustrate the detailed forecast by major route group for the most likely (central forecast) for the passenger and cargo forecasts, respectively.

1.3.6.8 In accordance with the MDG requirements, traffic projections to 2050 were developed for both the passenger and cargo forecasts (for the most likely, the low and the high scenarios of growth). The combined passenger and cargo traffic forecasts including projections to 2050 are presented in Table 9, expressed both in terms of average annual growth rates in revenue tonne-kilometres and in revenue tonne-kilometres.

Table 1. CAEP/9 Passenger Traffic Growth Rate Forecast – Central Forecast and Sensitivity Analysis
Most likely, High and Low Scenarios (Average annual growth rate of revenue passenger-kilometres)

Scenario / Sector	2010 -2020	2020 -2030	2030 -2040	2010 -2030	2010 -2040
High Scenario (Optimistic)	[% growth]				
Total International	6.4	5.4	4.6	5.9	5.5
Total Domestic	5.2	5.2	4.5	5.2	5.0
Global [International + Domestic]	**6.0**	**5.3**	**4.6**	**5.7**	**5.3**
Most Likely Scenario (Central Forecast)					
Total International	5.6	4.7	4.1	5.1	4.8
Total Domestic	4.7	4.2	3.8	4.4	4.2
Global [International + Domestic]	**5.3**	**4.5**	**4.0**	**4.9**	**4.6**
Low Scenario (Pessimistic)					
Total International	4.8	4.0	3.6	4.4	4.1
Total Domestic	4.2	3.2	3.0	3.7	3.5
Global [International + Domestic]	**4.6**	**3.7**	**3.4**	**4.2**	**3.9**

Table 2. CAEP/9 Passenger Traffic Forecast – Central Forecast and Sensitivity Analysis
Most likely, High and Low Scenarios

	Revenue passenger-kilometres [RPKs]			
	Actual	**CAEP/9 Forecast**		
Scenario / Sector	**2010**	**2020**	**2030**	**2040**
High Scenario (Optimistic)	[billions]			
Total International	3 253.6	6 064.4	10 292.2	16 125.3
Total Domestic	1 797.2	2 981.7	4 931.0	7 674.3
Global [International + Domestic]	5 050.8	9 046.0	15 223.3	23 799.6
Most Likely Scenario (Central Forecast)				
Total International	3 253.6	5 607.8	8 879.8	13 263.7
Total Domestic	1 797.2	2 845.2	4 276.8	6 197.9
Global [International + Domestic]	5 050.8	8 453.1	13 156.7	19 461.6
Low Scenario (Pessimistic)				
Total International	3 253.6	5 190.8	7 688.4	10 949.9
Total Domestic	1 797.2	2 716.6	3 732.7	5 036.9
Global [International + Domestic]	5 050.8	7 907.4	11 421.1	15 986.8

Table 3. CAEP/9 Cargo Traffic Growth Rate Forecast– Central Forecast and Sensitivity Analysis
Most likely, High and Low Scenarios (Average annual growth rate of revenue tonne-kilometres)

Scenario / Sector	2010 -2020	2020 -2030	2030 -2040	2010 -2030	2010 -2040
High Scenario (Optimistic)	[% growth]				
Total International	5.4	6.3	4.7	5.8	5.4
Total Domestic	4.0	5.3	4.4	4.6	4.6
Global [International + Domestic]	5.1	6.1	4.6	5.6	5.3
Most Likely Scenario (Central Forecast)					
Total International	5.2	5.7	4.7	5.4	5.2
Total Domestic	3.8	4.6	4.4	4.2	4.3
Global [International + Domestic]	4.9	5.5	4.6	5.2	5.0
Low Scenario (Pessimistic)					
Total International	5.0	4.4	4.3	4.7	4.5
Total Domestic	3.6	3.3	4.0	3.5	3.7
Global [International + Domestic]	4.8	4.2	4.2	4.5	4.4

Table 4. CAEP/9 Cargo Traffic Forecast – Central Forecast and Sensitivity Analysis
Most likely, High and Low Scenarios

	Revenue tonne-kilometres [RTKs]			
	Actual	**CAEP/9 Forecast**		
Scenario / Sector	**2010**	**2020**	**2030**	**2040**
High Scenario (Optimistic)	[billions]			
Total International	168.8	284.3	523.5	825.4
Total Domestic	34.4	51.0	85.3	131.1
Global [International + Domestic]	**203.2**	**335.3**	**608.8**	**956.5**
Most Likely Scenario (Central Forecast)				
Total International	168.8	278.9	483.8	764.2
Total Domestic	34.4	50.0	78.8	121.4
Global [International + Domestic]	**203.2**	**328.9**	**562.6**	**885.6**
Low Scenario (Pessimistic)				
Total International	168.8	274.0	419.6	638.0
Total Domestic	34.4	49.2	68.3	101.3
Global [International + Domestic]	**203.2**	**323.1**	**487.9**	**739.4**

Table 5. CAEP/9 Combined Passenger and Cargo Traffic Growth Rate Forecast – Central Forecast and Sensitivity Analysis – Most likely, High and Low Scenarios (Average annual growth rate of revenue tonne-kilometres)

Scenario / Sector	**2010 -2020**	**2020 -2030**	**2030 -2040**	**2010 -2030**	**2010 -2040**
High Scenario (Optimistic)	[% growth]				
Total International	6.1	5.7	4.6	5.9	5.5
Total Domestic	5.0	5.2	4.5	5.1	4.9
Global [International + Domestic]	**5.8**	**5.6**	**4.6**	**5.7**	**5.3**
Most Likely Scenario (Central Forecast)					
Total International	5.4	5.0	4.3	5.2	4.9
Total Domestic	4.6	4.2	3.9	4.4	4.2
Global [International + Domestic]	**5.2**	**4.8**	**4.2**	**5.0**	**4.7**
Low Scenario (Pessimistic)					
Total International	4.8	4.1	3.8	4.5	4.3
Total Domestic	4.1	3.2	3.2	3.7	3.5
Global [International + Domestic]	**4.6**	**3.9**	**3.7**	**4.3**	**4.1**

Table 6. CAEP/9 Combined Passenger and Cargo Traffic Forecast – Central Forecast and Sensitivity Analysis Most likely. High and Low Scenarios

	Revenue tonne-kilometres [RTKs]			
	Actual	**CAEP/9 Forecast**		
Scenario / Sector	**2010**	**2020**	**2030**	**2040**
High Scenario (Optimistic)	[billions]			
Total International	494.1	890.7	1 552.7	2 438.0
Total Domestic	214.1	349.2	578.4	898.5
Global [International + Domestic]	708.2	1 239.9	2 131.1	3 336.5
Most Likely Scenario (Central Forecast)				
Total International	494.1	839.7	1 371.8	2 090.6
Total Domestic	214.1	334.6	506.5	741.2
Global [International + Domestic]	708.2	1 174.2	1 878.3	2 831.7
Low Scenario (Pessimistic)				
Total International	494.1	793.1	1 188.4	1 733.0
Total Domestic	214.1	320.8	441.6	605.0
Global [International + Domestic]	708.2	1 113.9	1 630.0	2 338.0

Table 7. CAEP/9 Passenger Traffic Growth Rate– Most likely scenario (Central forecast)
(Average annual growth rate of revenue passenger-kilometres)

Sector / Route Groups	2010 -2020	2020 -2030	2030 -2040	2010 -2030	2010 -2040
International			[% Growth]		
1. North Atlantic	4.0	3.8	3.4	3.9	3.7
2. South Atlantic	5.6	4.6	4.0	5.1	4.7
3. Mid Atlantic	4.3	4.0	3.5	4.1	3.9
4. Americas ←→ China/Mongolia	7.7	6.1	5.0	6.9	6.3
5. Americas ←→ India/Southwest Asia	10.9	6.8	5.4	8.8	7.7
6. Americas ←→ Other Asia/Pacific	4.3	3.4	3.1	3.8	3.6
7. Europe ←→ China/Mongolia	8.2	6.0	4.9	7.1	6.4
8. Europe ←→ India/Southwest Asia	7.1	6.1	5.0	6.6	6.1
9. Europe ←→ Other Asia/Pacific	4.4	3.5	3.2	3.9	3.7
10. Europe ←→ Africa	5.0	4.1	3.6	4.5	4.2
11. Europe ←→ Middle East	5.8	4.4	3.8	5.1	4.7
12. North America ←→ South America	6.4	5.5	4.6	5.9	5.5
13. North America ←→ Central America and Caribbean	4.4	3.9	3.5	4.1	3.9
14. Middle East ←→ China/Mongolia	9.8	7.6	5.9	8.7	7.8
15. Middle East ←→ India/Southwest Asia	7.0	6.0	4.9	6.5	6.0
16. Middle East ←→ Other Asia/Pacific	7.1	5.2	4.4	6.1	5.6
17. Intra Africa	6.3	5.1	4.3	5.7	5.2
18. Intra Asia/Pacific	7.0	5.5	4.6	6.2	5.7
19. Intra Europe	4.5	4.0	3.5	4.2	4.0
20. Intra Latin America	7.5	6.3	5.1	6.9	6.3
21. Intra Middle East	6.5	5.0	4.3	5.7	5.3
22. Intra North America	2.8	2.6	2.4	2.7	2.6
23. Other International Routes	8.5	5.8	4.8	7.1	6.4
Total International	**5.6**	**4.7**	**4.1**	**5.1**	**4.8**
Domestic					
24. Africa	5.5	5.0	4.3	5.2	4.9
25. China/Mongolia	8.8	6.0	4.9	7.4	6.6
26. Europe	3.3	3.2	2.9	3.2	3.1
27. Latin America	6.5	5.6	4.7	6.0	5.6
28. Middle East	4.7	4.0	3.5	4.3	4.1
29. North America	2.4	2.2	2.1	2.3	2.2
30. Japan	2.2	1.6	1.5	1.9	1.8
31. Other Asia/Pacific	6.5	5.2	4.4	5.8	5.4
32. India/Southwest Asia	10.8	7.7	6.0	9.2	8.1
Total Domestic	**4.7**	**4.2**	**3.8**	**4.4**	**4.2**
Global [International + Domestic]	**5.3**	**4.5**	**4.0**	**4.9**	**4.6**

Table 8. CAEP/9 Cargo Traffic Growth Rate Forecast– Most likely scenario (Central forecast)
(Average annual growth rate of revenue tonne-kilometres)

Sector / Route Groups	2010 -2020	2020 -2030	2030 -2040	2010 -2030	2010 -2040
International			[% Growth]		
1. North Atlantic	3.1	3.7	2.7	3.4	3.2
2. South Atlantic	4.9	5.2	4.1	5.0	4.7
3. Mid Atlantic	4.9	5.2	4.1	5.0	4.7
4. Americas ←→ China/Mongolia	5.1	5.4	4.3	5.2	4.9
5. Americas ←→ India/Southwest Asia	5.1	5.4	4.3	5.2	4.9
6. Americas ←→ Other Asia/Pacific	5.1	5.4	4.3	5.2	4.9
7. Europe ←→ China/Mongolia	5.3	6.3	4.9	5.8	5.5
8. Europe ←→ India/Southwest Asia	6.3	5.7	5.2	6.0	5.7
9. Europe ←→ Other Asia/Pacific	5.3	6.3	4.9	5.8	5.5
10. Europe ←→ Africa	4.8	5.2	4.5	5.0	4.8
11. Europe ←→ Middle East	5.3	5.9	4.5	5.6	5.2
12. North America ←→ South America	5.4	5.1	4.2	5.2	4.9
13. North America ←→ Central America and Caribbean	5.4	5.1	4.2	5.2	4.9
14. Middle East ←→ China/Mongolia	5.3	5.0	4.6	5.1	5.0
15. Middle East ←→ India/Southwest Asia	5.3	5.0	4.6	5.1	5.0
16. Middle East ←→ Other Asia/Pacific	5.3	5.0	4.6	5.1	5.0
17. Intra Africa	5.3	5.0	4.6	5.1	5.0
18. Intra Asia/Pacific	7.2	7.7	6.4	7.4	7.1
19. Intra Europe	2.0	2.6	2.0	2.3	2.2
20. Intra Latin America	5.3	5.0	4.6	5.1	5.0
21. Intra Middle East	5.3	5.0	4.6	5.1	5.0
22. Intra North America	1.8	2.2	1.7	2.0	1.9
23. Other International Routes	5.3	5.0	4.6	5.1	5.0
Total International	**5.2**	**5.7**	**4.7**	**5.4**	**5.2**
Domestic					
24. Africa	5.3	5.0	4.6	5.1	5.0
25. China/Mongolia	8.0	7.6	6.5	7.8	7.4
26. Europe	2.0	2.6	2.0	2.3	2.2
27. Latin America	5.3	5.0	4.6	5.1	5.0
28. Middle East	5.3	5.0	4.6	5.1	5.0
29. North America	1.8	2.2	1.7	2.0	1.9
30. Japan	7.2	7.7	6.4	7.4	7.1
31. Other Asia/Pacific	7.2	7.7	6.4	7.4	7.1
32. India/Southwest Asia	5.3	5.0	4.6	5.1	5.0
Total Domestic	**3.8**	**4.6**	**4.4**	**4.2**	**4.3**
Global [International + Domestic]	**5.3**	**4.9**	**5.5**	**4.6**	**5.2**

Table 9. CAEP/9 Combined Passenger and Cargo Traffic Forecasts (including Projections to 2050) – Central Forecast and Sensitivity Analysis – Most likely, High and Low Scenarios (Average annual growth rate of revenue tonne-kilometres)

Scenario / Sector	2010 -2020	2020 -2030	2030 -2040	2040 -2050	Actual 2010	CAEP/9 Forecast 2020	2030	2040	2050
High Scenario (Optimistic)	[% growth]				[Billions RTK]				
Total International	6.1	5.7	4.6	4.2	494	891	1 553	2 438	3 679
Total Domestic	5.0	5.2	4.5	4.1	214	349	578	899	1 345
Global [International + Domestic]	**5.8**	**5.6**	**4.6**	**4.2**	**708**	**1 240**	**2 131**	**3 336**	**5 024**
Most Likely Scenario (Central Forecast)									
Total International	5.4	5.0	4.3	3.7	494	840	1 372	2 091	3 013
Total Domestic	4.6	4.2	3.9	3.5	214	335	506	741	1 049
Global [International + Domestic]	**5.2**	**4.8**	**4.2**	**3.7**	**708**	**1 174**	**1 878**	**2 832**	**4 062**
Low Scenario (Pessimistic)									
Total International	4.8	4.1	3.8	3.4	494	793	1 188	1 733	2 414
Total Domestic	4.1	3.2	3.2	3.0	214	321	442	605	812
Global [International + Domestic]	**4.6**	**3.9**	**3.7**	**3.3**	**708**	**1 114**	**1 630**	**2 338**	**3 226**

1.3.6.9 The passenger fleet mix forecast by seat category is presented in Table 10 for the most likely scenario. The fleet of passenger aircraft is expected to grow by an average annual rate of 3.6 per cent between 2010 and 2040. As a result, the size of the fleet will more than double by 2030 and almost triple in 2040. The biggest increases (in terms of number of aircraft) are expected to be in the 211-300, 176-210 and 151-175 seat categories.

Table 10. CAEP/9 Passenger Fleet Mix Forecast by Seat Category
Most Likely Scenario (Central Forecast)

Seat category	2010	2020	2030	2040
20-50	2 961	3 299	3 958	4 476
51-70	1 113	2 183	3 240	4 493
71-85	935	1 438	1 984	2 591
86-100	623	821	1 115	1 565
101-125	1 450	1 993	2 662	3 383
126-150	4 038	5 415	6 908	8 377
151-175	3 487	5 078	6 575	8 324
176-210	1 925	3 943	5 760	7 538
211-300	2 076	3 622	6 314	8 979
301-400	821	1 434	2 243	3 884
401-500	292	544	982	1 496
501-600	10	83	264	671
600+		19	238	762
Total	**19 732**	**29 872**	**42 242**	**56 537**

1.3.6.10 Although the fastest growth (in per cent) is expected to be observed in the fleet of aircraft with more than 400 seats, their share in the total fleet (in terms of number of aircraft) will be about 3.5

and 5.2 per cent in 2030 and 2040 respectively. The lowest growth is expected to be in the 101-125 and 126-150 seat categories whose combined share in the total fleet will fall from 27.1 per cent in 2010 to 21.6 per cent and 20 per cent in 2030 and 2040, respectively.

1.3.6.11 The fleet forecast for business jet aircraft is presented in Table 11.

Table 11. CAEP/9 Forecast of Aircraft with Less than 20 Seats
In-Service Business Jet Aircraft Fleet

Regions	**2010**	**2020**	**2030**	**2040**
Africa	320	545	965	1 641
Europe	2 180	3 975	6 650	10 831
Middle East	1 400	2 190	3 050	4 258
Latin America and Caribbean	380	745	1 435	2 593
North America	9 700	11 390	13 580	16 356
Asia/Pacific				
China	150	1 070	2 450	4 936
India/Southwest Asia	155	470	1 365	3 092
North Asia	56	110	200	347
Pacific and South East Asia	249	486	881	1 525
Total [World]	**14 590**	**20 981**	**30 576**	**45 579**

1.3.6.12 Table 12 presents the freighter fleet forecast for the most likely scenario by seat category.

Table 12. CAEP/9 Freighter Fleet Forecast by Seat Category
Most Likely Scenario (Central Forecast)

Seat category	**2010**	**2020**	**2030**	**2040**
20-50	765	819	891	973
51-70	133	113	115	117
71-85	2	29	35	37
86-100	70	71	79	86
101-125	225	36	39	49
126-150	44	130	354	539
151-175	59	245	395	606
176-210	192	460	484	701
211-300	583	633	913	1 342
301-400	227	342	698	1 044
401-500	60	33	11	11
501-600	295	329	300	437
600+	2	118	239	350
Total	**2 657**	**3 358**	**4 553**	**6 292**

1.3.7 Projections to 2050

1.3.7.1 Following a review of potential methodologies, a polynomial extrapolation approach was used to extend the forecast time horizon by an additional ten-year period and project the 2040 traffic volumes to 2050. The combined passenger and cargo traffic forecasts including projections to 2050 are presented in Table 13.

Table 13. CAEP/9 Combined Passenger and Cargo Traffic Forecasts (including Projections to 2050)
Central Forecast and Sensitivity Analysis – Most likely, High and Low Scenarios

Scenario / Sector	2010 -2020	2020 -2030	2030 -2040	2040 -2050	Actual 2010	CAEP/9 Forecast 2020	2030	2040	2050
High Scenario (Optimistic)	[% growth] [1]				[Billions RTK]				
Total International	6.1	5.7	4.6	4.2	494	891	1 553	2 438	3 679
Total Domestic	5.0	5.2	4.5	4.1	214	349	578	899	1 345
Global [International + Domestic]	**5.8**	**5.6**	**4.6**	**4.2**	**708**	**1 240**	**2 131**	**3 336**	**5 024**
Most Likely Scenario (Central Forecast)									
Total International	5.4	5.0	4.3	3.7	494	840	1 372	2 091	3 013
Total Domestic	4.6	4.2	3.9	3.5	214	335	506	741	1 049
Global [International + Domestic]	**5.2**	**4.8**	**4.2**	**3.7**	**708**	**1 174**	**1 878**	**2 832**	**4 062**
Low Scenario (Pessimistic)									
Total International	4.8	4.1	3.8	3.4	494	793	1 188	1 733	2 414
Total Domestic	4.1	3.2	3.2	3.0	214	321	442	605	812
Global [International + Domestic]	**4.6**	**3.9**	**3.7**	**3.3**	**708**	**1 114**	**1 630**	**2 338**	**3 226**

[1] Average annual growth rate of revenue tonne-kilometres [RTK].

1.3.7.2 The FESG Co-Rapporteur provided some FESG observations of the forecast work. The FESG CAEP/9 forecast was developed in the wake of an exceptional economic downturn. Oil and fuel also sustained unusually high prices for an extended period. These events are likely to affect the global outlook for a number of years and will continue to be a source of downward risk on the future evolution of air traffic. The FESG Co-Rapporteur suggested that the central forecast represents the most likely scenario, and in terms of alternatives, the low scenario is viewed as a more plausible outcome than the high scenario of growth.

Discussion and Conclusions

1.3.8 The meeting congratulated the FESG for the tremendous amount of high quality work done and in particular on the forecast which was developed in an accelerated manner in addition to the other tasks assigned by CAEP/8. Based on the observations made by the FESG, the shortened timeframe allocated to the review of the forecast within FESG itself was highlighted, and while not taking away from the quality of the forecast, a member suggested that future FESG work should include a more lengthy review period and that a closing report be presented to a future CAEP Steering Group meeting. The meeting once more commended FESG on its efforts and endorsed the FESG CAEP/9 forecast, recognising the importance of the forecast to informing CAEP/9 and future deliberations.

1.3.9 Following a discussion, the meeting also recognised the importance of considering the impact of constraints on the forecasted growth. The member also noted that the forecast is a projection and that economic upturns and downturns are not taken into account, thus the forecast may be optimistic.

1.3.10 **Recommendation**

1.3.10.1 In light of the foregoing discussion, the meeting developed the following recommendation:

Recommendation 1/1 — Acceptance of the Traffic and Fleet Forecasts

That the FESG Traffic and Fleet Forecasts be used as the basis for all environmental analyses undertaken by CAEP during the CAEP/10 cycle.

1.4 AIRPORT CARBON AND EMISSIONS REPORTING TOOL (ACERT)

1.4.1 A member and an observer explained that the Canadian Department of Transport and ACI have worked together to develop the Airport Carbon and Emissions Reporting Tool (ACERT). The tool is a self-contained Excel spread sheet that enables an airport operator to calculate its own greenhouse gas (GHG) emissions inventory. ACERT uses data on airport land and airside operations, including fuel, electricity and the movements of aircraft and passengers. A report is automatically generated showing the GHG inventory in tabular and graphical forms. Emissions are divided into Scopes 1, 2 and 3, depending on the ownership and locations of the emissions source. An airport can use ACERT to establish a GHG management program and ACI plans to compile the data in order to be able to aggregate regional and global airport-related emissions. ACERT is available at no cost to airports.

Discussion and Conclusions

1.4.2 There was general recognition of the value of such tools in order to support voluntary actions taken by airports.

1.4.3 On the issue of the calculation of aircraft operations by this tool, it was explained that ACERT computes aircraft emissions in a manner compatible with the ICAO Airport Air Quality Manual (Doc 9889). The data required by the tool is typically available for the airport and does not rely on specific data collection by aircraft operators.

1.4.4 The meeting agreed that there is no one size fits all solution and highlighted that the tool is available free of charge if a State wishes to use it.

1.4.5 In responding to a question regarding the existence of other tools addressing the same emissions and the possibility of double-counting, the meeting noted that some States have legal, technical, or specific local reasons (e.g. assumptions over fuel tankering and the use of de-icing) that may apply when considering using the ACERT tool. It was also explained that double-counting is avoided because the tool separates the scope 1, 2, and 3 emissions. The meeting encouraged that available tools be reviewed in order to select that which is most appropriate for the type of analysis being conducted.

1.5 AIRPORT CARBON ACCREDITATION PROGRAMME

1.5.1 An observer presented the *Airport Carbon Accreditation Programme*, for recognizing the progress by airports managing their greenhouse gas emissions and providing accreditation for different levels of achievement. *Airport Carbon Accreditation* is now available to airports in the European and

Asia-Pacific regions. After 3 years, 69 airports are accredited in Europe, including 14 airports at the highest level "Neutrality" and, after 1 year, 6 airports are accredited in Asia Pacific. Plans are underway to bring the scheme to other regions.

Discussion and Conclusions

1.5.2 Many members expressed their support to the *Airport Carbon Accreditation Programme*. The observer explained that third party verification is part of the process as a safeguard to ensure that appropriate data and methodologies have been used in developing the inventory, and that this allows the programme to be flexible enough to accommodate international differences.

1.6 CARBON FOOTPRINT OF INDIAN AVIATION

1.6.1 A member presented the first-ever comprehensive carbon footprint of Indian aviation for 2011. The main stakeholders of Indian aviation involved in the creation of this carbon footprint, the data collection process, and analyses calculation and data reliability issues were reviewed. The emission sources included in the analysis and the results of the carbon footprint calculations were provided.

1.7 RESEARCH EFFORTS TO REDUCE EMISSIONS FROM AVIATION

1.7.1 Two members explained that Canada and the United States are advancing a number of research efforts to reduce emissions from aviation. Under the auspices of the Next Generation Air Transportation System (NextGen), the U.S. Federal Aviation Administration (FAA), in collaboration with other government departments and agencies and aviation stakeholders, continues to advance and implement its five-pillar strategy to effectively address aviation environmental impacts. These efforts are being conducted in collaboration with Transport Canada through the Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER) Center of Excellence as well as other avenues. Under the Clean Transportation Initiative, Transport Canada, in collaboration with the National Research Council and aviation stakeholders, is funding projects to reduce aviation emissions in support of Government of Canada priorities.

Discussion and Conclusions

1.7.2 The meeting congratulated the members for their cooperation on such significant areas of research. The meeting also noted that similar cooperation is on-going in other regions of the world, encouraging further such coordination, and requested that relevant information resulting from these initiatives be shared with CAEP.

1.8 REPORT OF THE IMPACTS AND SCIENCE GROUP

1.8.1 The Co-Rapporteurs of the Impacts and Science Group (ISG) provided an overview of the activities of the ISG since CAEP/8. They gave details on papers that have been prepared by the ISG on aircraft particulate matter; aviation and climate; and the role of aviation in a 2 degree world. They explained that the papers were prepared considering the caveats associated with the source materials used and in the context of the materials available in each of the topic areas. The ISG Co-Rapporteurs explained that the information presented in the reports could be used for their quantitative and qualitative aspects, to support cost-benefit analyses, and to highlight areas where future work may be needed. It was also explained that the papers were developed without consideration of their political context, but based on scientific information alone.

1.8.2 **Aircraft Particulate Matter (PM) emissions: state of science**

1.8.2.1 Aircraft engines emit both non-volatile (i.e., soot) particulate matter and gases that condense to form volatile PM after emission. Condensable gases can both form new particles and can coat the emitted soot particles. Organic volatile PM species dominate total aviation particle number at idle powers for the engines studied to date, while soot particle numbers become as important at take-off powers where soot also dominates the mass emissions. Sulfur-related condensable emissions are important in nucleating new particles with typical fuel sulfur levels in jet fuel. A standardized measurement methodology to quantify non-volatile PM emissions is currently under development by SAE E-31. Despite smaller mass emissions from newer technology engines, the local and regional health implications of directly emitted and secondarily-formed PM require quantification and assessment. Quantification of emitted PM number concentrations may also be important for health characterization, related to elevated exposures in close proximity to aircraft operations.

Discussion and Conclusions

1.8.2.2 A member asked for an opinion of ISG on particulate matter from smaller and larger engines. It was explained that all gas turbine engines, independent of their thrust, emit similar PM emissions, however the work of the Committee will help to provide improved understanding in this area. The meeting agreed that should this report be updated in the future, that this discussion and the discussion related to the relationship between particle number, mass, and surface area should be further expanded.

1.8.3 **Aviation and climate: state of the science**

1.8.3.1 Aviation operations emit gases and aerosol that change the composition of the atmosphere, cause increases in cloudiness through contrail formation and spreading, and may modify natural clouds. At present, scientific studies suggest that that these changes represent a net positive forcing of Earth's climate system, which contributes to surface warming and other responses. There is substantial understanding of the components of aviation climate forcing specifically of the effects of CO_2 emissions. This paper presents a summary of these components and recent progress in the state of the science, especially related to contrails and induced cloudiness, aerosol and NOx effects, and emissions from alternative aviation fuels.

Discussion and Conclusions

1.8.3.2 The meeting identified a number of areas where additional information is desired, should the paper be updated in the future. The meeting noted that the effects of black carbon on the global climate are just starting to be understood, compared to the more direct link to health effects that have been established. The meeting also expressed their interest in being able to put the PM emissions from aviation into context with those from other sectors, such as the maritime sector, as well as to better understand the effects that alternative fuels can have on PM emissions. The meeting noted that analyses have shown that the combustion of alternative aviation fuels results in reduced particle mass, number, as well as diameter.

1.8.3.3 The meeting noted the scientific uncertainties associated with cirrus-induced cloudiness and agreed that additional understanding of these effects was needed. The ISG Co-Rapporteur explained that much of the information presented in this paper will also be discussed in the IPCC 5th Assessment Report.

1.8.4 **The role of aviation in a 2 degree world**

1.8.4.1 The Copenhagen Accord recognizes the scientific view that global mean surface temperatures should not increase by more than 2 degrees C by 2100, over pre-industrial levels (1750). The last IPCC WGI assessment report of 2007 showed that temperatures had already increased by 0.9 degrees C by 2005. Instrumental data records show that global mean concentrations of CO_2 continue to increase and recent global emissions assessments show that emissions continue to increase, despite the global economic crisis. The science indicates that emissions should peak in the near term and thereafter decline rapidly if the 2 degree target is achieved. If global emissions do not decrease, more rapid emissions decreases will be required after the peak, or at some point an increase in global mean surface temperature of more than 2 degrees will be inevitable. A recent assessment of UNEP examined whether current emissions reductions pledges by 2020 would be on track for the 2 degree target and showed that they were not enough, by 6 to 11 gigatones (Gt) of CO_2 equivalents. However, a sector-by-sector evaluation of potential emissions reductions showed that this 'emissions gap' between required emissions reductions and projected emissions could be closed. Aviation emissions were included in the UNEP assessment, and technology, biofuel substitution and operations all had a role to play. Market-based measures as a means to reduce aviation emissions were not included in the UNEP assessment. A range of published aviation emissions projections to 2050 were considered in the UNEP assessment, including those of CAEP, and it was shown that as a worst case, aviation emissions could be up to 15% of CO_2 emissions as a maximum by 2050 under a 2 degree scenario, if extra action is not taken by aviation and all other sectors made drastic changes.

1.8.4.2 The ISG Co-Rapporteurs also provided some views on how the broad context and information might be used within national and international policy and strategies contexts. This included: information on the availability of the three reports for use by States and ICAO; the view that the ISG papers present a consensus briefing of the latest state of the science, not a detailed scientific assessment, suited for briefing CAEP Members and Observers; an overview of the importance of global CO_2 emissions reductions and that a reduction of aviation CO_2 emissions can contribute toward the goal of limiting the increase in global mean surface air temperature to <2°C and; an outline of the potentially significant non-CO_2 effects from aviation and the impacts on human health from PM emissions.

1.8.4.3 The Co-Rapporteurs further noted that the overall context within CAEP is that of regulation and policies to address environmental effects. The ISG cannot offer advice on regulations and policies. Providing policy and regulatory advice would entail substantial discussion and debate which is outside the remit of ISG. The ISG Co-Rapporteurs do note that CAEP Members and observers may wish to make use of the information presented to inform policies and regulation. The information can be used in either a quantitative manner (as for example used by at least one Member State to perform Cost Benefit Analyses) or in a qualitative manner. The Co-Rapporteurs added that, overall, it is important to understand that we should aim to inform policy decisions and regulatory actions with the best available and most robust science. However, more robust scientific information will not necessarily make policy decisions easier, given the complexities of international policy decisions as well as the inherent complexities of the science itself, but it will hopefully make these decisions better informed.

Discussion and Conclusions

1.8.4.4 The meeting recommended that should this paper be updated in the future that it also consider the context of the goals being set specifically for aviation, such as those adopted by the 37th Session of the ICAO Assembly.

1.8.4.5 The meeting thanked the ISG for the clear presentation of the current science in these three areas and found the papers to be directly relevant for the work of CAEP. A member highlighted that the information will directly support policymaking in his State. The meeting also recognized that within the UN, scientific advice is provided first and foremost by the IPCC. However, that does not preclude the collection of interim information from groups like the ISG, bearing in mind that it reflects the view of the scientists involved and by no means constitutes a position or opinion of CAEP or ICAO on these matters.

1.9 AVIATION CO_2 EMISSIONS IN CONTEXT

1.9.1 The Secretariat explained that in support of constructive discussions related to the treatment of international aviation CO_2 emissions, it is useful to be able to place them in the appropriate context relative to other emissions sources. The last formal assessment by the IPCC (1999) may no longer be reflective of the current share of CO_2 emissions produced by international aviation. CAEP was asked to consider whether an update by the IPCC or through CAEP to those figures would be useful.

Discussion and Conclusions

1.9.2 The meeting agreed that prior to investing the significant resources required to thoroughly update the analysis conducted by the IPCC for the Aviation and the Global Atmosphere report, it would be best to first ask the ISG to compile peer-reviewed estimates of global CO_2 emissions by sector that can be used by ICAO. This would allow the Committee to better understand if further investigation was needed. The meeting supported adding this to the ISG work programme pending a discussion on priorities and resource availability.

1.9.3 An observer recommended that the updated information also consider the non-CO_2 effects of aviation emissions. The meeting noted that this information has been requested of the IPCC by ICAO and that current scientific uncertainties limit their ability to provide a complete response.

1.10 WMO METEOROLOGICAL AND CLIMATOLOGICAL SERVICES

1.10.1 An observer presented information on the meteorological and climatological services available through the WMO for supporting sustainable aviation. Information was presented on the role of WMO in climate monitoring and their on-going activities. The WMO Global Framework for Climate Services was established to better manage the risks of climate variability and change through the develop and incorporation of science-based climate information and prediction into planning, policy and practice. The WMO has also adopted a quality management framework to ensure the highest standards of data quality and integrity. The data available through these initiatives may be of interest to CAEP.

1.10.2 WMO aims to further collaborate to improve data collection from aircraft in support of climate research. In particular, measurements by aircraft can directly improve scientific understanding of contrail formation.

Discussion and Conclusions

1.10.3 The meeting found the initiatives by WMO interesting and potentially of significant benefit to ICAO analyses. The Secretariat confirmed that ICAO supports WMO in these activities and would strive to support WMO in establishing agreements to facilitate this project. The meeting found this type of cooperation to be a positive example of aviation being part of the climate change solution. The implementation of wide-scale airborne measurement would require resources, that are yet to be identified, however.

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APPENDIX

Summary of models and databases evaluated for CAEP/9

Modelling Area	Model / Database Name	Release	Release Date	Lead	Sponsoring Organization
Noise	AEDT	2.0	2011	Sathya Balasubramanian	US FAA
	ANCON2	2.3	October 2010	Darren Rhodes	UK DfT
	ICAO NoisedB	2.13	13 September 2012	Bruno Hamon	France DGAC http://noisedb.stac.aviation-civile.gouv.fr/
	STAPES	1.2	October 2009	Laurent Cavadini	EUROCONTROL/EC/EASA
Local air quality	ADMS	3.1	May 2012	David Carruthers	UK DfT
	AEDT	2.0	2011	Sathya Balasubramanian	US FAA
	ALAQS	V2.0	December 2009	Robin Deransy	EUROCONTROL
	LASPORT	2.0.11	March 2011	Ulf Janicke	Swiss Federal Office for Civil Aviation (FOCA) German Ministry of Transport (BMVBS)
	PEGAS	1.2	June 2011	Yury Medvedev	Russian Federation Civil Aviation Environmental Safety Center (CAESC)
Greenhouse Gas	AEDT	2.0	2011	Sathya Balasubramanian	US FAA
	AEM	AEM-Kernel v2	February 2012	Robin Deransy	EUROCONTROL
	Aero2k[1]	2.0	Nov 2008	Gareth Horton	UK DfT
	FAST	FAST_v2_CAEP9_100212	10 February 2012	David Lee	UK DfT
Economics	APMT/Economics*	5.4.19	5 April 2012	Maryalice Locke	US FAA
	NOx Cost	4.0	2009	Larry Gray	FESG
	Noise Cost	2.0	2012	Larry Gray	FESG
All	Airports Database	2.1.13	9 February 2012	Robin Deransy and Gregg Fleming	US FAA, EUROCONTROL
All	Common Operations Database	3.0	12 December 2010	Robin Deransy and Gregg Fleming	US FAA, EUROCONTROL
All	2006 Campbell-Hill Fleet Database	CAEP/8	December 2007	Nancy Young	A4A, WG1-WG3
All	2006 Campbell-Hill Fleet Database Extension	CAEP/9	December 2010	Gregg Fleming	US FAA
All	Population Database	2.0	29 March 2011	Gary Baker	US FAA, EASA • http://www.census.gov/main/www/cen2000.html • http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=1018 • http://sedac.ciesin.columbia.edu/gpw/index.jsp
LAQ, GHG	ICAO aircraft engine emissions databank (EDB)	18A	January 2012	Werner Hoermann	EASA http://easa.europa.eu/environment/edb/aircraft-engine-emissions.php
All	ANP - Aircraft Noise and Performance	2.0	To Be Posted	Laurent Cavadini	EUROCONTROL http://www.eurocontrol.int/eec/public/standard_page/EEC_News_2005_2_ANP.html

[1] Model is currently not participating in CAEP analyses.

Modelling Area	Model / Database Name	Release	Release Date	Lead	Sponsoring Organization
All	Base of Aircraft Data (BADA)	3.9	15 April 2011	Angela Nuic	EUROCONTROL http://www.eurocontrol.int/products/bada
All	Forecasting and Operations Module	3.0	12 December 2010	Sathya Balasubramanian	US FAA
All	FESG Traffic Forecast (pax. + cargo)	CAEP/8	July 2008	Chaouki Mustapha (pax.) Ricky Mack (cargo)	ICAO Secretariat, FESG, ICCAIA
All	FESG Retirement Curves	CAEP/8	July 2008	Larry Gray	ICCAIA, FESG
All	Growth & Replacement Database*	4.1g	April 2012	Willem Franken	EASA, ICCAIA, WG1, WG3

* Reviewed by MDG and FESG for Noise Stringency only.

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Agenda Item 2: Review of technical proposals relating to aircraft engine emissions

2.1 REPORT OF WG3 – EMISSIONS TECHNICAL

2.1.1 Overview by the Rapporteurs of Working Group 3

2.1.1.1 The Rapporteurs of Working Group 3 (WG3) presented the review of the activities of Working Group 3 - Emissions Technical during the CAEP/9 Work programme. Working Group 3 and its Task Groups have met nine times to address the CAEP/9 work programme. The report provided an overview of progress on each of the work items. Most of the work items have been dealt with by three Task Groups [CO_2 (CO2TG); Particulate Matter (PMTG); Certification (CTG)]. Ad-Hoc groups were formed to address very specific topics, working mainly via teleconferences. The remaining items were under the direction of WG3 itself. Liaison with WG1, WG2, MDG, FESG and SAE has been through focal points and the WG3 co-Rapporteurs. Details on the work of the CO2TG and PMTG are provided in sections 2.5 and 2.4. An overview of amendments to Annex 16, Volume II and the Environmental Technical Manual, Volume II are given in sections 2.2 and 2.3 respectively.

2.1.1.2 Regarding technology goals, the Independent Expert (IE) review on fuel burn reduction technology goals, that was started during the CAEP/8 cycle, was approved at the 2010 CAEP Steering Group. During 2010 this was published as ICAO Document 9963. There has been no formal IE NO_x goals Review during CAEP/9. However, details were provided on a manufacturer led review of NO_x technology. The Co-Rapporteurs pointed out that during this review evidence had been presented which indicated that medium-term goals had been achieved by some large lean burn engines, and for single aisle aircraft sized engines these will likely be achieved by both traditional and lean burn combustion cycle engines.

2.1.1.3 WG3 has established a Fuel Efficiency Metric ad hoc group to carry out and co-ordinate fuel efficiency metric work within the CAEP work programme, in line with the recommendations accepted at the CAEP/8 meeting. The work conducted during the CAEP/9 cycle has identified a number of issues to be resolved that go beyond the original remit and potentially involve additional expertise and other groups.

2.1.1.4 Regarding alternative fuels and emissions, an overview of the status report on this subject is given in section 2.10. On fuel composition and emissions effects, the WG3 Co-Rapporteurs suggested that fewer data are being collected characterising uplifted fuel. The manufacturers reported difficulty getting fuel to meet the emissions specification as fuel is generally cleaner with low aromatics and napthalenes.

2.1.1.5 The WG3 Co-Rapporteurs reported (on Remit Item E.13) that since January 2012 the ICAO Aircraft Engine emissions Databank (EDB) is accessible from the EASA website (www.easa.europa.eu) and from the following direct link: http://easa.europa.eu/environment/edb/aircraft-engine-emissions.php. It was acknowledged the previous work done by UK maintaining the EDB and the work by EASA in setting up the new website. It was highlighted that WG3 has agreed on: the reporting of the number of significant figures in the datasheet; the datasheet template; and that 'sub-models' with the same emissions will have a unique identification (UID) in the EDB.

2.1.1.6 It was reported (on Remit Item E.14) that WG3 contributed to the update of the Growth & Replacement (G&R) Database in providing NO_x emissions and fuel flow data. The G&R Database has supported the noise stringency and environmental goals assessment in allowing consideration of the trade-off with emissions.

2.1.1.7 Regarding remit Item E.15, the analyses conducted indicate that the current LTO NO_x Standard encourages cruise NO_x reduction for both lean burn and conventional combustors. Studies strongly suggest that modern lean combustors provide potential for cruise NO_x emissions reductions that exceed the reductions at LTO conditions. The relative reductions will vary depending on specific details of the engine and aircraft designs, and will depend on the mission flown. At this point, it is not possible to generalise on relative reductions in service. Regarding new combustor concepts, further study would be needed to come up with a general conclusion on the relative cruise NO_x benefits.

2.1.1.8 The WG3 Co-Rapporteurs reported that there has been a lack of progress on Item E.16 (on the requirements for supersonic aircraft engine certification) during CAEP/9 due to other priorities and also there was no immediate pressure for regulatory related design guidance. It was suggested that this item should be maintained in the future work programme for CAEP/10. The effort on E .17 has focused on alternative architectures such as the Open Rotor engines and on the appropriateness of the use of the current LTO cycle and the associated Standards. It is presently unknown how alternative architectures will be incorporated into the aviation system and there remains considerable uncertainty over whether these technologies will reach the market. It was suggested that work during CAEP/10 should continue on this subject.

2.1.1.9 On co-ordination issues, WG3 has been involved in several cross cutting issue with other working groups, and a number of these have been related to the CO_2 Standard setting process. Since the 2012 Steering Group WG3 has been involved in the (WG1-WG3-MDG-FESG) WMF Liaison Group which has investigated the schedule for the development of the CO_2 Standard. Further details on this can be found in section 2.6.3.

Discussion and Conclusions

2.1.1.10 The meeting noted the progress of WG3. A member expressed concern over the proposed future work activities of WG3, noting that the future proposed work programme seemed to be quite expansive and that the CAEP needed to understand priorities of the work items, and particularly in relation to the work on the CO_2 Standard work. It was highlighted that the regulatory authorities may not have the resources available to embark on the development of two Standards simultaneously (i.e. CO_2 Standard and the PM certification requirement).

2.1.1.11 The meeting recognised the tremendous amount of work undertaken by WG3 during the CAEP/9 cycle.

2.2 PROPOSED AMENDMENTS TO ANNEX16 , VOLUME II

2.2.1 The Co-Rapporteurs of WG3 presented proposed amendments to Annex 16, Volume II. These changes were the result of the work carried out by WG3 under the CAEP/9 cycle work programme, in fulfilment of Remit E.11.

2.2.2 Work Item 1: Clarification on smoke sample size (Appendix 2)

2.2.2.1 The output of this work item was proposed in the Environmental Technical Manual (ETM), Volume II (see section 2.3).

2.2.3 **Work Item 2: "sample" / "sampling" terminology**

2.2.3.1 The words "sample" and "sampling" are used inconsistently in Appendix 2 and in Appendix 3. The rule is that "sample" is the noun and "sampling" is the verb. It was proposed to change current words wherever necessary.

2.2.4 **Work Item 3: HC analyser oven temperature**

2.2.4.1 ARP1256D published in July 2011, specifies the temperature for the HC analyser oven which contains the detector and the sample-handling components within the range 150°C to 210°C. This range covers the complete spectrum of oven temperatures currently in use in HC analyses.

2.2.4.2 Since it is enough to consider the overall stability of the analyser which is provided by regular span and zero drift checks, the stability specification of the oven temperature is no more necessary. ARP1256D does not include a stability specification for the oven temperature.

2.2.4.3 It is proposed to align Attachment A to Appendix 3 to the current ARP1256D with the difference that Annex 16 specifies only the lower temperature of the range . CTG decided not to have a upper temperature in order to make sure that all the analysers are covered. Current analysers would not have an oven temperature higher than 210°C (upper limit in ARP1256D). A slight increase in temperature beyond 210°C would not affect the emissions.

2.2.5 **Work Item 4: Humidity measurement location**

2.2.5.1 Currently, Attachment F to Appendix 3 specifies that during engine emissions tests engine inlet humidity should be measured at a point within 15 metres ahead of the engine intake plane. This distance is more strict than the humidity measurement locations used for performance measurements at various manufacturers' test facilities.WG3 has agreed that for the purpose of emissions certification, the humidity measurement location used for performance measurements is acceptable. Therefore, it is proposed to change the current requirement from 15 metres to 50 metres in order to align the provision in Attachment F to Appendix 3 with the manufacturers performance measurements.

2.2.6 **Work Item 5: Humidity measurement accuracy**

2.2.6.1 The requirement for humidity measurement with an accuracy of ±5% of reading as in Attachment F to Appendix 3, may not be applicable to extremely low humidity environments. The engine manufacturers are currently using newer relative humidity measurement systems based on capacity sensors that have a humidity accuracy better than ±5% of reading requirements. But when the relative humidity is very low the accuracy can be more than ±5%.

2.2.6.2 It is proposed to use a constant accuracy value of ±5% of the reference value 0.00634 kg water/kg dry air for humidity conditions lower than the reference value. It has to be reminded that the inlet humidity value is used to correct the EINOx. An analysis of the variations of the NO_x correction factor as a function of ambient air humidity showed that the effect of the proposed change is acceptable (correction factor accurate within ±0.604%).

2.2.6.3 It is proposed that the accuracy of the humidity measurement should be changed to:

— ± 5% for ambient air humidity greater than or equal to 0.00634 kg water/kg dry air

— ± 0.000317 kg water/kg dry air for ambient air humidity less than 0.00634 kg water/kg dry air

2.2.7 **Work Item 6: Review and improve document numbering**

2.2.7.1 One of the basic structural principles for the development of the ETM is to mirror the structure of the Annex 16. Therefore the paragraph numbering of the Annex was reviewed and some inconsistencies became apparent.

2.2.7.2 It is proposed to amend the paragraph numbering system of the Annex where necessary following the ICAO editorial rules to provide a better handle for referencing specific text in the ETM.

2.2.7.3 It has to be noticed that no changes were proposed for Chapter 3 of Part III of Annex 16 and Appendix 5 which are related to turbojet and turbofan engines intended for propulsion at supersonic speed. As mentioned in the ETM, the current Standard is outdated and should not be applied to new engine projects. These sections need a complete revision. Any revision on the numbering would be visible as a new amendment and could lead to confusion with complete updated sections applicable to new supersonic engines.

2.2.8 **Work Item 7: Typographical**

2.2.8.1 Some typographical errors were noticed during the review of some parts of the Annex. Corrections to these typographical errors were proposed.

Discussion and Conclusions

2.2.9 The meeting took note that Annex 16, Volume II needs to be changed in order to provide an updated and consistent text reflecting current certification practice. The meeting then approved the changes to Annex 16, Volume II as presented in Appendix A.

2.2.10 **Recommendation**

2.2.10.1 In light of the foregoing discussion, the meeting developed the following recommendation:

RSPP | **Recommendation 2/1 — Amendments to Annex 16 — *Environmental Protection*, Volume II — *Aircraft Engine Emissions***

That Annex 16, Volume II be amended as indicated in Appendix A to the report on this agenda item.

2.3 PROPOSED AMENDMENTS TO THE ENVIRONMENTAL TECHNICAL MANUAL, VOLUME II

2.3.1 The Co-Rapporteurs of WG3 presented proposed amendments to the Environmental Technical Manual, Volume II. These changes were the result of the work carried out by WG3 under the CAEP/9 cycle work programme, in fulfilment of Remit E.12.

2.3.2 **Work item 1: Appendix 1 – Measurement of Reference Pressure Ratio**

2.3.2.1 It is proposed to allow basing engine pressure ratio and corrections to standard day on validated performance models and to allow the use of control system static pressure measurements for calculating compressor inlet and discharge total pressure.

2.3.2.2 The correlation between the compressor inlet and discharge total pressures and static pressures used by the engine control system are obtained as a matter of course from test data obtained during the performance model validation process.

2.3.3 **Work item 2: Appendix 2 – Smoke Sample Size**

2.3.3.1 It is proposed to provide guidance text to differentiate and clarify between the two options for sample size and their associated data analysis procedures.

2.3.3.2 Annex 16 and ARP1179C are in alignment however ARP1179C provides additional information dealing with sample size and analysis whereas Annex 16 text can be viewed as ambiguous. A decision was made to keep the Annex 16 text as is and add clarifying text, based on ARP1179C to the ETM.

2.3.4 **Work item 3: Appendix 3 Attachment A – Specification for HC Analyser**

2.3.4.1 It has been proposed, separately, to align Annex 16, volume II, Attachment A to Appendix 3 to the newly revised, July 2011, version of ARP1256D with the difference that Annex 16 specifies only the lower temperature of the range.

2.3.4.2 ETM guidance text is aligned with the expected changes in Annex 16 and, in-as-much-as-possible, with SAE ARP 1256D, Procedure for the Continuous Sampling and Measurement of Gaseous Emissions from Aircraft Turbine Engines, as revised.

2.3.5 **Work item 4: Appendix 3 Attachment B – Specification for CO and CO_2 analysers**

2.3.5.1 Guidance text for Attachment B has been prepared using ARP1256D as a reference. Measurements of engine exhaust emissions using NDIR analysers can be complex and difficult to do in practice. Guidance material has been prepared for Attachment B that, in addition to considerable explanatory information, has an equivalent method addressing sample temperature and two technical procedures dealing with calibration curves.

2.3.5.2 A question was raised relative to the desirability of more clarity in the procedures necessary to control for oxygen interference when measuring CO_2 with an NDIR analyser. Appropriate guidance text has been prepared that addresses the oxygen interference question and is being proposed for approval.

2.3.5.3 In addition to the question of oxygen interference it was noted that version of ARP1256C changed the diluent in the gas mixture required for spanning the instrument from zero air to nitrogen. While not eliminating the need for oxygen interference corrections when sampling for emission, this simplifies the determination and verification of the instrument response characteristics. Appropriate guidance text has been developed and is being proposed for inclusion in Appendix 3 Attachment D – Calibration and Test Gases.

2.3.6 Work item 5: Appendix 3 Attachment C – Specification for NO_X Analysers

2.3.6.1 Guidance text for Attachment C has been prepared using ARP1256D as a reference.

2.3.6.2 Chemiluminesence analysers are NO specific and require an NO_2 to NO converter to differentiate between NO and NO_2. The ETM provides technical information describing an alternative procedure from 1256D and described in early editions of 40CFR87.

2.3.7 Work item 6: Appendix 3 Attachment D – Calibration and Test Gases

2.3.7.1 In Annex 16 Attachment D concentrations of calibration gases are specified as being known to an accuracy ±2% over the 95% confidence interval. When this accuracy requirement was chosen 2% was in agreement with ARP1256A. In version ARP1256C the stringency of the accuracy requirement has been increased to 1%. CTG has decided not to increase the stringency in Annex 16. Explanatory text discussing this decision has been prepared accompanied by an overview of government programs, in Europe and the US, charged with creating and maintaining standard reference gases and in validating the secondary gas standards available from commercial vendors.

2.3.7.2 Guidance text, as described in 3.4.3 above, has been prepared and proposed for adding to the ETM.

2.3.8 Work item 7: Appendix 3 Attachment E – The Calculation of the Emissions Parameters

2.3.8.1 Attachment E provides a list of symbols including L, L' - analyser interference coefficient for interference by CO_2 and M, M' - analyser interference coefficient for interference by H2O.

2.3.8.2 No distinction is made between interference as caused by a change in instrument sensitivity or interference caused by a zero shift which can be confusing. Using ARP1533B Procedure for the Analysis and Evaluation of Gaseous Emissions from Aircraft Engines clarifying explanatory information was added to the ETM.

2.3.8.3 The formula for AFR in Attachment E uses an equivalent but different format than the formula in Appendix 3 7.1.2. Clarifying explanatory information was added to the ETM.

2.3.8.4 Attachment E 4. Alternate Methodology suggests the use of numerical procedures for calculating emissions parameters. Explanatory information was added to the ETM specifically identifying ARP1533B as an appropriate source for details explaining various calculation procedures.

2.3.9 Work item 8: Appendix 3 Attachment F (b) - humidity instrument distance of measurement and accuracy

2.3.9.1 An amendment to change the distance for measurement of humidity from 15m to 50m in Annex 16 has been proposed. Guidance text discussing this change has been written for Attachment F (b) of the ETM.

2.3.9.2 Attachment F (b) specifies a r equirement for measurement to an accuracy of ±5% of reading. Achieving this level of accuracy when ambient humidity levels are low is problematic. Detailed analysis of the effect of a somewhat reduced accuracy of the measurement on the resulting correction factor found it to be acceptably small and can be accommodated within the intent of the standard.

2.3.10 **Work item 9: Appendix 6 – Reference Standard Engine definition**

2.3.10.1 Discussions within WG3 CTG between EASA, the FAA, and the manufacturers have raised issues with respect to the definition of a “reference standard engine” for the purpose of emissions certification. One result from these discussions was agreement that there was a need for a common understanding and definition of the term ‘reference standard engine’ as used in Annex 16 Appendix 6.

Discussion and Conclusions

2.3.11 In approving the proposed amendments to the ETM, Volume II, the meeting recognised the astonishing amount of work conducted by WG3 in the maintenance of the manual.

2.3.12 The meeting agreed to publish an amended version of the ETM, Volume II.

2.3.13 **Recommendation**

2.3.13.1 In light of the foregoing discussion, the meeting developed the following recommendation:

Recommendation 2/2 — Amendments to the *Environmental Technical Manual — Volume II*

That the Environmental Technical Manual, Volume II be amended as indicated in Appendix B to the report on this agenda item, and that ICAO publish a new version of this document as soon as possible.

2.4 REPORT OF THE PARTICULATE MATTER TASK GROUP

2.4.1 For the CAEP/9 cycle, WG3 formed the Particulate Matter Task Group (PMTG) to address the particulate matter (PM) emissions remits. The development of the measurement system and methodology has been delegated to the SAE-International’s E31 Committee (SAE-E31). PMTG formed a liaison group to exchange technical information between SAE-E31 and WG3/PMTG.

2.4.2 The WG3 Co-Rapporteurs reported on the partial completion of task E18.01. During CAEP/9, a test site with the first prototype PM measurement system permanently installed in an aircraft engine test cell has been established in Switzerland. Results from seven test campaigns with international collaboration lead to a major breakthrough for SAE-E31 to define the extractive sampling process, provide methodology for determining sampling train particle size penetration, measurements of nvPM number and mass at the end of the sampling train, and a procedure for reporting the data as emission indices. All elements and specifications needed to fulfil remit E18.01 will be summarised in an Aerospace Recommended Practice (ARP). In its present form as a working draft ARP, the document contains sufficient information for engine manufacturers to begin purchasing capital equipment needed to build their own systems with confidence. A full working draft ARP is anticipated by early 2013. Engine manufacturers will now need time and resources to build ARP-compliant systems and conduct multiple engine measurement campaigns for validation, thereby providing SAE-E31 members enough information for formal ballot of the ARP.

2.4.3 The highest number concentrations of non-volatile particles (soot) emitted by modern aircraft gas turbine engines and measured with working draft ARP compliant systems occur normally in a particle size range of 15 to 40 nanometers. SAE-E31 has determined that it is technically feasible to count non-volatile particles in this size range and has included this capability in the number instrument specification. The resulting number measurement will best represent aircraft gas turbine engine non-volatile particulate matter emissions. The WG3 Co-Rapporteurs reported that WG3 agreed to the SAE-E31 size range specification for the particle number and would like to bring to the attention of CAEP that in fulfilment of remit E18.01 for particle number, the size range specification is different from the one used for roadway vehicles.

2.4.4 The Co-Rapporteurs reported that without the delivery of a fully tested and robust nvPM measurement system from SAE-E31, no progress could be made on remit E18.02 which is to “Develop an aircraft engine based metric and methodology for application as a non-volatile PM emissions certification requirement for new engine types.”

2.4.5 Regarding remit E19, which is to “Evaluate and document sampling and measurement techniques to characterise the formation of volatile PM. Note input from SAE-E31.” The WG3 Co-Rapporteurs reported that SAE-E31 had provided WG3 with a report on volatile PM formation, measurement techniques, and other related technical details.

2.4.6 The meeting recognised the excellent progress made by the PMTG on this important topic, and the meeting thanked all the participants involved in the work.

2.4.7 Several members and observers presented their joint support and appreciation for the work carried out in the field of non-volatile Particulate Matter (nvPM) to develop sampling and measurement methodologies for the setup of a certification requirement and Standard.The group also provided some information on the European work in this field. The same members and observers were of the opinion that the work on nvPM has made significant and positive progress towards establishing a certification requirement and setting a new Standard. The PM certification requirement for larger aircraft engines enables the regulators to monitor the PM emissions with appropriate metrics and on a robust basis. The certification requirement will provide the certainty that the progress made in the development of technology leading to extremely low nvPM emissions is encouraged and closely followed.

2.4.8 The group of members and observers supported the proposed WG3/PMTG future work to “develop an aircraft engine based non-volatile PM mass and number standard for turbofan/turbojet engines >26.7kN”. The collection of data from other engine types and the evaluation of the impact of the nvPM emissions which is required to support a cost effectiveness assessment is also supported. In addition, the group pointed out a number of certification related issues which need to be addressed. Examples include, effects of ambient conditions on nvPM measurements and proof that the current Annex 16 – Volume II fuel specifications are sufficiently precise for nvPM certification. Funding is necessary to obtain sufficient data that will help resolve these issues. The group of members and observers highlighted that an ISG workshop should be held on PM in the future.

2.4.9 The Secretary asked for clarification on the proposed ISG workshop. It was clarified that this would allow the impacts of PM to be better understood and this workshop should be held during the CAEP/10 cycle.

2.4.10 A member presented a position on the development of the nvPM Standard and the work which has taken place during the CAEP/9 cycle in the PMTG. Regarding the development (together with the SAE E31 Committee) of a new ARP specifying measurement methodology and instruments applicable to nvPM emissions by aircraft engines, the member offered appreciation for the comprehensive work being undertaken to develop the draft ARP, particularly given the high complexity of problems being solved. The member also offered support for the strategy proposed by the PMTG to make the nvPM emission Standard applicable first to large turbofan engines (>26.7 kN) whose aerodrome emissions have been already regulated by the Annex 16, Vol. II. The member also supported an investigation (during the CAEP/10 cycle) of technical feasibility, environmental efficiency and economical reasonability of applications of similar requirements to other engine categories (e.g. small turbofans, ≤26.7 kN).

2.4.11 A member presented views on PM work which included support for the activities of the SAE-E31 Committee to develop the ARP by mid-2014 as a key building block to the nvPM certification requirement. The member provided details on the joint co-sponsoring of the design, build and testing of an ARP-compliant nvPM sampling system in North America. The performance of this system – which is mobile and capable of connecting to existing Annex 16-compliant gaseous measurement systems used by manufacturers – has been successfully calibrated and tested in parallel with the European reference system located in Zurich, Switzerland. The member pointed out that the intent is to employ this system to measure nvPM at each engine manufacturer in North America. Additionally, the member supported the proposed CAEP/10 work programme as presented by the WG3/PMTG.

Discussion and Conclusions

2.4.12 The dual, concurrent approach proposed by WG3 to the applicability for a future nvPM certification requirement and subsequent emissions standard was unanimously agreed by the CAEP. This approach means that first WG3 should move forward with a certification requirement and subsequent nvPM emissions standard for turbofan/turbojet engines >26.7 kN, aiming to be completed on or before the CAEP/10 meeting. This objective would establish the data collection methodologies, reporting requirements, and database structures necessary to assist CAEP in making an informed decision on a nvPM certification requirement and emissions standard. Secondly and concurrently, WG3 should conduct the technical work needed to apply a potential nvPM emissions standard to turbofans/turbojets ≤26.7 kN, turboprops, helicopter turboshaft, and APU engines. This technical work would include defining an appropriate landing take off (LTO) or operating cycle for each engine category, which could be simultaneously used for both certification and emission inventory purposes. To assist this effort some existing data sources to start the work have been identified by WG3 members.

2.4.13 An observer commented that the manufacturers are currently going through a procurement procedure and are committed to future PM work. Following a question from a member on the appropriateness of including the small engines in the nvPM standard, the observer suggested that these engines do have a low environmental impact and urged the meeting to consider the need to prioritise, as by including the small engines the WG3 resources could be stretched. The observer highlighted that the manufacturers fully support the dual approach proposed by PMTG.

2.4.14 A member agreed with the proposed structure of PMTG – which includes measurement, procedures and metrics ad-hoc groups – but did highlight that these groups must have a concise remit and strict deliverables. The meeting urged any members who wish supply resources for future PM work to do so by approaching WG3.

2.5 REPORT OF THE CO_2 TASK GROUP

2.5.1 The CO2TG co-leads provided an overview of the significant work undertaken within the CO_2 Task Group since CAEP/8 to develop an aeroplane CO_2 Standard. The CO2TG work was divided into two phases. Phase 1 would develop the CO_2 certification requirement (E.08.01), while Phase 2 represented the standard setting process which would consider the regulatory limit and applicability date required to complete an aeroplane CO_2 Standard (E.08.02, E.08.03 and E.09). Phase 1 work has been primarily managed via three groups which included the Metrics ad-hoc group (MET), the Procedures ad-hoc group (PRO), and the Applicability and Implementation ad-hoc group (AIM).

2.5.2 It was agreed at the very first CO2TG meeting that the work on a CO_2 metric system was the highest priority. A decision on this aspect would inform the nature of the certification test procedures and the data required to support the CO_2 Standard setting process. The CO2TG reached a consensus on a CO_2 Metric System at the May 2012 meeting, and at the same time acknowledged several associated issues with respect to future work on developing an aeroplane CO_2 Standard. This recommended CO_2 Metric System was subsequently endorsed by CAEP Members at the 2012 Steering Group meeting.

2.5.3 Building on the CO_2 Metric System decision, the work to develop CO_2 certification procedures encompassed, amongst other things, flight test and measurement conditions, measurement of SAR, corrections to reference conditions, and definition of the Reference Geometric Factor (RGF) used in the CO_2 emissions metric. In order to engage and coordinate appropriate expert resources outside of CO2TG to support these discussions, and to facilitate oversight of commercially sensitive information, a Certification Expert (CE) Group was established within the PRO ad-hoc group.

2.5.4 The general objective of the CE group was to identify existing manufacturer practices in measuring aircraft fuel burn and high speed performance in order to understand how current practices could be used, or built on, to minimise the regulatory burden of an eventual CO_2 Standard. Based on information from eight airframe manufacturers, a “building blocks” document for the CO_2 certification procedures was agreed to. This document, along with input from MET and AIM, was used to develop a mature ICAO Annex 16, Volume III CO_2 certification requirement which WG3 reached a consensus on at the October 2012 meeting. It was highlighted that the CO2TG recommends that, going forward, CAEP should present this progress to the Air Navigation Commission (ANC) along with a recommendation to move forward to a full States’ review process and subsequent adoption by Council only after Annex 16 Volume III has been completed. The preliminary review of Volume III by ANC should also be reported to Council. Additionally, the CO2TG co-leads made it clear that in order to complete the Annex 16, Volume III, and thus an aeroplane CO_2 Standard, future CAEP/10 work will also need to include resolution of the following:

1) definition of a no-change criteria;

2) applicability requirements;

3) regulatory limit

4) applicability date for limit; and

5) compliance mechanism.

2.5.5 Regarding applicability and implementation, the CO2TG co-leads highlighted that the 2010 Steering Group had agreed that the term “aircraft” in E.08.01 referred to subsonic jets and turboprops which have an applicability weight threshold of MTOM>5700kg (12566lb) for subsonic jet aeroplanes and MTOM>8618kg (19000lb) for propeller driven aeroplanes. This represented >99% global fuel burn, flight distance and operations. It was also agreed that the scope of applicability should include "new" aeroplane types, but not "out of production", and that "in-production" types should not be ruled out at this time. It was highlighted that the CO2TG has agreed, in principle, that the CO_2 Standard should only be applied to the highest of all maximum certificated take-off masses for the specific airframe/engine combination, and any other maximum take-off mass for which CO_2 emissions certification is requested by the applicant. This is on the basis that the highest mass variant will have the smallest margin to the limit and all lower mass variants would automatically comply. The co-leads pointed out that this assumption will be verified during the Phase 2 standard setting work. Finally, the CO2TG co-leads highlighted the agreement that the approved CO_2 metric value, and associated limit, for certified aeroplane types should be compiled into a public ICAO Aeroplane CO_2 Emissions Metric Databank.

2.5.6 The mature ICAO Annex 16, Volume III CO_2 certification requirement is contained in Appendix C.

2.5.7 The meeting showed its appreciation for the hard work of the CO2TG in progressing such a large and challenging work programme.

2.5.8 A member raised concerns in rushing a decision on how the certification requirement would be reported to the ANC and Council. The member suggested that different possibilities could be envisaged which would take stock of the agreed metric system and certification requirement before the final Standard was set. The member stated that the group should consider the options carefully and that more time should be allocated to this decision.

2.5.9 An observer, speaking on behalf of several members and observers, presented their joint view on the ICAO Aeroplane CO_2 Standard. They supported the approval of the mature ICAO Annex 16 Volume III and to communicate this progress to ICAO ANC and Council; and to ultimately compile certified CO_2 Metric Values and associated limits into a public ICAO Aeroplane CO_2 Emissions Metric Databank. The group of members and observers continued to support the applicability of the Standard to 'new' aeroplane types within the weight thresholds agreed at the 2010 Steering Group meeting, and the exclusion of 'out of production' aeroplane types. The group of members and observers noted that the applicability to "in-production" aeroplane types was not ruled out at 2010 Steering Group meeting. The group of members and observers supported in-production aircraft types being included within the applicability scope. A member asked for clarification regarding the observer's position on applicability, expressing her view that it was premature to take a decision on applicability in advance of the analysis. The observer clarified his view that in production aircraft should be included in the analysis. Another member also raised concerns about taking a premature decision on applicability.

2.5.10 Based on the analysis of the CO_2 Metric System adopted by the 2012 Steering Group meeting, applied first of all to Russian aeroplanes, a member supported the CO_2 Metric System which will underpin the ICAO CO_2 Standard. The member proposed an extension to the involvement of the Russian Federation during the next phases of Standard development, signaling the intent to submit data into the Metric Value Database (MVdb) from Russian manufacturers related to in-production and projected aeroplanes. The member concluded by suggesting that during further developments of the CO_2 Standard, the consolidated position be taken into account of the Russian aeroplane manufacturers, formulated by Working Group of Union of Aviation Industrialists of Russia (UAI).

2.5.11 The meeting noted the Russian Federations intent to supply data into the CO_2 Standard process. Another member acknowledged the contribution from the Russian federation and looked forward to the group moving forward together to deliver a CO_2 Standard.

Discussion and Conclusions

2.5.12 The meeting approved the mature ICAO Annex 16, Volume III CO_2 certification requirement as shown in Appendix C of this report.

2.5.13 The Chairman congratulated the group on approving the certification requirement for the CO_2 Standard and highlighted that now is the time to decide on how to move forward with this important breakthrough. In summarising, the Chairman referred to an earlier intervention made by a member regarding reporting the certification requirement to the ANC and Council (see paragraph 2.5.8). The Chairman added that it is important that the CAEP be given sufficient time to decide on the exact process with regard to taking the certification requirement forward.

2.6 CO_2 STANDARD-RELATED MATTERS

2.6.1 Communicating the CO_2 Standard Certification Requirement

2.6.1.1 The Chaperones met in a small group with Members from Brazil and Canada, including the WG3 Co-Rapporteurs, to discuss the potential options regarding the formalization and communication of the CAEP/9-agreed CO_2 Standard certification requirement. Following a thorough discussion of the available options, including advice from industry observers and the ICAO Secretariat, the small group concluded that the most appropriate option would be to publish the agreed CO_2 certification requirement for information-only, as an ICAO Circular. This document will include the agreed CO_2 Standard certification requirement (as shown in Appendix C) and some introductory information drafted by the ICAO Secretariat. The resulting Circular will be forwarded to the CAEP members for approval by electronic means prior to its publication.

2.6.2 Recommendation

2.6.2.1 In light of the discussions the following recommendation was developed:

> **Recommendation 2/3 — Publication of the CO_2 Standard Certification Requirement as an ICAO Circular**
>
> That ICAO publish the agreed CO_2 Standard certification requirement as an ICAO Circular for information-only, as soon as possible.

2.6.3 Comprehensive Work Plan to Develop an Aircraft CO_2 Emissions Standard

2.6.3.1 The Working Group Rapporteurs and WMF Liaison presented a comprehensive work plan for the development of a CO_2 Standard which was developed by the WG1-WG3-MDG-FESG liaison group (WMF). WMF identified the remaining key work packages required to develop a CO_2 Standard. These are the remaining issues associated with the certification requirement, stringency options, industry response, sample problem, initial and final cost effectiveness analyses plus supporting data. The ambitious but achievable timescales for the individual activities were built up for both a baseline and an option plan.

2.6.3.2 From the baseline schedule analysis, the WMF concluded that a full economic and environmental cost effectiveness analysis can be completed in the late-2015 timeframe i.e. in time for an approval of a complete CO_2 Standard at a CAEP/10 meeting in February 2016. Regarding the option plan, WMF work has confirmed that a full CAEP analysis of a CO_2 Standard could not be completed before mid-2015 at the earliest but that it is most likely for it to be completed in the late-2015 timeframe.

2.6.3.3 The WMF recommended the baseline schedule timeframes. In addition, work programme approval should be given at CAEP/9 to develop both the stringency options and the industry response methodology, with a review at or around SG2013 to judge whether the work carried out will allow the schedule to be accelerated in line with the option plan schedule. If so, it was emphasised that mechanisms to provide approvals outside normal CAEP meeting timeframes would be required.

Discussion and Conclusions

2.6.3.4 A member asked about possible delays in the schedule if the group pursued anything other than a traditional pass/fail Standard. It was stated that the WMF Liaison Group did not have enough information on alternative compliance mechanisms to make a judgment on this and therefore all the WMF work planning was based on a pass/fail type of approach.

2.6.3.5 A member questioned whether the CO_2 Standard sample problem was on the critical path of the schedule proposed by the WMF Liaison group. In responding, the WMF liaison stated that the sample problem is crucial to the work moving forward, and that this is reflected on the critical path of the CO_2 Standard planning in both the baseline and option plans.

2.6.3.6 The meeting supported moving forward on the CO_2 Standard development and the group thanked the WMF for its efforts and hard work. The meeting also recognised the difficulty the WMF encountered in bringing all the details of the proposed future time schedules together.

2.6.3.7 The CAEP Secretary highlighted the expectations outside of the CAEP regarding the delivery of the CO_2 Standard in 2013 and that the extension to the timescales would need to be communicated appropriately. The Secretary thanked the WMF group for its excellent work in explaining the delivery options for the CO_2 Standard, and emphasized the importance of balancing a timely delivery and robust technical work. The Secretary highlighted that if the work is completed before the proposed late-2015 timeframe (in the baseline schedule) then it should be delivered to the CAEP earlier. It was made clear that the work should not be guided by the typical CAEP meeting schedule.

2.6.4 **Applicability and Implementation of the CO_2 Standard**

2.6.4.1 The CO2TG co-leads presented an overview of CO2TG discussions since CAEP/8 on applicability and implementation issues for the aeroplane CO_2 Standard. These views are focused on appropriate applicability requirements, applicability dates, and alternative compliance mechanisms.

2.6.4.2 The 2010 Steering Group agreed that the term “aircraft” in E.08.01 referred to subsonic jets and turboprops which have an applicability weight threshold of MTOM>5700kg (12566lb) for subsonic jet aeroplanes and MTOM>8618kg (19000lb) for propeller driven aeroplanes. The 2010 Steering Group also agreed that the scope of applicability should include “new” aeroplane types, but not “out of production”, and that “in-production” types should not be ruled out at that time. It was highlighted that the CO2TG has identified various applicability options for new and in-production aeroplane types, however a consensus has not yet been reached as to whether the Standard should apply to in-production aeroplane types and, if so, how requirements should be applied. Similarly, the CO_2TG has not reached consensus on how the CO_2 applicability requirements would be implemented in terms of certifying derived versions of new aeroplane types. However, the CO_2TG has agreed that, where possible, the applicability of the CO_2 Standard should be simple and avoid disincentives to introduce new fuel efficiency technology into the market.

2.6.4.3 Regarding the issue of applicability date, it was emphasised that this is linked to Phase 2 standard setting tasks, such as stringency options and alternative compliance mechanisms. Consequently the Task Group has identified this as future work. The CO2TG co-leads also highlighted that proposals had recently been presented to the CO2TG on the subject of alternative compliance mechanisms. The CO2TG was not able to reach a consensus on a way forward to deal with alternative compliance mechanisms, or even if further work should take place on developing and analysing proposed mechanisms.

2.6.4.4 The CO2TG co-leads requested guidance from the CAEP/9 meeting on both the potential applicability requirements and regulatory compliance mechanism for a proposed aeroplane CO_2 Standard. It was emphasised that input on these two issues is critical to expedite future work by focusing the anticipated Phase 2 standard setting process in the CAEP/10 work programme.

2.6.4.5 Several members supported leaving the applicability scope open, for example with regard to in-production aircraft, highlighting that a decision can only be taken once enough information is available from the modelling studies. The CO2TG co-leads highlighted that the more guidance CAEP members can give on applicability and implementation, the better the CO2TG can focus its work.

2.6.4.6 Working Group 3 has recently resumed discussions about the potential incorporation of flexible compliance mechanisms, notably averaging and banking (A&B), into ICAO's CO_2 Standard. An observer highlighted that certain stakeholders, particularly those with experience establishing or analysing efficiency standards for other transport modes, have expressed the view that such mechanisms could enable cost-effective emission reductions under ICAO's CO_2 Standard above and beyond those possible through the traditional pass/fail approach. The observer highlighted several advantages of an A&B approach and these included, among others, that an A&B mechanism can promote emission reductions over a broader range of aeroplane types, and provide manufacturers more discretion in determining their individualized strategy and timing for compliance. The observer went on to provide background regarding how flexible compliance mechanisms could be incorporated into the CO_2 Standard, along with a further perspective on their possible benefits.

2.6.4.7 A member referred to the possibility of back sliding in the context of aviation fuel burn technology and asked whether this had ever occurred. The observer stated, via an analysis of secondary data (e.g. using PIANO), that they have not seen any examples of back sliding per se. The observer went on to suggest that this actually supported the use of an alternative compliance mechanism. The member disagreed with this particular conclusion.

2.6.4.8 A member and observer shared their concerns regarding whether consideration had been given to possible implications to non-manufacturing States of a supplementary compliance condition, above and beyond a type certificate approach. The observer recognised the concern, but stated that no work had yet been done to address this issue.

2.6.4.9 A member highlighted the opinion that the CAEP is not the appropriate forum for a discussion on an averaging and banking compliance approach, and suggested that discussions on this could endanger the validity of the agreed CO_2 metric system. The observer suggested that an averaging approach should not endanger the metric system, and in fact could add some margin and certainty for the manufacturers.

2.6.4.10 The observer suggested that adopting an averaging alternative compliance approach could in fact expedite the modelling process in CAEP because it would mean moving away from the extremely detailed analysis (of every aircraft type) done currently and onto an averaged system.

2.6.4.11 Three members presented their joint position on alternative compliance mechanisms. As States of Design and as Certificating Authorities, the three members emphasised their strong concerns regarding a proposed (in WG3) new alternative compliance concept known as Averaging, Banking and Trading (AB&T) (also known as A&B), especially as i t is incompatible with the current pass/fail certification framework of ICAO Member States. These members voiced their concerns that dedicating CAEP resources to A&B will result in further delay to the delivery of the CO_2 certification requirement and Standard. In the opinion of the three members, the best way to move forward on the CO_2 Standard is to exclude the proposal for an alternative compliance mechanism from CAEP/10 cycle future work.

2.6.4.12 Several observers jointly presented their position on alternative regulatory compliance mechanisms, such as the recently proposed (in WG3) Corporate A&B Mechanism. After considered analysis the observers unequivocally have determined that any further work on a lternative compliance mechanisms, such as A&B, should be stopped. In the opinion of the observers, alternative compliance mechanisms, as p resented, introduce market-based elements that are adverse to technology-based standards and would likely provide a disincentive for introduction of new technologies, compromising industry's ability to realise environmental benefits. In addition, the observers suggested that implementation of such mechanisms would require comprehensive restructuring of the existing certification process and greatly increase the complexity of that process; overcoming these practical impediments (if possible at all) will significantly delay the implementation of the CO_2 Standard.

Discussion and Conclusions

2.6.4.13 An observer presented the joint opinion of several members and observers highlighting the risks involved in pursuing an A&B alternative compliance mechanism and recommended that the CAEP move forward with a traditional pass/fail approach. A member emphasized outstanding questions regarding how alternative compliance mechanisms (such as A&B) would work in the aviation context and as a result the member will undertake further consideration of A&B to better understand the issues. The Member stated that should a proposal be developed then it would support an analysis of the proposed technical merits by WG3, including the possible inclusion of A&B in the stringency analysis.

2.6.4.14 Some members suggested that a detailed analysis of A&B is required before any decision can be made, others suggested that this would slow down the delivery of the Standard. A member suggested that it is always important to look at technical issues from a different angle but that we should take care over the timescale involved which may lengthen the schedule for the CO_2 Standard delivery.

2.6.4.15 A member suggested that it is unlikely the agreed CO_2 metric system can be adapted to an A&B compliance approach. The member also highlighted the possible expense associated with the implementation of such an approach. It was suggested by the member that this is a new concept to ICAO and would most likely need to be discussed in the ICAO Council before it could be adopted as a Standard.

2.6.4.16 An observer asked whether the CAEP has the resources to investigate an alternative compliance mechanism and urged the CAEP to consider the timelines of the Standard. Several members and observers requested that the A&B compliance mechanism be removed from consideration by CAEP as it is currently not a mature proposal. Furthermore, if a member or observer continued to progress with this work, that it only be presented for consideration when fully matured including reasonable consideration of how the proposal would meet the CAEP Terms of Reference and the key criteria, and that it be presented at the Steering Group or CAEP meeting level, not at WG3.

2.6.4.17 In conclusion, in light of an overwhelming majority of members and observers showing concern with the proposal that CAEP considers an alternative compliance mechanism, it was decided that this item should not be part of the CAEP/10 work programme.

2.6.5 **Assumptions used in the analysis of CAEP Standards**

2.6.5.1 In quantification of the effectiveness of its standards, CAEP relies upon a large number of assumptions to expedite its assessment of environmental benefit and cost effectiveness. Over time, some of these assumptions have become a de facto standard approach without any periodic validation. An observer expressed their concern regarding the market driven production cut-off (MDPC) assumption for the CO_2 Standard. The view of the observer was that MDPC is inconsistent with intended applicability and has to date not been quantitatively verified. The observer explained that in order to ensure a robust, effective, and transparent CO_2 Standard that fully contributes to the sustainable growth of commercial aviation, the reasonableness and impact of the market driven production cut-off on effectiveness analysis should be quantified.

Discussion and Conclusions

2.6.5.2 The meeting discussed the market driven cut-off assumptions used in the current FESG analyses. Requesting clarification, a member asked about the reaction of industry to market forces, and specifically whether the market driven cut-off assumption is appropriate across different emissions. The member highlighted an example, that fuel (and so CO_2) is linked to market forces whereas PM is not. The member also suggested that an investigation into previous emissions analyses, where the market driven cut-off was used, could be helpful.

2.6.5.3 Another member referred to applicability of current assumptions when setting up the CO_2 Standard sample problem, and suggested that the market driven cut-off will need to be further investigated during the process of this study. The member, and the FESG co-Rapporteur, did not support any historical analysis (as suggested by a member in section 2.6.5.2), stating that looking backwards will be an additional resource burden. An observer supported this point of view and requested that we do not delay the main analysis of the CO_2 Standard.

2.6.5.4 The FESG co-Rapporteur was invited to provide further details on the current FESG modelling assumptions connected to the market driven production cut-off. The Co-Rapporteur clarified that there is no s tandard set of modelling assumptions that are systematically used. Moreover, the assumptions, inputs, models and approaches are revisited before any new analysis takes place. It was highlighted that the assumptions for CO_2 are currently being discussed within the working groups, and it was added that no assumption is set in stone. If there are alternative assumptions, for example to the market driven cut-off, then the FESG will consider them.

2.6.5.5 Returning to other CO_2 Standard related issues, the meeting discussed the inclusion, when available, of the certified aeroplane CO_2 metric value, and associated limit, in a p ublic ICAO Aeroplane CO_2 Emissions Metric Databank. In response to a question from a member, the CO2TG co-leads clarified that this would follow a similar approach to the current ICAO environmental Standards by compiling the certified data from the certification authorities. The meeting agreed that before any decision could be taken on whether the databank should be formed, that further details should be provided on the hosting, management and ownership of the databank. The Chairman summarised, stating that future work, and CAEP guidance for the CO2TG, would be discussed under Agenda item 5 and the issue regarding the immediate use and process for the agreed CO_2 Standard certification requirement (as highlighted in section 2.5.8) is discussed in section 2.6.1.

2.7 THE REPORT OF THE ACCS GROUP

2.7.1 The Co-Rapporteurs of ACCS presented the group's report on activities since CAEP/8. That meeting expanded the role of ACCS beyond the update to the methodology used by the ICAO Carbon Emissions Calculator to include related activities that would benefit from the expertise available within the group.

2.7.2 The CAEP/8 meeting requested ACCS to provide CAEP comments and recommendations on the proposed ICAO Fuel Form by March 2010, in the form of a report to be forwarded to the ICAO Statistics Division. Subsequently, ACCS was asked by the Tenth Meeting of the ICAO Statistics Division (STA/10) to comment on the associated Reporting Instructions for States. ACCS provided comment on the Definition of International and Domestic fuel consumption (emissions) used in the Reporting Instructions; the need for compatibility with existing ICAO reporting requirements; the extent to which fuel uplift records can be used as a reliable proxy for fuel consumed; the treatment of biofuels, and; the need to update the form in the future to request information on the volume of carbon offsets. ACCS also reviewed the definition of biofuels used in the Reporting Form. This task was completed and the Reporting Form, along with the Reporting Instructions, has since been sent to States by ICAO.

2.7.3 ACCS was also tasked with refining the methodology and database associated with the ICAO Carbon Emissions Calculator. This is an important task given the increasing prominence of the Calculator within the UN and elsewhere, and the continual need to improve accuracy by addressing gaps in the existing database. The Secretariat is engaged in positive discussions with several entities that hold modelled and measured data, and ACCS will review any new data when it becomes available. There is no progress to report since the CAEP/8 meeting and this remains an item for future work.

2.7.4 ACCS was asked to develop Frequently Asked Questions text for the ICAO website on the difficulties of accurately estimating the CO_2 emissions attributable to air freight at this time. As a next step it was suggested that ACCS could develop a set of non-binding guidelines to enable interested parties to develop a carbon calculator methodology for belly freight. This task remains an item for future work.

2.7.5 Initial progress has been made toward the development of a report on ways in which ICAO can collect data on the quantity of offsetting associated with air travel and how such data could be used by ICAO. In taking this forward, the ACCS rapporteurs liaised with the task lead on WG3's Fuel Efficiency Metric Ad-hoc Group set up to evaluate fleet-wide efficiencies. A preliminary discussion paper by the WG3 task lead covering these issues was presented to the Steering Group.

2.7.6 ICAO received a direct request from the Issue Management Group of the United Nations Environment Management Group (UNEMG-IMG) about the volume of air travel already being offset given that some local/regional emissions trading systems have begun to include aviation, and some airlines are voluntarily offsetting their emissions. Specifically, the UNEMG-IMG asked whether a methodology to support the accounting of offset emissions from aviation could be ready in time for generating the 2012 emissions inventories for the UN (to be implemented in an updated version of the UN interface to the ICAO Carbon Emissions Calculator by June 2013). Acknowledging that this could be a potentially large task with a challenging timetable, the Steering Group agreed that ACCS should investigate the feasibility of developing a methodology by CAEP/9.

2.7.7 In approaching this feasibility study, ACCS identified three elements, namely: the identification of which emission reduction units to take to recognise and include as an offset (e.g. carbon offsets, ETS allowances); the identification of how information can be collated (including the degree of accuracy, frequency of updates, and administrative arrangements for providing information), and; the identification of a methodology that would allow the information to be used in the ICAO Carbon

Calculator consistent with the principles of transparency and accuracy. As there is considerable overlap between this feasibility study and an existing ACCS task "C04 Explore ways to collect data on offsetting and its use", the two tasks were combined. The report concludes that it is feasible to develop such a methodology.

Discussion and Conclusions

2.7.8 The meeting thanked ACCS for their work and noted that additional tasking for the group would be discussed under agenda item 5, future work. The Secretary highlighted that the work of ACCS is of critical importance to the UN system and that the ICAO Carbon Emissions Calculator has received many accolades from the UN. Regarding the carbon offset accounting methodology, the meeting was reminded that the recipient of this methodology is the United Nations Environment Management Group – Issue Management Group (UNEMG-IMG). This group will further review the recommendations from CAEP along with any software that is developed by the ICAO Secretariat to implement it. The meeting agreed that in its initial implementation, the methodology should allow auctioned allowances and other economic instruments to be considered as having offset the emissions, but that this assumption could be changed based on further review.

2.7.9 Recognizing that ACCS was successfully able to advance their work programme meeting exclusively by teleconference, the meeting invited ICSA to present a paper to the first meeting of the Steering Group during the CAEP/10 cycle with a proposal for how the other CAEP working groups might be able to reduce their need for face-to-face meetings.

2.8 REPORT OF WG2 – OPERATIONS

2.8.1 Status of WG2 Activities

2.8.1.1 The Co-Rapporteurs of WG2 presented the group's report on activities since CAEP/8. The three tasks assigned to WG2 for this CAEP cycle have been completed. Following the Independent Expert (IE) process, recommendations for operational goals for noise and fuel burn in the mid-term (10 years) and the long term (20 years) have been made; updates to chapters previously in ICAO Circular 303, now being proposed to be published in a new ICAO Manual are complete; and new guidance material "Environmental Assessment Guidance for Proposed Air Traffic Management Operational Changes" has been prepared.

Discussion and Conclusions

2.8.1.2 The WG2 Co-Rapporteur explained that WG2 is unique in that it does not have a set work programme where the tasks evolve from one CAEP cycle to the next. This requires that the membership and structure evolve with each CAEP cycle to ensure that the right expertise is available to carry out the work. The meeting urged members to consider the specific tasks to be carried out when nominating experts to participate in WG2. In particular, the meeting noted that States are asking for new guidance that has not been previously considered in CAEP. As an example, the meeting noted that climate change was not previously a focus area when the ICAO Airport Planning Manual, Part 2: Land Use and Environmental Control was developed, with only noise and local air quality being considered. Today, strong interest in guidance for building ecological airports has been expressed with a number of new facilities being built worldwide. The meeting appreciated that WG2 has consistently demonstrated its flexibility in being able to respond to the needs of States, in particular developing States.

2.8.2 Operational Opportunities to Reduce Fuel Burn and Emissions

2.8.2.1 WG2 has completed their work related to the development of a new ICAO Manual on operational opportunities to reduce fuel burn and emissions. It is based on the premise that the most effective way to reduce aircraft emissions is to reduce the amount of fuel used in operating each flight. The new Manual is based on revisions and updates to ICAO Circular 303, and replaces the Circular. The manual contains information on current practices followed by aircraft operators, airport operators, air navigation service providers (ANSP), other industry organizations and States. The text presented for the consideration of CAEP has been reviewed by the ICAO Operations Panel (OPSP).

Discussion and Conclusions

2.8.2.2 The meeting congratulated WG2 on finalizing the manual, noting the tremendous progress that was achieved during this CAEP cycle in order to finalize it. The contribution of the many experts on the task group and the support of their nominating States and organisations was acknowledged. The meeting appreciated the teamwork shown, noting that the task required the application of a very wide range of expertise, which also reflects the fact that many fuel and emissions saving initiatives are themselves multidisciplinary exercises and involve a mix of stakeholders. The meeting expressed its desire to have the manual made available quickly and for it to be made available free of charge. The Secretary explained that the decision regarding whether the document would be sold or made available free of charge is at the discretion of the Council and their policy on ICAO publications. The meeting urged that the Council consider, at a minimum, making the electronic version of the manual available free of charge.

2.8.2.3 The meeting asked that the completed draft chapters be removed from the ICAO website prior to the publication of this manual. It also asked that the ICAO Secretariat update references in other documentation to Circular 303 to refer to the appropriate section in this manual.

2.8.3 Recommendation

2.8.3.1 In light of the foregoing discussion, the meeting developed the following recommendation:

> **Recommendation 2/4 — Publication of a new ICAO Manual on operational opportunities to reduce fuel burn and emissions**
>
> ICAO is requested to publish the new Manual on operational opportunities to reduce fuel burn and emissions as soon as possible, free of charge, and that this manual replace ICAO Circular 303.

2.8.4 Environmental Assessment Guidance for Proposed Air Traffic Management Operational Changes

2.8.4.1 WG2 has completed drafting the guidance document: "Environmental Assessment Guidance for Proposed Air Traffic Management Operational Changes." The document is focused in scope on environmental impacts assessment (including both engine emissions and noise) related to proposed operational procedures changes airspace redesigns, and other similar operational aspects.

2.8.4.2 Following a request from the ICAO Secretariat to have an initial draft of the main document available to be used by States in drawing up their action plans on emissions reduction, the development of the guidance document was accelerated. As a result, the initial draft document, without appendices, was completed and accepted by the Steering Group, and was placed on the ICAO "Action Plan for Emissions Reduction" (APER) restricted website for States to use in 2011.

Discussion and Conclusions

2.8.4.3 The meeting expressed that this guidance was needed and that the Committee was very pleased with what was developed by WG2. The meeting noted that similar sentiments were expressed at each of the action plan for CO_2 emissions reduction hands-on training workshops, with the participants in those workshops finding the guidance practical and contributing directly to the development of their action plans. A member explained that the methodology included in this guidance has already been integrated into the SESAR programme. Noting the tremendous success in advancing this work primarily through the use of conference calls, the task lead was asked to contribute to the recommendation being prepared by an observer for the first steering group meeting on holding successful conference calls. The participants expressed, in particular their thanks for holding two sets of teleconferences, one for those participants in the Eastern Hemisphere and another for those in the Western Hemisphere, for each virtual meeting in order to accommodate participation from all regions of the world.

2.8.4.4 As with the manual on operational opportunities to reduce fuel burn and emissions, the meeting asked that the guidance document be published as soon as possible and that the Council considers making it available free of charge. The meeting also asked that ICAO replace all previous versions of this document on the ICAO APER secure site with the version presented to CAEP.

2.8.5 **Recommendation**

2.8.5.1 In light of the foregoing discussion, the meeting developed the following recommendation:

Recommendation 2/5 — Publication of the new ICAO document: "Environmental Assessment Guidance for Proposed Air Traffic Management Operational Changes"

ICAO is requested to publish the material on Environmental Assessment Guidance for Proposed Air Traffic Management Operational Changes and that it be made available free of charge.

2.8.6 **Operational Goals for Fuel Burn and Noise**

2.8.6.1 The lead of the Independent Experts Operational Goals Group (IEOGG) presented proposed mid-term and long-term operational goals for fuel and noise in accordance with CAEP-Memo/72. The meeting was reminded that these goals have been prepared by a group of independent experts using their judgment concerning available research and studies. The IEOGG was asked to develop challenging and aspirational Operational Environmental Goals, and as such highlighted a number of limitations associated with the goals, including that they require new technology investments, substantial reduction in taxi-in and taxi-out emissions through efficient queuing and use of electric taxi systems, and changes in policies and practices by ANSPs, flight operators, and states.

2.8.6.2 The IEOGG estimates the 2010 worldwide operational fuel and atmospheric emissions benefit pool to be 12.75%. This corresponds to a worldwide system efficiency level of 87.25%. The lower limit of the IEOGG confidence range for the benefit pool is 10.25%, which corresponds to an efficiency level of 89.75%.

2.8.6.3 The size of this benefit pool is larger than the size estimated by the prior IEOGG and earlier CANSO estimates. The IEOGG used an alternate methodology compared with the prior work so there could be many reasons for differences, however three factors stand out: 1) The IEOGG estimated the benefit pool for those regions with limited data availability, e.g. the Middle East, China and India, South America and Africa, to be larger than the pools estimated earlier. This difference was based on access to some additional data and also anecdotal evidence obtained in discussions with local experts. 2) IEOGG considers all taxi-in and taxi-out emissions to be part of the benefit pool due to the potential for electric taxi systems to eliminate the majority of these emissions. 3) The IEOGG analysis took into account recent research that estimated inefficiencies in typical cruise speed and altitude values.

2.8.6.4 The IEOGG worldwide operational fuel usage and atmospheric emissions goals are:

	2020	2030	2040
Goal	3.25%	6.75%	9.00%
Lower Confidence Limit	2.25%	4.50%	5.75%

2.8.6.5 The IEOGG analysis produced a benefit pool and goals for each phase of flight: taxi-out, climb, cruise, descent and taxi-in. The phase-of-flight specific benefit pool and goals are given below.

Benefit Pool	**TAXI-OUT**	**CLIMB**	**CRUISE**	**DESCENT**	**TAXI-IN**
2010 POOL	100.00%	1.50%	6.25%	19.75%	100.00%
LCL	76.75%	1.25%	4.25%	15.25%	76.75%

Goal	**TAXI-OUT**	**CLIMB**	**CRUISE**	**DESCENT**	**TAXI-IN**
2020 GOAL	33.50%	0.50%	1.50%	4.75%	27.25%
LCL	22.25%	0.25%	0.75%	3.25%	18.75%
2030 GOAL	62.25%	0.75%	3.50%	12.00%	50.50%
LCL	39.00%	0.50%	1.75%	7.50%	30.75%
2040 GOAL	81.25%	1.00%	4.75%	14.75%	66.50%
LCL	49.75%	0.75%	2.50%	9.00%	40.75%

2.8.6.6 The CAEP/9 IEOGG is in concurrence with the findings of the previous CAEP/8 IEOGG, which noted that Operational enhancements offer limited noise reduction. Aircraft/engine technologies offer the primary opportunities for reducing aircraft noise. Of expected operational enhancements over the next three decades, moving aircraft ground tracks, enabled by increased use of PBN technologies, to less populated areas provides the highest potential noise benefit. It should be noted that changing flight tracks for noise reduction has the potential to increase flight distance, thus reducing fuel efficiency. The emergence of quieter aircraft technologies may provide opportunities to reduce negative fuel burn impacts of noise abatement procedures. The IEOGG offers two goals:

— Reduce population exposed to significant aircraft noise around appropriate airports at suitable DNL levels by 2040, through strategic placement of ground tracks using advanced PBN technologies;

— Reduce aircraft noise 55DNL contour area, and associated exposed population, by 10% by 2040, through operational improvements such as continuous descent operations.

2.8.6.7 The IEOGG further recommends additional research into new noise impact metrics that can take advantage of changes outside the 55DNL and also measure personal impact of noise such as annoyance impact, awakenings, health impacts, and economic impact. The IEOGG also recommends that CAEP call for additional detailed research concerning operational noise reduction techniques.

Discussion and Conclusions

2.8.6.8 The meeting thanked the IEOGG for its analysis and in communicating its results clearly to CAEP. The meeting noted that the analysis of noise was not fully mature and identified that additional consideration of interdependencies was needed in a future update to the analysis. They recommended that at least one noise expert be included as a member of the next IEOGG. A member offered to provide this expertise for the future update. The meeting welcomed the inclusion of the 50 DNL noise contour in the analysis. The meeting noted that there are regional initiatives underway aimed at better understanding local airport noise effects that may inform a future update to the analysis. A member asked that for a future review, the group aim to provide a recommendation on additional metrics that may help to better inform the work of CAEP.

2.8.6.9 The meeting noted that the methodology developed to estimate changes in fuel consumption from operational initiatives was designed to be repeatable and that it could be easily adapted to accommodate varying levels of fidelity in input data. The tools and methodologies used by the IEOGG may be able to directly support a future analysis of fuel consumption benefits associated with the aviation system block upgrades.

2.8.6.10 The meeting expressed concern over the limited geographical representation of the independent experts and urged that future reviews include broader participation.

2.8.6.11 The meeting agreed that the goals expressed in the report are based on an idealistic analysis. Bearing the limitations and uncertainties associated with the analysis in mind, the meeting recommended that they be incorporated into the updated CAEP trends analysis, but not as the sole source of information; rather, as one of the scenarios. The meeting also agreed that only the portion of the report related to fuel consumption be published at this time, following an editorial review by the Secretariat, and that the remaining text be retained within CAEP in support of a future report.

2.8.7 Recommendation

2.8.7.1 In light of the foregoing discussion, the meeting developed the following recommendation:

Recommendation 2/6 — Publication of the "Independent Experts Operational Goals Group (IEOGG) report on mid-term and long-term operational goals for fuel burn

That the report of the IEOGG regarding fuel burn be published by ICAO as soon as possible, following an editorial review by the Secretariat.

2.9 ENVIRONMENTAL BENEFITS ANALYSIS OF AVIATION SYSTEM BLOCK UPGRADES

2.9.1 The Secretariat explained that a key challenge for the aviation community in recent years has been in prioritizing and developing consensus around the latest technologies, procedures and concepts of operations, due to the various and many national and regional ATM modernization programmes which have been progressing worldwide. The multidisciplinary and interrelated aspect of these modernization efforts requires intense collaboration between stakeholders representing every aspect and component of the international air transport system. In an effort to address this need, ICAO developed, along with its industry partners and with extensive feedback from States, the Aviation System Block Upgrade (ASBU) strategy, which now forms a critical element and serves as the implementation planning mechanism of the ICAO Global Air Navigation Plan (GANP). As such, implementation of the ASBU strategy is a top priority for ICAO.

2.9.2 Many of the ASBU modules are expected to deliver fuel burn, and therefore CO_2 emissions savings and that to-date there has been no global estimate of the magnitude of these benefits. A group of geographically-diverse experts led by the Secretariat presented a terms of reference for a an analysis task the results from which could help to refine the CAEP global trends assessment as well as to help stakeholders understand the environmental costs associated with not implementing the modules.

2.9.3 The terms of reference described the methodology and resources required to conduct and document a global assessment of the change in fuel consumption and resultant CO_2 emissions from the implementation of the Aviation System Block Upgrade, Block 0 using a phased approach. The Secretariat explained that the results from the analysis would be published in the inaugural Air Navigation Report and would be presented in other venues.

2.9.4 The Secretariat, on behalf of the expert group, presented the initial progress achieved to-date.

Discussion and Conclusions

2.9.5 The meeting expressed its congratulations for the progress achieved to-date that will provide a sound basis for the work of CAEP in this area. The meeting found this task to be important with a number of members sharing that the ASBU framework is an integral part of their air traffic management system upgrades and that environmental performance is considered as a key performance indicator in this implementation. The meeting agreed that CAEP is the appropriate forum for conducting the environmental analysis of global air navigation measures, such as through the ASBU framework, and that the work should be carried out in conjunction with the ASBU module experts.

2.9.6 Beyond the team already established to carry out this work, additional members offered their support. Noting the challenging schedule to complete the work, the meeting thanked the experts for presenting a mature task proposal to CAEP from which definitive action can be taken. The implementation of this task will be discussed further under agenda item 5: future work.

2.9.7 **Recommendation**

2.9.7.1 In light of the foregoing discussion, the meeting developed the following recommendation:

Recommendation 2/7 — Environmental Benefits from ASBUs

That the Council consider the analysis of CAEP as the basis for understanding the environmental benefits from Aviation System Block Upgrades (ASBUs).

2.10 ALTERNATIVE FUELS AND EMISSIONS

2.10.1 The WG3 Co-Rapporteurs reported on the relation between alternative fuel composition and emissions (Task E.05), which deals with the emissions consequences resulting from the use of alternative fuels. The scope of the task was defined in CAEP/8 as follows: “Examine and report on the emissions consequences resulting from the use of alternative fuels for aviation (both ‘drop-in’ replacements and 'non-drop-in'). Does not include lifecycle CO_2 emissions.” Variations in emissions between conventional and alternative fuels are mainly caused by differences in aromatics content and carbon/hydrogen ratio and primarily affect particulate matter. The WG3 Co-Rapporteurs highlighted that future work may take place in CAEP/10 cycle, and if so, it should be coordinated with other ICAO activities on alternative fuels.

Discussion and Conclusions

2.10.2 The meeting thanked WG3 for the information provided and agreed that future work in this area should be coordinated with other activities related to alternative fuels and would be subject to resource availability. The meeting agreed to consider this work further under Agenda Item 5: Future Work.

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APPENDIX A

PROPOSED AMENDMENT TO ANNEX 16, VOLUME II

The text of the amendment is arranged to show deleted text with a line through it and new text highlighted with grey shading, as shown below:

1. ~~Text to be deleted is shown with a line through it.~~	text to be deleted
2. New text to be inserted is highlighted with grey shading.	new text to be inserted
3. ~~Text to be deleted is shown with a line through it~~ followed by the replacement text which is highlighted with grey shading.	new text to replace existing text

TEXT OF PROPOSED AMENDMENTS TO THE

INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES

ENVIRONMENTAL PROTECTION

ANNEX 16 TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME II AIRCRAFT ENGINE EMISSIONS

. . .

PART III. EMISSIONS CERTIFICATION

. . .

CHAPTER 2. TURBOJET AND TURBOFAN ENGINES INTENDED FOR PROPULSION ONLY AT SUBSONIC SPEEDS

. . .

2.1 General

. . .

2.1.2 Emissions involved

The following emissions shall be controlled for certification of aircraft engines:

Smoke
Gaseous emissions
Unburned hydrocarbons (HC);
Carbon ~~mo3noxide~~ monoxide (CO); and
Oxides of nitrogen (NO_x).

. . .

APPENDIX 2. SMOKE EMISSION EVALUATION

1. INTRODUCTION AND DEFINITIONS

. . .

1.2 Where the following expressions and symbols are used in this Appendix, they have the meanings ascribed to them below:

~~Sampling~~ Sample reference size. The sample mass, 16.2 kg/m^2 of stained filter area, which if passed through the filter material results in a change of reflectance which gives a value of the SN parameter.

~~Sampling~~ Sample size. A chosen exhaust sample, the magnitude of whose mass (expressed in kilograms per square metre of stained filter surface area) lies in the range prescribed in 2.5.3 h) of this Appendix which, when passed through the filter material, causes a change in reflectance yielding a value for the SN parameter.

~~***Sampling***~~ ***Sample volume***. The chosen sample volume (expressed in cubic metres) whose equivalent mass, calculated as indicated in 3 of this Appendix, conforms to the above definition of sampling size.

. . .

2. MEASUREMENT OF SMOKE EMISSIONS

2.1 Sampling probe for smoke emissions

The sampling probe shall meet the following requirements:

a) The probe material with which the exhaust emission sample is in contact shall be stainless steel or any other non-reactive material.

. . .

2.3 Smoke analysis system

Note.— The method prescribed herein is based upon the measurement of the reduction in reflectance of a filter when stained by a given mass flow of exhaust sample.

Editorial note.— Removed the paragraph indent from the paragraph immediately below

The arrangement of the various components of the system for acquiring the necessary stained filter samples shall be as shown schematically in Figure A2-1. An optional bypass around the volume meter may be installed to facilitate meter reading. The major elements of the system shall meet the following requirements:

. . .

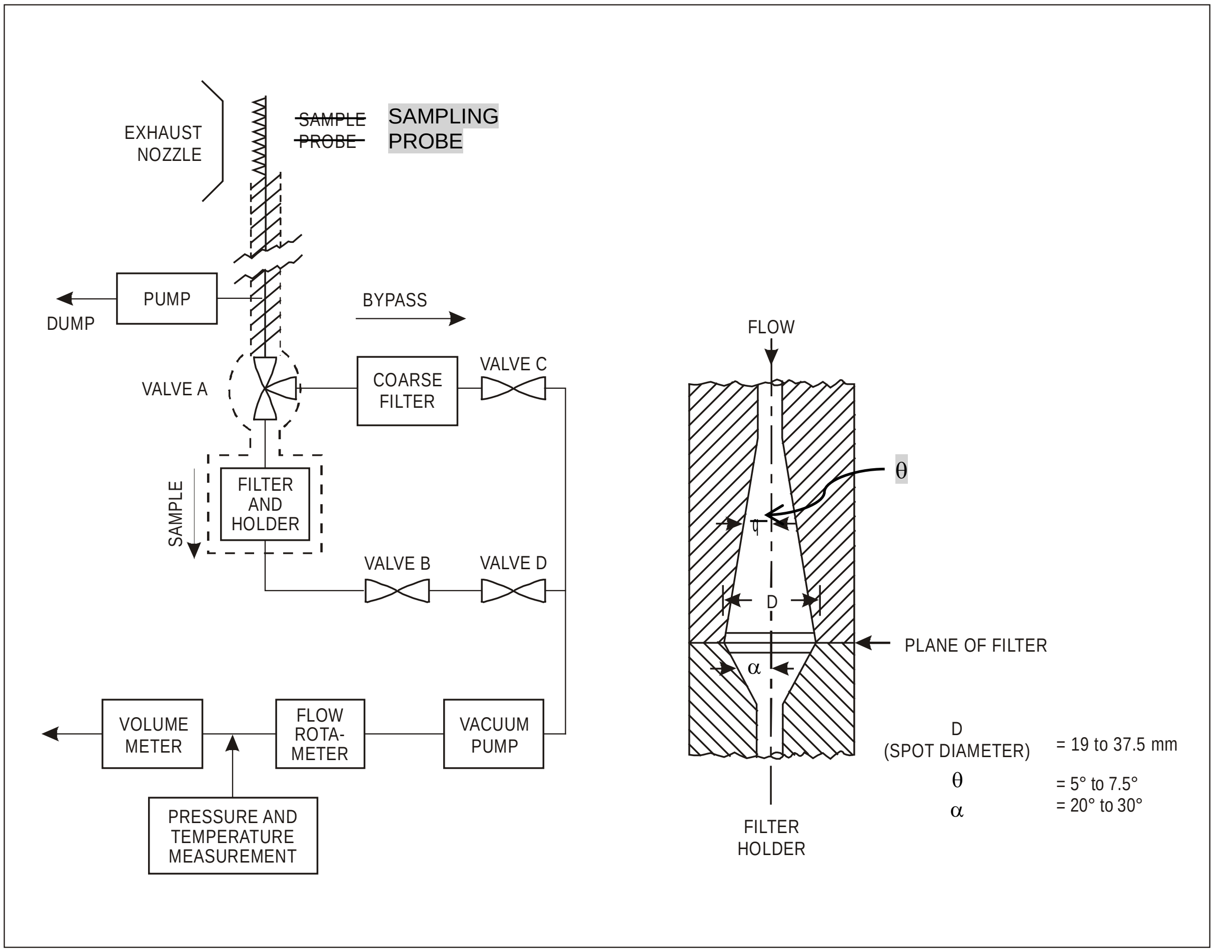

Figure A2-1. Smoke analysis system

. . .

3. CALCULATION OF SMOKE NUMBER FROM MEASURED DATA

Editorial note.— A paragraph indent was included for paragraphs 3.1 to 3.3

3.1 The stained filter specimens obtained as outlined in 2.5.3 s hall be analysed using a reflectometer as specified in 2.3. The backing material used shall be black with an absolute reflectance of less than 3 per cent. The absolute reflectance reading RS of each stained filter shall be used to calculate the reduction in reflectance by

$$SN' = 100(1 - R_S/R_W)$$

where R_W is the absolute reflectance of clean filter material.

3.2 The masses of the various samples shall be calculated by

$$W = 0.348\ PV/T \times 10^{-2} (\text{kg})$$

where P and T are, respectively, the sample pressure in Pascal and the temperature in Kelvin, measured immediately upstream of the volume meter. V is the measured sample volume in cubic metres.

3.3 For each engine condition in the case that the sample sizes range above and below the reference value, the various values of SN′ and W shall be plotted as SN′ versus log W/A, where A is the filter stain area (m^2). Using a least squares straight line fit, the value of SN′ for W/A = 16.2 kg/m^2 shall be estimated and reported as the Smoke Number (SN) for that engine mode. Where sampling at the reference size value only is employed, the reported SN shall be the arithmetic average of the various individual values of SN′.

. . .

APPENDIX 3. INSTRUMENTATION AND MEASUREMENT TECHNIQUES FOR GASEOUS EMISSIONS

. . .

3. DATA REQUIRED

. . .

3.2 Other information

In order to normalize the emissions measurement data and to quantify the engine test characteristics, the following additional information shall be provided:

— a) inlet temperature;
— b) inlet humidity;
— c) atmospheric pressure;
— d) hydrogen/carbon ratio of fuel;
— e) other required engine parameters (for example, thrust, rotor speeds, turbine temperatures and gas-generator air flow).

This data shall be obtained either by direct measurement or by calculation, as presented in Attachment F to this appendix.

. . .

5. DESCRIPTION OF COMPONENT PARTS

. . .

5.1 Sampling system

5.1.1 Sampling probe

The sampling probe shall meet the following requirements:

a) The probe material with which the exhaust emission sample is in contact shall be stainless steel or any other non-reactive material.

b) If a probe with multiple ~~sample~~ sampling orifices is used, all sampling orifices shall be of equal diameter. The probe design shall be such that at least 80 per cent of the pressure drop through the probe assembly is taken at the orifices.

c) The number of locations sampled shall not be less than 12.

d) The sampling plane shall be as close to the engine exhaust nozzle exit plane as permitted by considerations of engine performance but in any case shall be within 0.5 nozzle diameter of the exit plane.

e) The applicant shall provide evidence to the certificating authority, by means of detailed traverses, that the proposed probe design and position does provide a representative sample for each prescribed thrust setting.

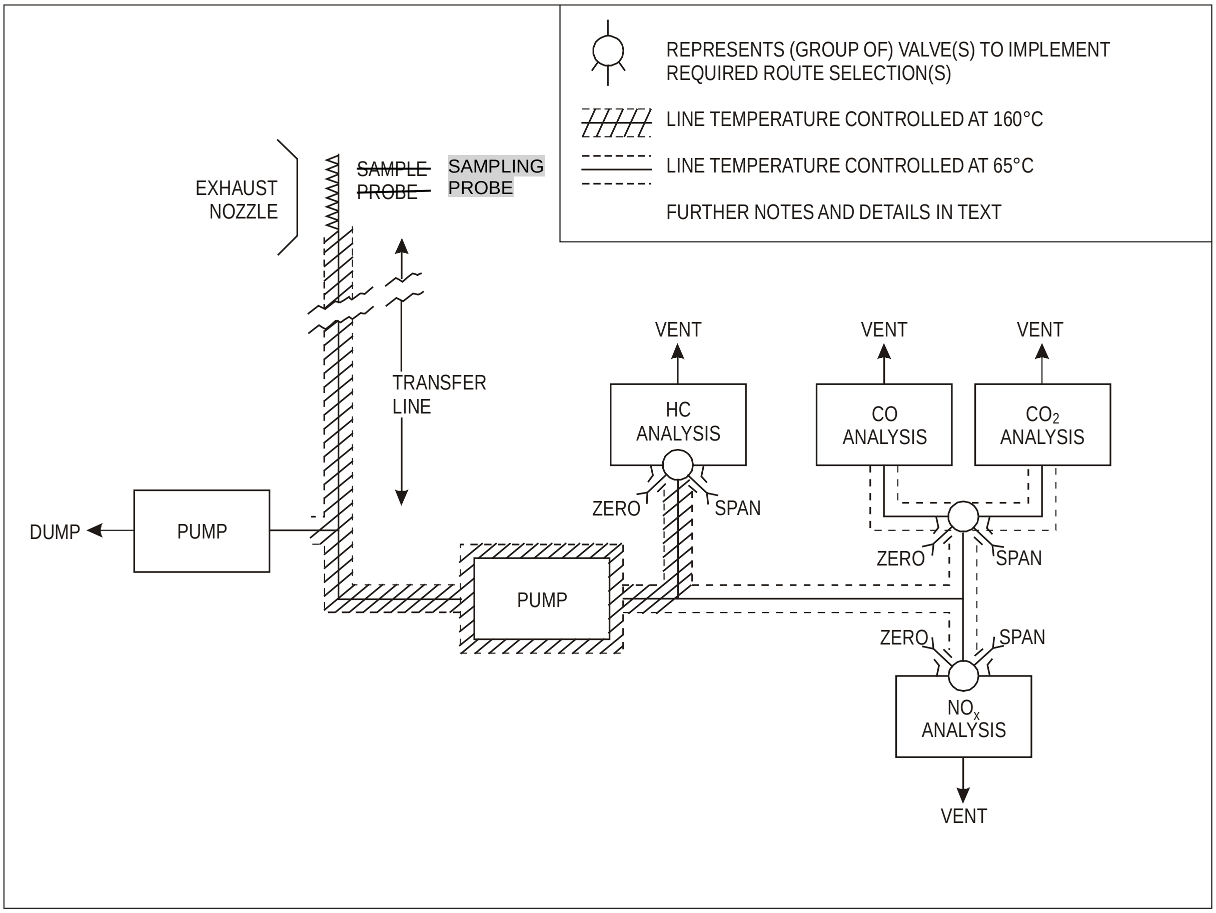

Figure A3-1. Sampling and analysis system, schematic

. . .

7. CALCULATIONS

7.1 Gaseous emissions

. . .

7.1.2 Basic parameters

. . .

Editorial note.— Removed paragraph indent from the paragraph immediately below

The value of *n/m*, the ratio of the atomic hydrogen to atomic carbon of the fuel used, is evaluated by fuel type analysis. The ambient air humidity, h_{vol}, shall be measured at each set condition. In the absence of contrary evidence as to the characterization (*x,y*) of the exhaust hydrocarbons, the values $x = 1$, $y = 4$ are to be used. If dry or semi-dry CO and CO_2 measurements are to be used then these shall first be converted to the equivalent wet concentration as shown in Attachment E to this appendix, which also contains interference correction formulas for use as required.

7.1.3 Correction of emission indices to reference conditions

Editorial note.— A paragraph indent was included for paragraph 7.1.3.1

7.1.3.1 Corrections shall be made to the measured engine emission indices for all pollutants in all relevant engine modes to account for deviations from the reference atmospheric conditions (ISA at sea level) of the actual test inlet air conditions of temperature and pressure. These corrections may also be used to account for deviations of the tested engine from the reference standard engine where appropriate (see Appendix 6, 1 f)). The reference value for humidity shall be 0.00634 kg water/kg dry air.

Editorial note.— Removed paragraph indent from the sentence immediately below

Thus, EI corrected = K × EI measured,

where the generalized expression for K is:

$$K = (P_{Bref}/P_B)^a \times (FAR_{ref}/FAR_B)^b \times \exp([T_{Bref} - T_B]/c) \times \exp(d[h_{mass} - 0.00634])$$

P_B Combustor inlet pressure, measured

T_B Combustor inlet temperature, measured

FAR_B Fuel/air ratio in the combustor

h_{mass} Ambient air humidity, kg water/kg dry air

P_{ref} ISA sea level pressure

T_{ref} ISA sea level temperature

P_{Bref} Pressure at the combustor inlet of the engine tested (or the reference engine if the data is corrected to a reference engine) associated with TB under ISA sea level conditions.

T_{Bref} Temperature at the combustor inlet under ISA sea level conditions for the engine tested (or the reference engine if the data is to be corrected to a reference engine). This temperature is the temperature associated with each thrust level specified for each mode.

FAR_{ref} Fuel/air ratio in the combustor under ISA sea level conditions for the engine tested (or the reference engine if the data is to be corrected to a reference engine).

a,b,c,d Specific constants which may vary for each pollutant and each engine type.

Editorial note.— Removed paragraph indent from the sentence immediately below.

The combustor inlet parameters shall preferably be measured but may be calculated from ambient conditions by appropriate formulas.

~~7.1.4~~ 7.1.3.2 Using the recommended curve fitting technique of 7.2 to relate emission indices to combustor inlet temperature effectively eliminates the exp $((T_{Bref} - T_B)/c)$ term from the generalized equation and for most cases the (FAR_{ref} / FAR_B) term may be considered unity. For the emissions indices of CO and HC many testing facilities have determined that the humidity term is sufficiently close to unity to be eliminated from the expression and that the exponent of the (P_{Bref}/P_B) term is close to unity.

Thus,

EI(CO) corrected = EI derived from (P_B / P_{Bref}) ~~-~~ × EI(CO) v. T_B curve

EI(HC) corrected = EI derived from (P_B / P_{Bref}) ~~-~~ × EI(HC) v. T_B curve

EI(NO_x) corrected = EI derived from EI(NO_x) × $(P_{Bref} / P_B)^{0.5}$ ~~exp~~ × exp (19 $[h_{mass} - 0.00634]$) v. T_B ~~curve~~ curve

Editorial note.— Removed paragraph indent from paragraphs immediately below.

If this recommended method for the CO and HC emissions index correction does not provide a satisfactory correlation, an alternative method using parameters derived from component tests may be used.

Any other methods used for making corrections to CO, HC and NO_x emission indices shall have the approval of the certificating authority.

7.2 Control parameter functions (D_p, F_{oo}, π)

7.2.1 Definitions

D_p The mass of any gaseous pollutant emitted during the reference emissions landing and take-off cycle.

F_{oo} Rated thrust (see Part I, Chapter 1, Definitions)

F_n Thrust at LTO operating mode~~,~~ n, (kN)

W_f Fuel mass flow rate of the reference standard engine under ISA sea level conditions (kg/s).

$W_{f n}$ ~~n~~ $_{fn}$ Fuel mass flow rate of the reference standard engine under ISA sea level conditions at LTO operating mode, ~~n~~ n.

π The ratio of the mean total pressure at the last compressor discharge plane of the compressor to the mean total pressure at the compressor entry plane when the engine is developing take-off thrust rating at ISA sea level static conditions.

7.2.2 The emissions indices (EI_n) for each pollutant, corrected to reference atmospheric conditions and, if necessary, to the reference standard engine, (EI_n (corrected)), shall be obtained for each LTO operating mode. A minimum of three test points shall be required to define the idle mode. The following relationships shall be determined under reference atmospheric conditions for each gaseous emission:

a) between EI (corrected) and T_B ; and

b) between W_f and T_B ; and

c) between F and T_B ;

Note 1.— These are illustrated, for example, by Figure A3-2 a), b) and c).

Note 2.— The relationships b) and c) may be established directly from engine test data, or may be derived from a validated engine performance model.

Editorial note.— A paragraph indent was included for paragraphs 7.2.2.1 and 7.2.2.2

7.2.2.1 A reference engine is defined as an engine substantially configured to the production standard of the engine type and with fully representative operating and performance characteristics.

7.2.2.2 The manufacturer shall also supply to the certificating authority all of the necessary engine performance data to substantiate these relationships and for ISA sea level ambient conditions:

~~d)~~ a) rated thrust (F_{oo}); and

~~e)~~ b) engine pressure ratio (π) at maximum rated thrust.

Note.— These are illustrated by Figure A3-2 d).

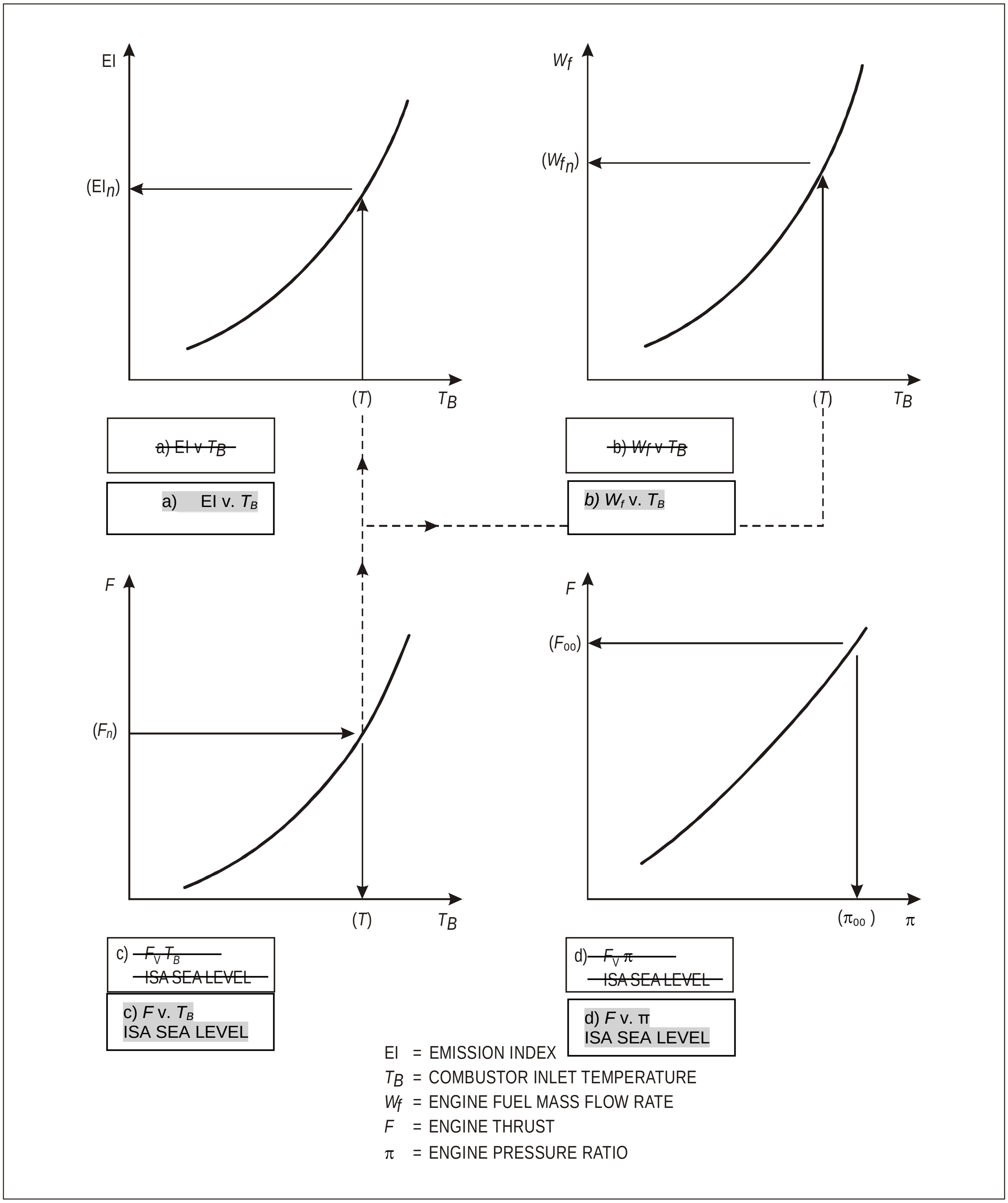

Figure A3-2. Calculation procedure

. . .

ATTACHMENT A TO APPENDIX 3. SPECIFICATION FOR HC ANALYSER

. . .

1. GENERAL

Precautions: The performance specifications indicated are generally for analyser full scale. Errors at part scale may be a significantly greater percentage of reading. The relevance and importance of such increases shall be considered when preparing to make measurements. If better performance is necessary, then appropriate precautions shall be taken.

Editorial note.— Removed paragraph indent from the paragraph immediately below

The instrument to be used shall be such as to maintain the temperature of the detector and sample-handling components at a set point ~~temperature within the range 155°C to 165°C to a stability of ±2°C~~ not less than 150°C. The leading specification points shall be as follows, the detector response having been optimized and the instrument generally having stabilized:

a) *Total range*: 0 to 5 000 ppmC in appropriate ranges.

. . .

2. SYNERGISTIC EFFECTS

. . .

Oxygen response: measure the response with two blends of propane, at approximately 500 ppmC concentration known to a relative accuracy of ±1 per cent, as follows:

~~1)~~ a) propane in 10 ±1 per cent O_2, balance N_2

~~2)~~ b) propane in 21 ±1 per cent O_2, balance N_2

. . .

ATTACHMENT B TO APPENDIX 3. SPECIFICATION FOR CO AND CO_2 ANALYSERS

. . .

CO and CO_2 Analysers

. . .

Editorial note.— A paragraph indent was included for sub-paragraphs 1) and 2), below

c) *Calibration curves*:

~~i)~~ 1) Analysers with a linear signal output characteristic shall be checked on all working ranges using calibration gases at known concentrations of approximately 0, 30, 60 and 90 per cent of full scale. The maximum response deviation of any of these points from a least squares straight line, fitted to the points and the zero reading, shall not exceed ±2 per cent of the full scale value. If it does then a calibration curve shall be prepared for operational use.

~~ii)~~ 2) Analysers with a non-linear signal output characteristic, and those that do not meet the requirements of linearity given above, shall have calibration curves prepared for all working ranges using calibration gases at known concentrations of approximately 0, 30, 60 and 90 per cent of full scale. Additional mixes shall be used, if necessary, to define the curve shape properly.

. . .

ATTACHMENT C TO APPENDIX 3. SPECIFICATION FOR NO_x ANALYSER

. . .

3. The principal performance specification, determined for the instrument operated in an ambient temperature stable to within 2°C, shall be as follows:

. . .

g) *Interference*: suppression for samples containing CO_2 and water vapour, shall be limited as follows:

~~—~~1) less than 0.05 per cent reading/per cent CO_2 concentration;

~~—~~2) less than 0.1 per cent reading/per cent water vapour concentration.

. . .

ATTACHMENT D TO APPENDIX 3. CALIBRATION AND TEST GASES

. . .

Editorial note.— Removed paragraph indent from the three paragraphs immediately below.

Carbon monoxide and carbon dioxide calibration gases may be blended singly or as dual component mixtures. Three component mixtures of carbon monoxide, carbon dioxide and propane in zero air may be used, provided the stability of the mixture is assured.

Zero gas as specified for the CO, CO_2 and HC analysers shall be zero air (which includes “artificial” air with 20 to 22 per cent O_2 blended with N_2). For the NO_x analyser zero nitrogen shall be used as the zero gas. Impurities in both kinds of zero gas shall be restricted to be less than the following concentrations:

1 ppm C
1 ppm CO
100 ppm CO_2
1 ppm NO_x

The applicant shall ensure that commercial gases, as supplied, do in fact meet this specification, or are so specified by the vendor.

. . .

ATTACHMENT E TO APPENDIX 3. THE CALCULATION OF THE EMISSIONS PARAMETERS — BASIS, MEASUREMENT CORRECTIONS AND ALTERNATIVE NUMERICAL METHOD

. . .

2. BASIS OF CALCULATION OF EI AND AFR PARAMETERS

. . .

2.4 Determination of the remaining unknowns requires the solution of the following set of linear simultaneous equations, where (1) to (4) derive from the fundamental atomic conservation relationships and (5) to (9) represent the gaseous product concentration relationships.

. . .

Editorial note.— Removed paragraph indent from the paragraph immediately below

The above set of conditional equations is for the case where all measured concentrations are true, that is, not subject to interference effects or to the need to correct for sample drying. In practice, interference effects are usually present to a significant degree in the CO, and NO measurements, and the option to measure CO_2 and CO on a dry or partially dry basis is often used. The necessary modifications to the relevant equations are described in 2.5 and 2.6.

2.5 The interference effects are mainly caused by the presence of CO_2 and H_2O in the sample which can affect the CO and the NO_x analysers in basically different ways. The CO analyser is prone to a zero-shifting effect and the NO_x analyser to a sensitivity change, represented thus:

$$[CO] = [CO]_m + L[CO_2] + M[H_2O]$$

$$\text{and } [NO_x]_c = [NO_x]_{cm}\,(1 + L'[CO_2] + M'[H_2O])$$

which transform into the following alternative equations to (6), (8) and (9), when interference effects require to be corrected,

[CO]~~m~~ $_m P_T + LP_1 + MP_4 = P_5$ .... (6A)

$[NO_x]_{cm}\,(P_T + L'P_1 + M'P_4) = \eta P_7 + P_8$ .... (8A)

$[NO]_m\,(P_T + L'P_1 + M'P_4) = P_8$ .... (9A)

2.6 The option to measure CO_2 and CO concentrations on a dry or partially dry sample basis, that is, with a sample humidity reduced to h_d, requires the use of modified conditional equations as follows:

$$[CO_2]_d\,(P_T - P_4)\,(1 + h_d) = P_1 \quad \text{(5A)}$$

and

$$[CO]_d\,(P_T - P_4)\,(1 + h_d) = P_5$$

Editorial note.—Removed paragraph indent from the paragraph immediately below

However, the CO analyser may also be subject to interference effects as described in 2.5 and so the complete alternative CO measurement concentration equation becomes

$$[CO]_{md}\,(P_i - P_4)\,(1 + h_d) + LP_1 + Mh_d\,(P_T - P_4) = P_5 \quad \text{(6B)}$$

3. ANALYTICAL FORMULATIONS

. . .

3.2 Equation for conversion of dry concentration measurements to wet basis

Concentration wet = K × concentration dry; that is,

$$[\ \ ] = K\,[\ \ ]_d$$

Editorial note.— Removed paragraph indent from the sentence immediately below

The following expression for K applies when CO and CO_2 are determined on a "dry" basis:

$$K = \frac{\{4 + (n/m)\,T + ([n/m]T - 2h_{vol})\,([NO_2] - (2[HC]/x)) + (2 + h_{vol})\,([y/x] - [n/m])\,[HC]\}\,(1{+}h_d)}{(2 + h)\,\{2 + (n/m)\,(1 + h_d)\,([CO_2]_d + [CO]_d)\} - ([n/m]\,T - 2h)\,(1 - [1 + h_d]\,[CO]_d)}$$

. . .

3.4 Equation for estimation of sample water content

. . .

Editorial note.— Removed paragraph indent from the paragraph immediately below

It should be noted that this estimate is a function of the various analyses concentration readings, which may themselves require water interference correction. For better accuracy an iterative procedure is required in these cases with successive recalculation of the water concentration until the requisite stability is obtained. The use of the alternative, numerical solution methodology (4) avoids this difficulty.

. . .

ATTACHMENT F TO APPENDIX 3. SPECIFICATIONS FOR ADDITIONAL DATA

As required in 3.2 of Appendix 3, in addition to the measured sample constituent concentrations, the following data shall also be provided:

a) inlet temperature: measured as the total temperature at a point within one diameter of the engine intake plane to an accuracy of ±0.5°C;

b) inlet humidity (kg water/kg dry air): measured at a point within ~~15 m~~ 50 meters of the intake plane ahead of the engine to an accuracy of ~~±5 per cent of reading;~~ :

1) ± 5 per cent of reading for ambient air humidity greater than or equal to 0.00634 kg water/kg dry air; or

2) ± 0.000317 kg water/kg dry air of reading for ambient air humidity less than 0.00634 kg water/kg dry air;

c) atmospheric pressure: measured within 1 km of the engine test location and corrected as necessary to the test stand altitude to an accuracy of ±100 Pa;

d) fuel mass flow: by direct measurement to an accuracy of ±2 per cent;

e) fuel H/C ratio: defined as *n/m*, where C_mH_n is the equivalent hydrocarbon representation of the fuel used in the test and evaluated by reference to the engine fuel type analysis;

f) engine parameters:

1) thrust: by direct measurement to an accuracy of ±1 per cent at take-off power and ±5 per cent at the minimum thrust used in the certification test, with linear variation between these points;

2) rotation speed(s): by direct measurement to an accuracy of at least ±0.5 per cent;

3) gas generator airflow: determined to an accuracy of ±2 per cent by reference to engine performance calibration.

Editorial note.— Removed paragraph indent from the paragraph immediately below.

The parameters a), b), d) and f) shall be determined at each engine emissions test setting, while c) shall be determined at intervals of not less than 1 hour over a period encompassing that of the emissions tests.

— — — — — — — —

APPENDIX B

PROPOSED CHANGES TO DOC 9501 AN/929

ENVIRONMENTAL TECHNICAL MANUAL
VOLUME II
Procedures for the Emissions Certification of Aircraft Engines

1. **INTRODUCTION**

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2. New text to be inserted is highlighted with grey shading.	new text to be inserted
3. ~~Text to be deleted is shown with a line through it~~ followed by the replacement text which is highlighted with grey shading.	new text to replace existing text

APPENDIX 1. MEASUREMENT OF REFERENCE PRESSURE RATIO

~~**[Reserved]**~~

1. GENERAL

1.1 Pressure shall be established using a representative engine.

1.2 Reference pressure ratio shall be derived by correlating measured pressure ratio with engine thrust corrected to standard day ambient pressure and entering this correlation at the standard day rated take-off thrust.

EXPLANATORY INFORMATION

Engine pressure ratio and corrections to standard day may be based on the validated engine performance model that is used to represent the reference engine.

2.1 Total pressure shall be measured at the last compressor discharge plane and the first compressor front face by positioning at least four probes so as to divide the air flow area into four equal sectors and taking a mean of the four values obtained.

Note.— Compressor discharge total pressure may be obtained from total or static pressure measured at a position as close as possible to the compressor discharge plane. However the certificating authority may approve alternative means of estimating the compressor discharge total pressure if the engine is so designed that the provision of the probes referred to above is impractical for the emission test.

EXPLANATORY INFORMATION

Compressor inlet and discharge total pressures are measured with multiple probes during validation of the engine performance model. As part of the model validation process, engine performance data, along with detailed analyses of the flow field between the compressor and combustor, are also used to develop methods to calculate compressor inlet and discharge total pressures based on static pressure measurements that are used by the engine control system. The static pressure tappings for measurement of compressor discharge pressure are typically located on the engine casing between the compressor discharge and the combustor inlet. During actual emissions certification tests, compressor discharge pressure is normally calculated based on these control-system static pressure measurements.

APPENDIX 2. SMOKE EMISSION EVALUATION

…

2.5.3 Smoke Measurement

EXPLANATORY INFORMATION

It is common practice, while sampling for smoke, to also measure levels of CO_2 as an operational check of the sampling system. The engine fuel-air ratio is calculated from the measured CO_2 and compared to the fuel-air ratio obtained from engine performance data. These should be in agreement within ±10 per cent at engine power above idle and within ±15 per cent at idle.

Paragraphs 2.5.3 a) through d) provide for adjusting and setting the sample flow rate through the filter holder. To duplicate the pressure drop through the filter holder during actual sampling conditions, a clean filter is clamped into the holder. This filter should be removed and discarded before clamping a clean filter into the holder as described in 2.5.3 d).

Paragraphs 2.5.3 h and 3 describe two different options for determining sample size:

Option 1: Sample size is within 12 and 21 kg/m2 and the values taken are above and below 16.2 kg/m2. In this case SN’ will have to be plotted vs log W/A. Using a straight line square fit SN’ at a value of 16.2 kg/m2 has to be determined which is reported as the SN for this mode.

Option 2: The alternative way is to take consecutive samples at 16.2 kg/m2. In this case the reported SN would be the arithmetic mean of the three SN’ values taken. It is good practice that sample size would be within 16.2 kg/m2 ±0.7 kg/m2 and all three SN’ sample would agree with ±3SN (see also ARP 1179C).

ATTACHMENT A TO APPENDIX 3. SPECIFICATION FOR HC ANALYSER

Note 1.— As outlined in 5.2 of Appendix 3, the measuring element in this analyser is the flame ionization detector (FID) in which the whole or a representative portion of the sample flow is admitted into a hydrogen-fuelled flame. With suitably positioned electrodes an ionization current can be established which is a function of the mass rate of hydrocarbon entering the flame. It is this current which, referred to an appropriate zero, is amplified and r anged to provide the output response as a m easure of the hydrocarbon concentration expressed as ppmC equivalent.

Note 2.— See Attachment D for information on calibration and test gases.

Note: This specification is for analysers that measure the total, non speciated, hydrocarbon content of the sample by means of a flame ionization detector (FID) as defined in Appendix 3. Section 2. Definitions.

1. GENERAL

***Precautions*:** The performance specifications indicated are generally for analyser full scale. Errors at part scale may be a significantly greater percentage of reading. The relevance and importance of such increases shall be considered when preparing to make measurements. If better performance is necessary, then appropriate precautions shall be taken.

EXPLANATORY INFORMATION

The performance specifications for these analysers, given in terms of full-scale response, can have a significant and adverse impact on part scale measurements. In extreme instances, concentrations of hydrocarbons at high power, such as take-off, can differ from concentrations at idle by orders of magnitude. In general it is always good practice to use a multi-range instrument and to adjust ranges such as to keep the measurement in the upper 30 per cent of the instrument response range. Calibrations should be performed on each range used as required.

The instrument to be used shall be such as to maintain the temperature of the detector and sample-handling components at a set point ~~temperature within the range 155°C to 165°C to a stability of ±2°C~~not less than 150°C.

EXPLANATORY INFORMATION

Annex 16, Volume II, previously had (Amendment 6 and before) a set point temperature within the range of 155ºC to 165ºC to a stability of ±2°C. This was adopted from SAE ARP 1256, "Procedure for the Continuous Sampling and Measurement of Gaseous Emissions from Aircraft Turbine Engines", 1971. ARP 1256 specified this range to meet the need for minimizing the condensation of hydrocarbons in the instrument, maintain instrument stability and in recognition of the operating characteristics of then commercially available total hydrocarbon analysers. Since then commercial analysers have evolved and the ARP has been revised and now ~~requires~~ recommends that the sample handling components of the total hydrocarbon analysers are housed in a temperature control recommends that the sample handling components of the total hydrocarbon analysers are housed in a temperature controlled oven housing maintained in the range of 423 to 483K (159 to 210 ºC, 302 to 410 º F). A temperature stability requirement being implicit in the instrument manufacturer's performance specifications is not required explicitly. The stability of the instrument is controlled as long as the operational requirements (hourly checks, checks for span and zero drift as required in Annex 16 as well as the handling instructions of the instrument manufacturer) for the analyzers are met. ~~A single temperature set point of not less than 160ºC but with a temperature stability requirement. Commercially available THAs have evolved and the more common detector housing temperatures approach 200 ºC~~. ~~This~~The increase in the set temperature does not affect the emissions ~~certification measurements but does place an unnecessary constraint on the test procedure~~.

a) *Total range*: 0 to 5 000 ppmC in appropriate ranges.

EXPLANATORY INFORMATION

A total range of 0 to 5 000 ppmC, while appropriate for the engines in use when Annex 16, Volume II, was published in 1981, is broader than needed for today's engines where concentrations are much lower. Appropriate instruments should be used to ensure best practice measurements in the upper 30 per cent of the range. Thus an instrument with a range upper limit of 5 000 ppmC may not be necessary and may, in fact, negatively affect the ability to ensure suitable range span due to instrument design limitations.

b) *Resolution*: ~~better than 0.5 per cent of full scale of range used or 0.5 ppmC, whichever is greater.~~ [Reserved]

c) *Repeatability:* ~~better than ± 1 per cent of full scale of range used, or ± 0.5 ppmC, whichever is greater~~ [Reserved]

d) *Stability*: better than ±2 per cent of full scale of range used or ±l.0 ppmC, whichever is greater, in a period of 1 hour.

EXPLANATORY INFORMATION

Stability, taken to be span stability and sometimes referred to as ~~repeatability or reproducibility~~ span drift, is the maximum variation in instrument output over a specified time period and within specified environmental conditions when identical concentration samples, near full-scale deflection, are passed through the instrument and after zero corrections have been made. Stability is the sum of time-dependent drift, i.e., the change in output under invariant laboratory conditions, and changes in output due to other factors such as environmental temperature and/or variations in the instruments Flame Ionization Detector (FID) enclosure temperature. Stability is highly dependent on h ow, and under what environmental conditions the analyser is used. As such it is out of the manufacturers' control and they choose to specify a value for time-dependent drift along with a range of environmental temperatures, i.e. basically under laboratory conditions. Due to improvement of instruments using solid-state electronics the drift specifications from modern HC analysers quote better drift performance (<1 per cent full scale over eight hours in laboratory conditions) than the stability requirements of the standard. Errors associated with this factor are small to negligible. Because measurements are not taken under laboratory conditions and changes in environmental conditions are the norm rather than the exception, operational procedures as described in 6.3.2 d) of Appendix 3 are required.

e) *Zero drift*: ~~less than ± 1 per cent of full scale of range used or ± 0.5 ppmC, whichever, is greater in a period of 1 hour.~~ [Reserved]

f) *Noise*: 0.5 Hz and greater, less than ±1 per cent of full scale of range used or ±0.5 ppmC, whichever is greater.

EXPLANATORY INFORMATION

The FID requires fuel and oxidant gases for operation. The fuel gas is typically either a mixture of hydrogen/nitrogen or hydrogen/helium. If the noise specification cannot be met and a hydrogen/nitrogen mixture is being used as the fuel gas, it can be helpful to change to a hydrogen/helium mixture.

g) *Response time*: ~~shall not exceed 10 seconds from inlet of the sample to the analysis system, to the achievement of 90 per cent of the final reading~~ [Reserved]

h) *Linearity*: ~~response with propane in air shall be linear for each range within ± 2 per cent of full scale, otherwise calibration corrections shall be used.~~ [Reserved]

2. SYNERGISTIC EFFECTS

Oxygen response: measure the response with two blends of propane, at approximately 500 ppmC concentration known to a relative accuracy of ±1 per cent, as follows:

1) propane in 10 ± 1 per cent O2, balance N2

2) propane in 21 ± 1 per cent O2, balance N2

If $R1$ and $R2$ are the respective normalized responses then ($R1 – R2$) shall be less than 3 per cent of $R1$.

ATTACHMENT B TO APPENDIX 3. SPECIFICATION FOR CO AND CO_2 ANALYSERS

Note 1. [Reserved]

Note 2. [Reserved]

Precautions: The performance specifications indicated are generally for analyser full scale. Errors at part scale may be a significantly greater percentage of reading. The relevance and importance of such increases shall be considered when preparing to make measurements. If better performance is necessary, then appropriate precautions shall be taken.

EXPLANATORY INFORMATION

The performance specifications for these analyzers, given in terms of full scale response, can have a significant and adverse impact on part scale measurements. This needs to be considered when planning and executing the test and in evaluating the accuracy of the measurements after the test. Concentrations of CO, when going from the idle mode to take-off, can differ by orders of magnitude. In general, where concentrations of species to be measured are known to vary this way, it is always good practice to use a multi-range instrument and to choose ranges such as to keep the measurement in the upper 30% of scale on the range in use, where possible. A measurement made at 20% of full scale could result in an error 5 times the error specified as a percent of full scale. This is a general precaution. Some modern instruments with internal electronic ranging and calibration capability can be used over their entire range without penalty. Calibrations should be performed on each range used as required. Relative to the precautions mentioned above, ranges are chosen such that the instrument responds in the upper 30% of scale for the range in use. While this may not always be possible it should be a goal.

The principal performance specification shall be as follows:

CO Analyser

a) *Total range:* [Reserved]

b) *Resolution:* [Reserved]

c) *Repeatability:* [Reserved]

d) *Stability:* [Reserved]

e) *Zero drift:* [Reserved]

f) *Noise:* [Reserved]

g) *Interferences:* to be limited with respect to indicated CO concentration as follows:

1) less than 500 ppm/per cent ethylene concentration

EXPLANATORY INFORMATION

It is unlikely that high concentrations of ethylene will be found in gas turbine engine exhaust. The highest concentration of hydrocarbons is found at idle, corresponding to the highest concentrations of CO. If all of the hydrocarbons were ethylene, C_2H_4, and the concentration were 100% of the maximum range, 5,000 ppmC, – corresponding to 2,500 ppm ethylene, the allowable interference would be less than 125 ppm, or less than 5% of the highest CO range, 2,500 ppm. Since the interference limit is in absolute terms, the relative error will increase for measurements made at less than full scale. If ethylene is present in significant concentrations then corrections to the data are required.

2) less than 2 ppm/per cent CO_2 concentration

3) less than 2 ppm/per cent water vapour.*

EXPLANATORY INFORMATION

These two interferents, CO_2 and water vapour, are additive. Being the major products of combustion they increase and decrease together and are at their highest levels at the highest power. Unfortunately concentrations of CO tend to be at their lowest concentrations at the highest power. This can cause significant problems in the accuracy of the measurement even if the interference limits are met. It is not unusual for tests to be conducted with the sample dried before measurement and the interference due to the remaining interferent, CO_2, compensated for through use of gas or optical filters. It does bear mentioning that the contribution of high power CO concentrations to the total gross CO emission measured over the LTO cycle is relatively small.

CO_2 Analyser

a) *Total range:* 0 to 10 per cent in appropriate ranges.

EXPLANATORY INFORMATION

Although the total range specified for CO_2 is 0 to 10% concentrations most often will vary between 1% and 5%. This range is considerably narrower than that for CO. Never-the-less good practice dictates using ranges that keep the instrument response in the upper 30% of the meter scale as appropriate.

b) *Resolution:* [Reserved]

c) *Repeatability:* [Reserved]

d) *Stability:* [Reserved]

e) *Zero drift:* [Reserved]

f) *Noise:* [Reserved]

g) The effect of oxygen (O_2) on the CO_2 analyser response shall be checked. For a change from 0 per cent O_2 to 21 per cent O_2, the response of a given CO_2 concentration shall not change by more than 2 per cent of reading. If this limit cannot be met an appropriate correction factor shall be applied.

* Need not apply where measurements are on a "dry" basis.

Note.— It is recommended, as consistent with good practice, that such correction procedures be adopted in all cases.

EXPLANATORY INFORMATION

Gas turbine engines use a considerable amount of internal cooling air that mixes with the combustion products before exiting the engine. Oxygen rich exhaust samples warrant close attention because of its effect on the CO_2 measurement.

Annex 16 does not provide any means to address this effect. ARP 1533 however provides all the necessary steps to determine coefficient J for the interference of O_2 on the CO_2 measurement. In order to take into account oxygen interference the P1 (CO_2) term in the basic combustion equation in 2.1 of Attachment E would become:

$P_1\ [CO_2] = [CO_2]_{measured} \times P_T + J \times ([CO_2]_{measured} \times P_3)$

Where

P_1 = real number of moles of CO_2 in the exhaust sample per mole of fuel
P_3 = real number of moles of O_2 in the exhaust sample per mole of fuel
P_T = total number of moles in the exhaust

J = Oxygen interference coefficient for effect of O_2 on the measurement of CO_2 (concentration factor)With the "concentration factor" interference effect (or sensitivity effect), the interfering specie modifies the slope of the response of the analyser : therefore the effect is proportional to the concentration measured. This is the case for the interference of O_2 on CO_2. An interference coefficient is required that quantifies the modification of the parts per volume measured.

The same equation can be expressed in concentrations rather than moles:

$[CO_2]_{real} = [CO_2]_{measured} \times (1+J \times ([O_2]_{measured}))$

Case1:

If the NDIR analyser had been calibrated with CO_2 in zero air (with an O_2/N_2 mixture) where the amount of oxygen was equal to the amount of oxygen in the exhaust measurement, the oxygen effect would become zero.

$[CO_2]_{real} = [CO_2]_{measured} \times (1+J \times ([O_2]_{test} - [O_2]_{cal}))$

Case 2:

In cases where the oxygen concentration in the exhaust is unknown or may vary the preferred way to calibrate the NDIR analyser would be to use a CO_2 calibration gas balanced with pure nitrogen and adjust for the effect of O_2 interference using the Technical Procedure described below.

TECHNICAL PROCEDURE

The Annex 16 does not contain a procedure to correct for oxygen effect.

When a correction is required for the interference of the oxygen on the CO_2 measurement, the correction can be expressed as follows (equivalent to the equations for CO and NO in paragraph 3.3 of Attachment E):

$[CO_2] = [CO_2]m \times (1+J \times [O_2])$

Where

$[CO_2]$ = the mean concentration of CO_2 in exhaust sample, vol/vol.

$[CO_2]m$ = the mean concentration measurement indicated before instrument correction applied, vol/vol.

J = the analyser interference coefficient for interference by O_2.

$[O_2]$ = the mean concentration of O_2 in exhaust sample, vol/vol.

The oxygen modifies the slope of the response of the NDIR. Therefore the effect is proportional to the concentration measured.

A representative value of J is given in ARP1533B. However this is an arbitrary value and it is recommended that the J coefficient is measured individually for each analyser used. It could be obtained according to the calculations provided in ARP1533B. It could also be obtained in the laboratory by making a first measurement (m1) with a calibration gas of CO_2 in N_2 ($[O_2]$=0) in the appropriate range of the analyser and a second one (m2) with a test gas of high concentration of O_2. J can be obtained from the following equation:

$J = ([CO_2]m1/[CO_2]m2 - 1) / [O_2]$

However, analysers are often calibrated by the instrument manufacturer to automatically correct for O_2 interference. The existence of such corrections should be established before using any correction procedure.

CO and CO_2 Analysers

a) *Response time:* [Reserved].

b) *Sample temperature:* the normal mode of operation is for analysis of the sample in its (untreated) "wet" condition. This requires that the sample cell and all other components in contact with the sample in this subsystem be maintained at a temperature of not less than 50°C, with a stability of ±2°C. The option to measure CO and CO_2 on a dry basis (with suitable water traps) is allowed, in which case unheated analysers are permissible and the interference limits for H_2O vapour removed, and subsequent correction for inlet water vapour and water of combustion is required.

EQUIVALENT PROCEDURE

Stability is defined in terms of a time interval which, because this is a temperature control set point, can be taken as the duration of the test, or one hour to be consistent with the stability limits placed on the detection system.

The temperature quoted for the CO and CO_2 subsystems, 50°C, is on the low end of the sample line specification, 65°C ±15°C. Good practice would suggest that the subsystem temperature be approximately the same as the sample gas temperature. If the samples are dried and the analysers unheated, it would be reasonable to lower the sample temperature to that of the analyser. If water is removed prior to analysis, corrections must be applied to compensate for the loss of water of combustion and inlet water vapour. Correction procedures are detailed in Attachment F of this Appendix.

c) *Calibration curves:*

1) Analysers with a linear signal output characteristic shall be checked on all working ranges using calibration gases at known concentrations of approximately 0, 30, 60 and 90 per cent of full scale. The maximum response deviation of any of these points from a least squares straight line, fitted to the points and the zero reading, shall not exceed ±2 per cent of the full scale value. If it does then a calibration curve shall be prepared for operational use.

TECHNICAL PROCEDURE

Straight line fits to sets of linear data can be arrived at graphically or analytically. If graphically, the results are subject to interpretation, i.e., best estimate by 'eye' by individual. If analytically, there is assurance that each case and all data are handled the same way each time. The most appropriate technique is to perform a linear regression, or 'least-squares fit' for a line. The calibration gas values are the independent ―variables and are assumed to be correct (to have negligible error) for the purpose of this analysis. The instrument response values are the 'dependent' variables and are assumed to have errors and that these errors are normally (Gaussian) distributed about the true line. The equation describing the straight line is:

$$\mathbf{y_i = A + B * x_i}$$

true value for response yi = A (a constant) + B (another constant) * (calibration gas value xi)
For instruments which have been adjusted such that zero input results in zero output, and where the variance in known to be proportional to the reading the slope B can be shown to be equal to the ratio of the averages and can be expressed as:

$$\frac{\bar{y}}{\bar{x}}$$

Often A and B are not such simple values for intercept and slope but must be calculated as if the variance were not known to be proportional to the instrument response. Again if we set the instrument to read zero for zero gas input then A = 0 which makes the calculation relatively simple. The generalized expression for B can be found in any elementary statistics or error analysis text and is:

$$B = \frac{N\sum_{i=1}^{N} x_i y_i - \sum_{i=1}^{N} x_i \sum_{i=1}^{N} y_i}{N\sum_{i=1}^{N} x_i^2 - \left(\sum_{i=1}^{N} x_i\right)^2}$$

Where xi is the calibration gas value and yi is the instrument response and N refers to the number of points used in the analysis.
With N = 4, corresponding to 0, 30, 60 and 90% of full scale, this equation can be rewritten as:

$$B = \frac{4\sum_{i=1}^{4} x_i y_i - \sum_{i=1}^{4} x_i \sum_{i=1}^{4} y_i}{4\sum_{i=1}^{4} x_i^2 - \left(\sum_{i=1}^{4} x_i\right)^2}$$

A simple table, for the four sets of values, can be used for organizing the information thereby simplifying the calculation:

Measurement Number i	**X_i cal gas value i**	**Y_i Response i**	**X_i^2**	**X_iY_i**
1				
2				
3				
4				
N=4	**$\sum X_i$**	**$\sum Y_i$**	**$\sum X_i^2$**	**$\sum X_iY_i$**

If the instrument is not set to zero-zero (zero response for zero input) then A must be determined. The equation for A (for N = 4) is:

$$A = \frac{\sum_{i=1}^{4} x_i \sum_{i=1}^{4} y_i}{4\sum_{i=1}^{4} x_i^2 - \left(\sum_{i=1}^{4} x_i\right)^2}$$

The table shown earlier can be used to organize the elements of this equation as well.
Usually the next step would be to calculate the uncertainty in yi about this line. However, instead of controlling uncertainty about the line, ICAO chose to set an absolute limit of ±2% deviation of the full scale value for each point. This should make clear the advantage in using the upper region (top 30%) of the range for all measurements.

2) Analysers with a non-linear signal output characteristic, and those that do not meet the requirements of linearity given above, shall have calibration curves prepared for all working ranges using calibration gases at known concentrations of approximately 0, 30, 60 and 90 per cent of full scale. Additional mixes shall be used, if necessary, to define the curve shape properly.

TECHNICAL PROCEDURE

For analysers with a non-linear signal output characteristic calibration curves shall be prepared, again using approximately 0, 30, 60 and 90% of full scale calibration gases. If a curve is substantially non-linear in shape, it is recommended that additional calibration gases be used with values between the ones specified. These calibration curves can be determined analytically using a least squares fit, but in this case the fit would be to a polynomial or exponential. The equations for doing this can be found in any basic text on statistics or error analysis. It should be noted that for exponential fits it is often convenient to work with the logarithm of the expression, which reduces the problem to a least-squares-fit about a line as is described above. (This technique is used in analysing smoke filters as required in paragraph 3 of Appendix 2). Although not stated explicitly, the presumption is that the same ±2% of full scale response deviation is true for non-linear as well as linear instruments. The use of a gas divider is an acceptable alternative to acquiring and maintaining additional gas resources.

The table below summarizes the specifications for CO and CO_2 analysers. These are typical of those analysers offered by major analyser manufacturers.

NDIR ANALYSER PERFORMANCE SPECIFICATIONS

Parameter	Value	
	CO_2	CO
Total Range	0 to 10% in appropriate ranges	0 to 2 500 ppm in Appropriate ranges
Resolution	better than 0.5% fs range used or 100 ppm whichever greater	better than 0.5% fs range used or 1 ppm whichever greater
Repeatability	better than ±1% fs range used or ±100 ppm whichever greater	better than ±1% fs range used or ±2 ppm whichever greater
Stability	better than ±2% fs range used or ±100 ppm whichever greater period of 1 hr	better than ±2% fs range used or ±2 ppm whichever greater period of 1 hr
Zero Drift	< ±1% fs range used or ±100 ppm whichever greater period 1 hr	< ±1% fs range used or ±2 ppm whichever greater period 1 hr
Noise	> 0.5 Hz, < ±1% fs range used or ±100ppm whichever greater	> 0.5 Hz, < ±1% fs range used or ±1ppm whichever greater
Interference	≤ 2% of reading for O_2 between 0 and 21%	< 500 ppm/% ethylene < 2 ppm/% CO_2 < 2 ppm/% water vapor
Response Time	≤ 10 seconds from instrument inlet to 90% fs	≤ 10 seconds from instrument inlet to 90% fs
Sample Temperature	wet samples ≥ 50 °C stability ± 2 °C	wet samples ≥ 50 °C stability ± 2 °C

ATTACHMENT C TO APPENDIX 3. SPECIFICATION FOR NO_x ANALYSER

Note.— See Attachment D for information on calibration and test gases.

1. [Reserved]

2. [Reserved]

Precautions: The performance specifications indicated are generally for analyser full scale. Errors at part scale may be a significantly greater percentage of reading. The relevance and importance of such increases shall be considered when preparing to make measurements. If better performance is necessary, then appropriate precautions shall be taken.

EXPLANATORY INFORMATION

The performance specifications for these analysers given in terms of full scale response can have a significant and adverse impact on part scale measurements. This needs to be considered when planning and executing the test and in evaluating the accuracy of the measurements after the test. Concentrations of NOX, when going from the idle mode to take-off, can differ by orders of magnitude. In general, where concentrations of species to be measured are known to vary this way, it is always good practice to use a multi-range instrument, and to choose ranges such as to keep the measurement in the upper 30% of scale on the range in use. A measurement made at 20% of full scale could result in an error 5 times the error specified as a percent of full scale. This is a general precaution. Some modern instruments with internal electronic ranging and calibration capability can be used over their entire range without penalty. Calibrations should be performed on each range used as required.

3. The principal performance specification, determined for the instrument operated in an ambient temperature stable to within 2°C, shall be as follows:

a) *Total range:* 0 to 2,500 ppm in appropriate ranges.

EQUIVALENT PROCEDURE

Taking into account the NO_X emissions concentration of current engines NO_X analysers with a lower total range, typically 0 – 1,000 ppm, would be acceptable.

b) *Resolution:* [Reserved].

c) *Repeatability:* [Reserved].

d) *Stability:* [Reserved].

e) *Zero drift:* [Reserved].

f) *Noise:* [Reserved].

g) *Interference:* [Reserved].

h) *Response time:* [Reserved].

i) *Linearity:* [Reserved].

j) *Converter:* this shall be designed and operated in such a manner as to reduce NO_2 present in the sample to NO. The converter shall not affect the NO originally in the sample.

The converter efficiency shall not be less than 90 per cent.

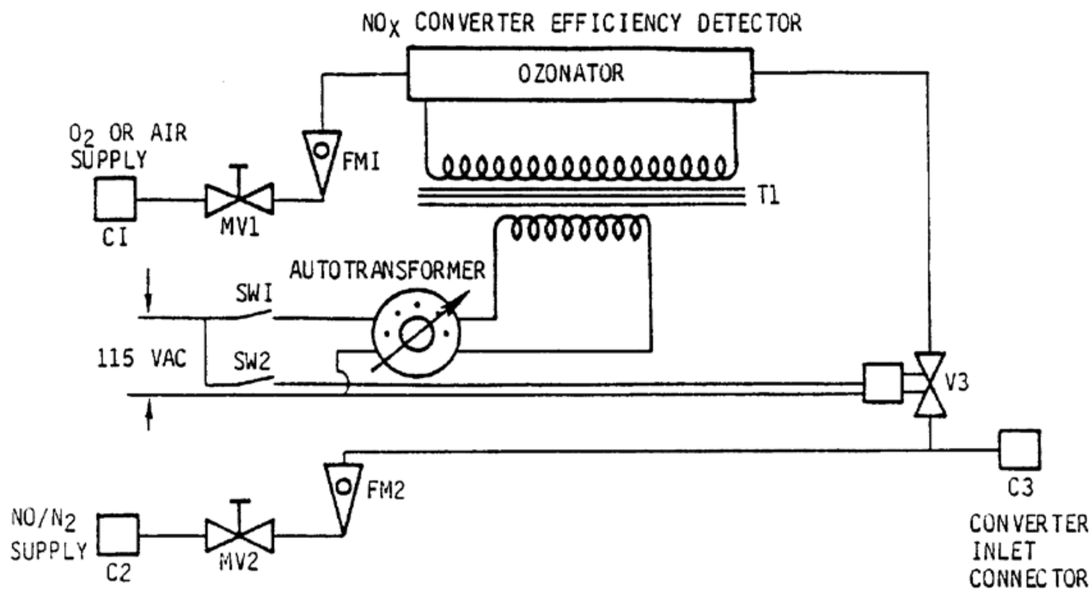
This efficiency value shall be used to correct the measured sample NO_2 value (i.e. $[NO_x]_c$ – [NO]) to that which would have been obtained if the efficiency had been 100 per cent.

EQUIVALENT AND TECHNICAL PROCEDURES

When available follow the NO_X analyser instrument manufacturer's procedures for determining the NO_2 converter efficiency. Alternatively a separate commercially available NO_2 converter tester can be used along with the NO_X analyser being evaluated.

A third alternative, described below, is a procedure that was originally required by the U.S. Environmental Protection Agency in 40CFR Part 87, "Control of Air Pollution from Aircraft and Aircraft Engines" 1973, and subsequently incorporated into the SAE Aerospace Recommended Practice ARP1256, "Procedure for the Continuous Sampling and Measurement of Gaseous Emissions from Aircraft Turbine Engines". The procedure, as described, uses a device requiring acquisition and assembly of the component parts and considerable hands-on operation. However its utility and versatility is implicit when considering the range of applications for which the Environmental Protection Agency either requires it to be used or allows it as an alternative procedure, e.g., land based vehicles and continuous emissions monitors for stationary sources.

The following Figure schematically depicts such a device. This device is intended for use with the NO_X analyser specified in Attachment C. It depends on the reaction: $NO + O_3 \rightarrow NO_2 + O_2$



Starting with a known concentration of NO in N_2, measurements are made through – and bypassing – the chemiluminescence analyser converter, the inlet to which is shown as "C3" in the diagram. With the NO_X converter ozonator alternately on, r educing the NO concentration by approximately 80%, and off, allowing 100% of the NO to reach the analyser the analyser's converter efficiency can be determined. This efficiency should be used to correct test data as required.

The specific instructions for using this device are as follows:

(i) Attach the NO/N_2 supply (150-250 ppm.) at "C2", the O_2 supply at "C1", and the analyser inlet connection to the efficiency detector at C3. If lower concentrations of NO are used, air may be used in place of O_2 to facilitate better control of the NO_2 generated during step (iv).

(ii) With the efficiency detector autotransformer off, place the NO_X converter in bypass mode and close valve "V3". Open valve "MV2" until sufficient flow and stable readings are obtained at the analyser. Zero and span the analyser output to indicate the value of the NO concentration being used. Record this concentration.

(iii) Open valve V3 (on/off flow control solenoid valve for O_2) and adjust valve "MV1" (O_2 supply metering valve) to blend enough O_2 to lower the NO concentration (ii) to about 10 percent. Record this concentration.

(iv) Turn on the ozonator and increase its supply voltage until the NO concentration of (iii) is reduced to about 20 percent of (ii). NO is now being formed from the NO + O_2 reaction. There must always be at least 10 percent unreacted NO at this point. Record this concentration.

(v) When a stable reading has been obtained from (iv), place the NOX converter in the convert mode. T he analyser will now indicate the total NO_X concentration. R ecord this concentration.

(vi) Turn off the ozonator and allow the analyser reading to stabilize. The mixture NO + O_3 is still passing through the converter. This reading is the total NO_X concentration of the dilute NO span gas used in step (iii). Record this concentration.

(vii) Close valve V3. The NO concentration should be equal to or greater than the reading of (ii) indicating whether the NO contains any NO_2.

Calculate the efficiency of the NO_X converter by substituting the concentrations obtained during the test into the following equation:

$$\% \text{ Efficiency} = [(v)-(iv)] / [(vi)-(iv)] \times 100 \%$$

To improve the effectiveness of thermal converters, particularly those with efficiencies of less than 90%, it is sometimes helpful to raise the temperature of the converter.

ATTACHMENT D TO APPENDIX 3. CALIBRATION AND TEST GASES

EXPLANATORY INFORMATION

Calibration and test gases are normally obtained from commercial specialty gas companies and are available with traceability to the appropriate National Metrology Institute (NMI), e.g., NIST in the US, NPL in the UK, NMi in the Netherlands or KRISS in Korea. These institutes work in collaboration, to ensure and improve the accuracy of primary gas standards.

With few exceptions calibration gases, although traceable to, are not directly available from an NMI.

Traceability is arrived at through adherence to a strict protocol that relates the uncertainty in the concentration of the gas, in high pressure cylinders, provided by the specialty gas company (vendor) to a standard gas being maintained by the NMI.

In the U.S. NIST is the designated NMI. NIST generates and maintains standard reference materials (SRMs) as well as employing very high accuracy analytical techniques (≤0.5%) to determine and validate the uncertainty in the gases provided by the vendors. The validation procedure requires the vendor to analyse all of the gas cylinders in a production lot and provide the data to NIST who, after reviewing and accepting the data, choses, on a random basis, 10% of the cylinders for NIST audit. NIST then certifies the lot based upon the vendor data and NIST audit. Once the cylinders are certified the vendor can either sell these cylinders, as NTRMs (NIST Traceable RMs) or use them to produce other categories of traceable calibration gases. NIST in describing the EPA Protocol Gas Suppliers Audit program summarized the uncertainty of this validation procedure as follows: "If the analytical uncertainty claims of NIST (≤ 0.5%) and the gas vendors (≤1.0%) are valid and there is no bias … then the difference between the NIST analysis and the vendor certificated concentrations of the audit mix should ideally be ≤ 1% relative and as a worse case, no more than 2% relative".

In Europe the different National Metrology Institutes use very similar concepts for accurate, nationally-traceable gas calibration Standards. In the UK the National Physical Laboratory NPL prepares and maintains the primary standard gas mixtures (PSMs) which are prepared by absolute gravimetric methods and produced through a chain of direct comparisons to the national measurement standards. Reputable vendors provide calibrated gas mixtures at secondary gas standards by comparison with PSM (< 0.1%) and primary reference gas mixtures (< 0.3%) from the NPL. These secondary gas standards provide a fraction uncertainty of ± 0.5% to ± 1% (95% level of confidence). These are usually labelled in accordance with ISO 6141 and meet all other appropriate ISO specifications.

Because of the accuracy required and the sophistication of the techniques necessary to produce and analyse gases to the required standards, most if not all engine manufacturers rely on the commercial vendors' analysis and certification of traceability for concentration and uncertainty and use in-house checks via instrument response for consistency of assay. It is good practice to check all calibration and test gases as they come from the vendor and prior to the use as working gases. This is normally also addressed within existing internal audit procedures for periodic calibration of the different analysers.

In Annex 16 the accuracy specification of the calibration gases is ±2% whereas in the ARP1256D this specification is ±1%. The reason for having a higher value in Annex 16 comes from the difficulty for the engine manufacturers to cross check the gas vendor certificated value within an accuracy better than 2%.

Annex 16 does not provide information regarding special problems that occur with gas cylinders. Stability can be particularly troublesome with cylinders of very low concentration gases. Even though vendors take considerable care in the manufacture and preparation of cylinders before filling them there can be defects in the cylinder that result in changes in concentration after the cylinder leaves the vendor. In addition in defect free cylinders the practice of conditioning the cylinder with high concentrations of the gas of interest at high pressure can result in adsorption of some of this gas which remains after the cylinder is flushed and filled with the low concentration gas. Some of the adsorbed gas can be released as the cylinder pressure drops and if the cylinder temperature increases.

Although not a calibration gas or, strictly speaking, a test gas, the FID combustive gases should also meet a hydrocarbon specification. For hydrogen/nitrogen or hydrogen/helium fuel mixtures, total hydrocarbons present should be < 1 ppmC. The oxidant should be hydrocarbon free grade air, containing < 1 ppmC hydrocarbon.

EQUIVALENT PROCEDURE

The mixture and composition of calibration and test gases between ARP 1256D and Attachment D of Annex 16 are different. While the Annex specifies zero air as a diluent for CO and CO_2 test gases, the ARP 1256D recommends as a preferred test gas for spanning the NDIR analyser zero nitrogen (nitrogen as a diluent) thereby eliminating the need for oxygen interference correction when determining or checking the analyser calibration curve.

It should be noted that engine exhaust does contain significant concentrations of O_2 and correcting for O_2 interference when measuring CO_2 is necessary. However, analysers are often calibrated by the instrument manufacturer to automatically correct for O2 interference. The existence of such corrections should be established before using any correction procedure.
When zero nitrogen would be used as a zero gas it shall be high purity nitrogen (99.99% nitrogen or better) with less than 1 ppm C, 1 ppm CO, 100 ppm CO_2 and 1 ppm NO_X.

ATTACHMENT E TO APPENDIX 3. THE CALCULATION OF THE EMISSIONS PARAMETERS - BASIS, MEASUREMENT CORRECTIONS AND ALTERNATIVE NUMERICAL METHOD

1. SYMBOLS

…

L, L' analyser interference coefficient for interference by CO_2

EXPLANATORY INFORMATION

L is the interference effect of CO_2 on the measurement of CO interpreted in terms of a zero shift. *L'* is the interference effect of CO_2 on the measurement of NO and NOx interpreted in terms of a sensitivity change.

Note: The values of these interference effects are specific to and must be determined for the individual analysers.

M, M' analyser interference coefficient for interference by H_2O

EXPLANATORY INFORMATION

M is the interference effect of H_2O on the measurement of CO interpreted in terms of a zero shift. *M'* is the interference effect of H_2O on the measurement of NO and NO_x interpreted in terms of a sensitivity change.

Note: The values of these interference effects are specific to and must be determined for the individual analysers.

2. BASIS OF CALCULATION OF EI AND AFR PARAMENTERS

2.1 It is assumed that the balance between the original fuel and air mixture and the resultant state of the exhaust emissions as sampled can be represented by the following equation:

…

$$AFR = P_0 \left[\frac{M_{AIR}}{mM_C + nM_H} \right]$$

EXPLANATORY INFORMATION

This is a slightly different formulation for AFR than that stated in Appendix 3 7.1.2, " Basic parameters". In this formulation *m,* the "number of C atoms in characteristic fuel molecule" is placed within the bracket. There is no particular advantage to using one formulation over the other.

2.2 [Reserved]
2.3 [Reserved]
2.4 [Reserved]
2.5 The interference effects are mainly caused by the presence of CO_2 and H_2O in the sample which can affect the CO and NO_x analysers in basically different ways. The CO analyser is prone to a zero-shifting effect and the NO_x analyser to a sensitivity change represented thus:

$$[CO] = [CO]_m + L[CO_2] + M[H_2O]$$

and $$[NO_x]_c = [NO_x]_{cm}(1 + L'[CO_2] + M'[H_2O])$$

EXPLANATORY INFORMATION

With a zero shift interference effect, the interfering specie creates an offset on the measurement, which does not vary with the concentration measured. This is the case for the interference of CO_2 and H_2O on CO.
With a sensitivity change interference effect, the interfering specie modifies the slope of the response of the analyser: therefore the effect is proportional to the concentration measured. This is the case for the interference of CO_2 and H_2O on NO.
Note: The values of these interference effects are specific to and must be determined for thee individual analysers

2.6 [Reserved]

3. ANALYTICAL FORMULATIONS
[Reserved]

4. ALTERNATIVE METHODOOGY – NUMERICAL SOLUTION

EXPLANATORY INFORMATION

Details explaining various calculation procedures can be found in SAE Aerospace Recommended Practice (ARP) 1533B, Procedure for the Analysis and Evaluation of Gaseous Emissions from Aircraft Engines. ARP 1533B includes, among other things, derivation of equations, the combustion chemical equation, and a matrix method of solving the combustion chemical equation.

ATTACHMENT F TO APPENDIX 3. SPECIFICATION FOR ADDITIONAL DATA

As required in 3.2 of Appendix 3, in addition to the measured sample constituent concentrations, the following data shall also be provided:

a) inlet temperature: [Reserved]

b) inlet humidity (kg water/kg dry air): measured at a point within 50 m of the intake plane ahead of the engine to an accuracy of ±5 per cent of reading or ± 0.000317 kg water/kg dry air, whichever is larger;

EXPLANATORY INFORMATION

Originally, Annex 16, Volume II, required humidity measurements within 15 m of the engine intake plane, but the requirement was extended to 50 m based on a study of humidity measurements currently used in engine performance testing. These measurements are completed to measure the representative humidity of the air that will be entering the engine from the upstream airflow, hence the use of the words "ahead of the engine" in the Annex.

Selection of a suitable site for the humidity measurement is based on topography of the test site, prevailing winds and the test bed(s) intake arrangements. A survey of engine manufacturer's test sites showed the location of performance humidity measurement typically falls within 50 meters of the engine inlet, so the required distance between the humidity instrument and engine was increased to allow use of the performance instrumentation.

The requirement for accuracy of the humidity measurement was also changed from "±5 per cent of reading" to ± 5% of the measured value or ± 0.000317 kg water/kg dry air, whichever is larger. This change was made to enable use of modern humidity instruments that, but are not capable of meeting ±5 % accuracy at very low humidity levels. In practice, engine manufacturers have found the actually attained accuracy in routine operation is just as acceptable with the newer systems as the older systems.

For most operating conditions these instruments have humidity accuracy significantly better than ±5% of reading requirements; however, the accuracy of these instruments can be more than ±5% of reading when relative humidity is very low (little water is in the air). These are the cases, however, where humidity uncertainty has the least impact on the reported emissions.

The lower limit for accuracy was selected to be ±0.000317 kg water/kg dry air. This corresponds to ± 5% at the standard reference humidity of 0.00634 kg water/kg dry air. When this lower limit for accuracy is used, the accuracy of the humidity correction is within ± 0.604 percent.

APPENDIX 6. COMPLIANCE PROCEDURES FOR GASEOUS EMISSIONS AND SMOKE

~~[Reserved]~~

1. GENERAL

The following general principles shall be followed for compliance with the regulatory levels set forth in Part III, 2.2, 2.3, 3.2 and 3.3:

a) [Reserved]

b) [Reserved]

c) [Reserved]

d) [Reserved]

e) [Reserved]

f) the engines submitted for testing shall have emissions features representative of the engine type for which certification is sought. However, at least one of the engines shall be substantially configured to the production standard of the engine type and have fully representative operating and performance characteristics. One of these engines shall be declared to be the reference standard engine. The methods for correcting to this reference standard engine from any other engines tested shall have the approval of the national certificating authority. The methods for correcting test results for ambient effects shall be those outlined in 7 of Appendix 3 or 7 of Appendix 5, as applicable.

EXPLANATORY INFORMATION

A "reference standard engine" as defined in ICAO Annex 16, volume 2, appendix 6, section 1f) is required “to be substantially configured to the production standard of the engine type and have fully representative operating and performance characteristics". The "reference standard engine" performance must be evaluated at ISA SL conditions per section 7 of Appendix 3 (or 5 as appropriate). In ICAO Annex 16, volume 2, appendix 3, section 7.2.2, it is specifically stipulated that the relationship between W_f and T_B, and between F_n and T_B can be derived from a validated engine performance model. As such, while standard engine performance may be based on measurements from a "physical engine" or number of "physical engines" configured as above (correcting appropriately for ambient conditions), a "performance model" based on measurements from one or more physical engines may be equivalently used.

A "performance model" (equivalently named as performance deck or cycle deck) is a computer program that provides detailed airflow, fuel flow, temperature, pressure, shaft speed information for all engine components, conforming to applicable industry practices (e.g. relevant portions of SAE Aerospace Standards AS681). Although other calculation methods are possible, in current practice this computer program solves a mass, energy and momentum balance with specific component performance maps and secondary flow maps. The "performance model" is calibrated to engine test data (speeds, temperatures, pressures) applicable to the specific engine model being considered under various ambient and altitude conditions. The "performance model" is evaluated at ISA Sea level static conditions with no off-take bleeds and accessory loads other than those necessary for the engine's basic operation.

The performance model may be used to derive the relationship between W_f and T_B, between F_n and T_B and between P_B and T_B for the purposes of defining a "reference standard engine".

The "performance model" can be created with data from the engine used for the emissions test. Alternatively, the performance model can be developed with data from a number of engines of similar technology. In this case, it may be shown that the emission relevant parameters (T_3, P_3, W_f, F_n) of the emissions test engine corrected to the same ambient condition, and taking into account issues such as deterioration, match well enough with he "performance model" parameters.

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APPENDIX C

TEXT OF PROPOSED NEW
ANNEX 16, VOLUME III — *CO_2 CERTIFICATION REQUIREMENT*

TEXT OF PROPOSED NEW ANNEX 16, VOLUME III

International Standards and
Recommended Practices

Annex 16
to the Convention on
International Civil Aviation

Environmental Protection

Volume III
CO_2 Certification Requirement

First Edition
xxxx 201x

International Civil Aviation Organization

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APPENDICES

FOREWORD

Historical background

Standards and Recommended Practices for Environmental Protection were first adopted by the Council on 2 April 1971 pursuant to the provisions of Article 37 of the Convention on International Civil Aviation (Chicago, 1944) and designated as Annex 16 to the Convention. This Volume III to Annex 16 was developed in the following manner:

At the 36th Session of the ICAO Assembly in 2007, Contracting States adopted Assembly Resolution A36-22 *Consolidated statement of continuing ICAO policies and practices related to environmental protection.* This resolution provided for the establishment of a process which led to the development and recommendation to the Council a Programme of Action on International Aviation and Climate Change and a common strategy to limit or reduce greenhouse gas emissions attributable to international civil aviation.

The development of an aeroplane CO_2 standard as part of the range of measures for addressing greenhouse gas emissions from international aviation was one of the recommended elements within the ICAO Programme of Action on International Aviation and Climate Change. This was subsequently endorsed by the ICAO High Level Meeting of Member States in October 2009.

In line with the ICAO Programme of Action, the Eighth Meeting of the Committee on Aviation Environmental Protection (CAEP/8) in February 2010 agreed to develop International Standards and Recommended Practices for Aeroplane CO_2 Emissions. This was approved by the ICAO Council in May 2010. Subsequently the 37th Session of the ICAO Assembly in 2010 adopted resolutions A37-18 and A37-19, requesting that the Council develop a global CO_2 Standard for aircraft. The CAEP developed draft International Standards and Recommended Practices for aircraft CO_2 emissions and, after amendment following the usual consultation with the Contracting States of the Organisation, this Annex 16, Volume III was adopted by the Council.

Table A shows the origin of amendments to the Annex 16 Volume III over time together with a list of the principal subjects involved and the dates on which the Annex and the amendments were adopted by the Council, when they became effective and when they became applicable.

Applicability

Part I of Volume III of Annex 16 contains definitions and symbols. Part II contains Standards, Recommended Practices and guidelines for certification of aeroplane CO_2 emissions based on the consumption of fuel applicable to the classification of aeroplane specified in individual chapters of that part, where such aeroplanes are engaged in international air navigation.

Action by Contracting States

Notification of differences. The attention of Contracting States is drawn to the obligation imposed by Article 38 of the Convention by which Contracting States are required to notify the Organization of any differences between their national regulations and practices and the International Standards contained in this Annex and any amendments thereto. Contracting States are invited to extend such notification to any differences from the

Recommended Practices contained in this Annex, and any amendments thereto, when the notification of such differences is important for the safety of air navigation. Further, Contracting States are invited to keep the Organization currently informed of any differences which may subsequently occur, or of the withdrawal of any differences previously notified. A specific request for notification of differences will be sent to Contracting States immediately after the adoption of each amendment to this Annex.

The attention of States is also drawn to the provisions of Annex 15 related to the publication of differences between their national regulations and practices and the related ICAO Standards and Recommended Practices through the Aeronautical Information Service, in addition to the obligation of States under Article 38 of the Convention.

Use of the Annex text in national regulations. The Council, on 13 April 1948, adopted a resolution inviting the attention of Contracting States to the desirability of using in their own national regulations, as far as is practicable, the precise language of those ICAO Standards that are of a regulatory character and also of indicating departures from the Standards, including any additional national regulations that were important for the safety or regularity of international air navigation. Wherever possible, the provisions of this Annex have been written in such a way as to facilitate incorporation, without major textual changes, into national legislation.

Status of Annex components

An Annex is made up of the following component parts, not all of which, however, are necessarily found in every Annex; they have the status indicated:

1.— *Material comprising the Annex proper:*

a) *Standards* and *Recommended Practices* adopted by the Council under the provisions of the Convention. They are defined as follows:

   Standard: Any specification for physical characteristics, configuration, material, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which Contracting States will conform in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38.

   Recommended Practice: Any specification for physical characteristics, configuration, material, performance, personnel or procedure, the uniform application of which is recognized as desirable in the interest of safety, regularity or efficiency of international air navigation, and to which Contracting States will endeavour to conform in accordance with the Convention.

b) *Appendices* comprising material grouped separately for convenience but forming part of the Standards and Recommended Practices adopted by the Council.

c) *Provisions* governing the applicability of the Standards and Recommended Practices.

d) *Definitions* of terms used in the Standards and Recommended Practices which are not self-explanatory in that they do not have accepted dictionary meanings. A definition does not have an independent status but is an essential part of each Standard and Recommended Practice in which the term is used, since a change in the meaning of the term would affect the specification.

2.— *Material approved by the Council for publication in association with the Standards and Recommended Practices:*

a) *Forewords* comprising historical and explanatory material based on the action of the Council and including an explanation of the obligations of States with regard to the application of the Standards and Recommended Practices ensuing from the Convention and the Resolution of Adoption.

b) *Introductions* comprising explanatory material introduced at the beginning of parts, chapters or sections of the Annex to assist in the understanding of the application of the text.

c) *Notes* included in the text, where appropriate, to give factual information or references bearing on the Standards or Recommended Practices in question, but not constituting part of the Standards or Recommended Practices.

d) *Attachments* comprising material supplementary to the Standards and Recommended Practices, or included as a guide to their application.

Selection of language

This Annex has been adopted in four languages — English, French, Russian and Spanish. Each Contracting State is requested to select one of those texts for the purpose of national implementation and for other effects provided for in the Convention, either through direct use or through translation into its own national language, and to notify the Organization accordingly.

Editorial practices

The following practice has been adhered to in order to indicate at a glance the status of each statement: *Standards* have been printed in light face roman; *Recommended Practices* have been printed in light face italics, the status being indicated by the prefix **Recommendation**; *Notes* have been printed in light italics, the status being indicated by the prefix *Note*.

It is to be noted that in the English text the following practice has been adhered to when writing the specifications: Standards employ the operative verb "shall" while Recommended Practices employ the operative verb "should".

The units of measurement used in this document are in accordance with the International System of Units (SI) as specified in Annex 5 to the Convention on International Civil Aviation. Where Annex 5 permits the use of non-SI alternative units these are shown in parentheses following the basic units. Where two sets of units are quoted it must not be assumed that the pairs of values are equal and interchangeable. It may, however, be inferred that an equivalent level of safety is achieved when either set of units is used exclusively.

Any reference to a portion of this document which is identified by a number includes all subdivisions of that portion.

Table A. Amendments to Annex 16

Amendment	*Source(s)*	*Subject(s)*	*Adopted* *Effective* *Applicable*
1st Edition	xx Meeting of the Committee on Aviation Environmental Protection		**xx March 20xx** **xx July 20xx** **xx November 20xx**

INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES

PART I. DEFINITIONS AND SYMBOLS

CHAPTER 1. DEFINITIONS

Aeroplane. A power-driven heavier-than-air aircraft, deriving its lift in flight chiefly from aerodynamic reactions on surfaces which remain fixed under given conditions of flight.

Derived version of an aeroplane. An aeroplane which incorporates changes in type design that may adversely affect its CO_2 emissions evaluation metric.

Note 1.— Where the certificating authority finds that the proposed change in design, configuration, power or mass is so extensive that a s ubstantially new investigation of compliance with the applicable airworthiness regulations is required, the aeroplane should be considered to be a new type design rather than a derived version.

Technical Note (to be removed when the full Annex 16, Vol. III text is agreed by CAEP).
With reference to *Note 2* (below). Future work: "CO2 change criteria" to be defined and possibly "significant" change criteria.

Note 2.— "Adversely" refers to an increase of more than xx in the CO_2 emissions evaluation metric.

Equivalent procedures. A test or analysis procedure which, while differing from the one specified in this volume of Annex 16, in the technical judgement of the certificating authority yields effectively the same CO2 emissions evaluation metric as the specified procedure.

In-production aeroplane. Those aeroplane types which have already received a Type Certificate, and for which manufacturers either have existing undelivered sales orders or would be willing and able to accept new sales orders.

Maximum certificated take-off mass. The highest of all maximum certificated take-off masses for the specific airframe/engine combination, and any other maximum take-off mass for which CO_2 emissions certification is requested by the applicant.

Note.— The requirement that the highest of all maximum certificated take-off masses be certificated is mandatory. In addition the applicant may apply for the certification of take-off masses other than the highest of all maximum certificated take-off masses if desired.

Optimum conditions. The combination of altitude and airspeed within the approved operating envelope defined in the aeroplane flight manual that provides the highest specific air range value at each reference aeroplane mass.

Reference conditions. Conditions that may affect specific air range and that need to be specified in order to determine a standard specific air range value. Such conditions are specified in 2.5.

Reference Geometric Factor. A measure of aeroplane cabin size based on a two-dimensional projection of the cabin as described in Appendix 1.

Specific air range. The distance an aeroplane travels in the cruise flight phase per unit of fuel consumed.

State of Design. The State having jurisdiction over the organization responsible for the type design.

Subsonic aeroplane. An aeroplane incapable of sustaining level flight at speeds exceeding flight Mach number of 1.

Type Certificate. A document issued by a Contracting State to define the design of an aircraft type and to certify that this design meets the appropriate airworthiness requirements of that State.

CHAPTER 2. SYMBOLS

Where the following symbols are used in Volume III of this Annex, they have the meanings ascribed to them below:

APU	Auxiliary power-unit
CG	Centre of gravity
CO_2	Carbon Dioxide
MTOM	Maximum certificated take-off mass (kg)
OML	Outer mould line
RGF	Reference geometric factor (m^2)
RSS	Residual sum of squares
SAR	Specific air range (km/kg)
TAS	True air speed (km/h)
W_f	Total aeroplane fuel flow (kg/h)

PART II. CERTIFICATION STANDARD FOR AEROPLANE CO_2 EMISSIONS BASED ON THE CONSUMPTION OF FUEL

CHAPTER 1. ADMINISTRATION

1.1 The provisions of 1.2 to 1.7 shall apply to all aeroplanes included in the classifications defined for CO_2 certification purposes in Chapter 2 of this part where such aeroplane are engaged in international air navigation.

1.2 CO_2 emissions certification shall be granted or validated by the State of Registry of an aeroplane on the basis of satisfactory evidence that the aeroplane complies with requirements that are at least equal to the applicable Standards specified in this Annex.

1.3 Contracting States shall recognize as valid a CO_2 emissions certification granted by another Contracting State provided that the requirements under which such certification was granted are at least equal to the applicable Standards specified in this Annex.

1.4 The amendment of this volume of the Annex to be used by a Contracting State shall be that which is applicable on the date of submission to that Contracting State for either a Type Certificate in the case of a new type, approval of a change in type design in the case of a derived version, or under equivalent application procedures prescribed by the certificating authority of that Contracting State.

Note.— As each new edition and amendment of this Annex becomes applicable (according to Table A of the Foreword) it supersedes all previous editions and amendments.

1.5 Unless otherwise specified in this volume of the Annex, the date to be used by Contracting States in determining the applicability of the Standards in this Annex shall be the date the application for a Type Certificate was submitted to the State of Design, or the date of submission under an equivalent application procedure prescribed by the certificating authority of the State of Design.

Note.— The means of compliance and the use of equivalent procedures are subject to the acceptance of the certificating authority of the Contracting State.

1.6 An application shall be effective for the period specified in the designation of the airworthiness regulations appropriate to the aeroplane type, except in special cases where the certificating authority accepts an extension of this period. When this period of effectivity is exceeded, the date to be used in determining the applicability of the Standards in this Annex shall be the date of issue of the Type Certificate or approval of the change in type design, or the date of issue of approval under an equivalent procedure prescribed by the State of Design, less the period of effectivity.

1.7 The certificating authority shall publish in an approved data sheet the certified value of the CO_2 emissions evaluation metric granted or validated by that authority.

CHAPTER 2.

Technical Note (to be removed when the full Annex 16, Vol. III text is agreed by CAEP).
With reference to the Applicability of the Standard. Future work: Applicability date to be determined.

1.— SUBSONIC JET AEROPLANES OVER 5 700 kg— Application for Type Certificate submitted on or after 1 January 20xx

2.— PROPELLER-DRIVEN AEROPLANES OVER 8 618 kg — Application for Type Certificate submitted on or after 1 January 20xx

2.1 Applicability

Note.— See also Chapter 1, 1.4, 1.5, 1.6 and 1.7.

2.1.1 The Standards of this chapter shall, with the exception of those propeller-driven aeroplanes specifically designed and used for fire-fighting purposes, be applicable to:

a) all subsonic jet aeroplanes, including their derived versions, of over 5 700 kg maximum certificated take-off mass, for which either the application for a Type Certificate was submitted, or another equivalent prescribed procedure was carried out by the certificating authority, on or after 1 January 20xx; and

b) all propeller-driven aeroplanes, including their derived versions, of over 8 618 kg maximum certificated take-off mass, for which either the application for a Type Certificate was submitted, or another equivalent prescribed procedure was carried out by the certificating authority, on or after 1 January 20xx.

Technical Note (to be removed when the full Annex 16, Vol. III text is agreed by CAEP).
With reference to the Applicability of the Standard. Future work: Whether and how to apply Standard to in-production aircraft under discussion. Additional changes may be needed in Chapter 1 according to outcome of applicability discussions.

2.2 CO_2 emissions evaluation metric

The metric used to evaluate CO_2 emissions shall be defined in terms of $(1/SAR)_{AVG}/RGF^{0.24}$, where $(1/SAR)_{AVG}$ is the average of the 1/SAR values established at each of the three reference masses defined in 2.3.

2.3 Reference aeroplane masses

The 1/SAR value shall be established at each of the following three reference aeroplane masses, when tested in accordance with these Standards:

a) high gross mass: 92% MTOM

b) mid gross mass: Average of high gross mass and low gross mass

c) low gross mass: $(0.45 \times MTOM) + (0.63 \times (MTOM^{0.924}))$

2.4 Maximum permitted CO_2 emissions evaluation metric

The certified CO_2 emissions evaluation metric defined in 2.2, when determined in accordance with the aeroplane CO_2 emissions evaluation method of Appendix 1, shall not exceed the following:

Technical Note (to be removed when the full Annex 16, Vol. III text is agreed by CAEP).
With reference to a) (below). Future work: Potential regulatory limit and compliance mechanism yet to be decided.

a)

2.5 Reference conditions for determining aeroplane specific air range

2.5.1 Reference conditions shall be established by the applicant, to the satisfaction of the certificating authority, in accordance with the provisions of this section. The reference conditions shall consist of the following conditions within the approved normal operating envelope of the aeroplane:

a) the aeroplane gross masses defined in 2.3;

b) a combination of altitude and airspeed selected by the applicant for each of the specified reference aeroplane gross masses;

Note.— These conditions are generally expected to be the combination of altitude and airspeed that results in the highest SAR value, which is usually at the maximum range cruise Mach number at the optimum altitude. The selection of conditions other than optimum conditions will be to the detriment of the applicant because the SAR value will be adversely affected.

c) steady (un-accelerated), straight, and level flight in the direction of true North;

d) aeroplane in longitudinal and lateral trim;

e) ICAO standard day atmosphere;

f) standard gravity, g_0 (9.80665 m/s^2);

g) fuel lower heating value equal to 43.217 MJ/kg (18 580 BTU/lb);

h) a reference aeroplane CG position selected by the applicant to be representative of a mid-CG point relevant to design cruise performance at each of the three reference aeroplane masses;

Note.— For an aeroplane equipped with a longitudinal CG control system, the reference CG position may be selected to take advantage of this feature.

i) applicant selected electrical and mechanical power extraction and bleed flow relevant to design cruise performance and in accordance with manufacturer recommended procedures;

Note.— Power extraction and b leed flow due to the use of optional equipment such as passenger entertainment systems need not be included.

j) engine handling/stability bleeds operating according to the nominal design of the engine model for the specified conditions; and

k) engine deterioration level selected by the applicant to be representative of the initial deterioration level (a minimum of 15 take-offs or 50 engine hours).

2.5.2 If the test conditions are not the same as the reference conditions, then corrections for the differences between test and reference conditions shall be applied as described in Appendix 1.

2.6 Test Procedures

2.6.1 The SAR values that form the basis of the CO_2 emissions evaluation metric levels shall be established either directly from flight tests or from a model validated by flight tests.

2.6.2 The test aeroplane shall be representative of the configuration for which certification is requested.

2.6.3 The test procedures and measurements shall be conducted and processed in an approved manner to yield the CO_2 emissions evaluation metric, as described in Appendix 1. These procedures shall address the entire flight test and data analysis process, from pre-flight actions to post-flight data analysis.

2.6.4 The fuel used for each flight test shall meet the specification defined in either ASTM D1655[1] or DEF STAN 91-91[2].

2.6.5 Any test or adjustment procedures which differ from the reference procedures shall be subject to the approval of the certificating authority.

[1] ASTM D1655-12 entitled "Standard Specification for Aviation Turbine Fuels". This ASTM publication may be obtained from the American National Standards Institute, 25 W 43rd Street, 4th Floor, New York, NY, USA.

[2] Defence Standard 91-91, Issue 7, Amendment 1, entitled "Turbine Fuel, Kerosene Type, Jet A-1". This Ministry of Defence Standard may be obtained from Defence Equipment and Support, UK Defence Standardization, Kentigern House, 65 Brown Street, Glasgow G2 8EX, UK.

APPENDIX 1. DETERMINATION OF AEROPLANE CO_2 EMISSIONS EVALUATION METRIC

Technical Note (to be removed when the full Annex 16, Vol. III text is agreed by CAEP).
With reference to 1. and 2. (below). Future work: Date to be determined.

1.— SUBSONIC JET AEROPLANES OVER 5 700 kg — Application for Type Certificate submitted on or after 1 January 20xx

2.— PROPELLER-DRIVEN AEROPLANES OVER 8 618 kg — Application for Type Certificate submitted on or after 1 January 20xx

1. INTRODUCTION

The process for determining the value of the CO_2 emissions evaluation metric includes:

a) determination of the reference geometric factor (see Appendix 2);

b) certification test and measurement criteria and procedures for determination of SAR either by direct flight test or by way of a validated performance model, including:

1) measurement of parameters needed to determine SAR;

2) correction of measured data to reference conditions for SAR; and

3) validity of data for calculation of the certified CO_2 emissions evaluation metric;

c) calculation of the CO_2 emissions evaluation metric; and

d) reporting of data to the certificating authority.

Note.— The instructions and procedures ensure uniformity of compliance tests, and permit comparison between various types of aeroplanes.

2. METHODS FOR DETERMINING SPECIFIC AIR RANGE

2.1 Specific air range may be determined by either direct flight test measurement of SAR test points, including any corrections of test data to reference conditions, or a performance model approved by the certificating authority. A performance model, if used, shall be validated by actual SAR flight test data.

2.2 In either case the SAR flight test data shall be acquired in accordance with the procedures defined in this Standard and approved by the certificating authority.

Note 1.—Model validation need only to be shown for the test points and c onditions relevant to showing compliance with the standard. Test and analysis methods, including any algorithms that may be used, should be described in sufficient detail.

Note 2.— The notion of a model is not intended to imply a specific type of software. A model is a tool developed or validated from corrected flight test data that is used to calculate a SAR value for any given input conditions. It could be either a model based on first principles that calculates SAR from aeroplane lift, drag and engine fuel flow for given values of mass, speed, and altitude, or a simple regression curve through corrected test data.

3. SPECIFIC AIR RANGE CERTIFICATION TEST AND MEASUREMENT CONDITIONS

3.1 General

This section prescribes the conditions under which SAR certification tests shall be conducted and the measurement procedures that shall be used.

Note.— Many applications for certification of a CO_2 emissions metric value involve only minor changes to the aeroplane type design. The resultant changes in the CO_2 emissions metric value can often be established reliably by way of equivalent procedures without the necessity of resorting to a complete test.

3.2 Flight test procedure

3.2.1 Pre-flight

The pre-flight procedure shall be approved by the certificating authority and shall include the following elements:

a) **Aeroplane conformity**. The test aeroplane shall be confirmed to be in conformance with the type design configuration for which certification is sought.

b) **Aeroplane weighing**. The test aeroplane shall be weighed. Any change in mass after the weighing and prior to the test flight shall be accounted for.

c) **Fuel lower heating value**. A sample of fuel shall be taken for each flight test to determine its lower heating value. Fuel sample test results shall be used for the correction of measured data to reference conditions.

Note 1.— The fuel lower heating value shall be determined in accordance with methods which are at least as stringent as those defined in ASTM specification D4809-09A[1].

Note 2.— Procedures acceptable to the certificating authority shall be followed to ensure that the fuel sample is representative of the fuel used for each flight test.

[1] ASTM D4809-09A entitled "Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)". This ASTM publication may be obtained from the American National Standards Institute, 25 W 43rd Street, 4th Floor, New York, NY, USA.

d) **Fuel specific gravity and viscosity**. A sample of fuel shall be taken for each flight test to determine its specific gravity and viscosity when volumetric fuel-flow meters are used.

Note 1.— The fuel specific gravity shall be determined in accordance with methods which are at least as stringent as those defined in ASTM specification D4052[2].

Note 2.— The fuel kinematic viscosity shall be determined in accordance with methods which are at least as stringent as those defined in ASTM specification D445[3].

Note 3.— When using volumetric fuel-flow meters the fuel viscosity is used to determine the volumetric fuel flow from the parameters measured by a volumetric fuel flow meter. The fuel specific gravity (or density) is used to convert the volumetric fuel flow to a mass fuel flow.

3.2.2 Flight test conditions

The flight tests shall be performed in accordance with the flight test method and stability conditions described in 3.2.3 and 3.2.4.

3.2.3 Flight test method

The following criteria shall be adhered to during the test conditions flown to determine SAR:

a) the aeroplane is flown at constant pressure altitude and constant heading along isobars to the extent that is practicable;

b) the engine thrust/power setting is stable for un-accelerated level flight;

c) the aeroplane is flown as close as practicable to the reference conditions to minimize the magnitude of any corrections;

d) there are no changes in trim or engine power/thrust settings, engine stability and handling bleeds, and electrical and mechanical power extraction (including bleed flow). Any changes in the use of aeroplane systems that may affect the SAR measurement shall be avoided; and

e) movement of on-board personnel is kept to a minimum.

3.2.4 Test condition stability

3.2.4.1 For a SAR measurement to be valid, the following parameters shall be maintained within the indicated tolerances throughout a 3-minute test condition during which the SAR data is acquired:

a) Mach number within ±0.005;

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[2] ASTM D4052-11 entitled "Standard Test Method for Density and Relative Density of Liquids by Digital Density Meter". This ASTM publication may be obtained from the American National Standards Institute, 25 W 43rd Street, 4th Floor, New York, NY, USA.

[3] ASTM D445-12 entitled "Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)" This ASTM publication may be obtained from the American National Standards Institute, 25 W 43rd Street, 4th Floor, New York, NY, USA.

b) ambient temperature within ±1°C;

c) heading within ±3 degrees;

d) track within ±3 degrees;

e) drift angle less than 3 degrees;

f) ground speed within ±3.7 km/h (±2 kt); and

g) pressure altitude within ±23 m (±75 ft).

Note.— Alternatives to the stable test condition criteria listed above may be used provided that stability can be sufficiently demonstrated to the certificating authority.

3.2.4.2 Test points that do not meet the stable test criteria defined in 3.2.4.1 should normally be discarded. However, test points that do not meet the stability criteria of 3.2.4.1 may be acceptable subject to the approval of the certificating authority.

3.2.5 Verification of aeroplane mass at test conditions

The mass of the aeroplane during a flight test may be determined by subtracting the fuel used (i.e. integrated fuel flow) from the mass of the aeroplane at the start of the test flight, If such a procedure is followed the accuracy of the determination of the fuel used shall be verified by weighing the test aeroplane on calibrated scales either before and after the SAR test flight, or before and after another test flight provided that flight occurs within one week of the SAR test flight and the fuel flow meters are unchanged.

Note.— Procedures for the determination of aeroplane mass at test conditions, including the use of integrated fuel flow, shall be subject to the approval of the certificating authority.

4. MEASUREMENT OF AEROPLANE SPECIFIC AIR RANGE

4.1 Measurement System

4.1.1 The following parameters shall be recorded at a minimum sampling rate of 1 Hz:

a) airspeed;

b) ground speed;

c) true airspeed;

d) fuel flow;

e) engine power setting parameter (e.g. N1, EPR, torque, shaft horse power);

f) pressure altitude;

g) temperature;

h) heading;

i) track; and

j) fuel used (gross mass, CG position).

4.1.2 The following parameters shall be recorded at a suitable sampling rate:

a) latitude;

b) engine bleed positions and power off-takes; and

c) power extraction (electrical and mechanical load).

4.1.3 The value of each parameter used for the determination of SAR, except for ground speed, shall be the arithmetic average of the measured values for that parameter obtained throughout the stable test condition (see 3.2.4.1).

Note.— The rate of change of ground speed during the test condition is to be used to evaluate and correct any acceleration or deceleration that might occur during the test condition.

4.1.4 The resolution of the individual measurement devices shall be sufficient to determine that the stability of the parameters defined in 3.2.4.1 is maintained.

4.1.5 The overall measurement system is considered to be the combination of instruments and devices, including any associated procedures, used to acquire the parameters necessary for the determination of SAR (see 4.1.1 and 4.1.2).

4.1.6 The accuracy of the individual elements that comprise the overall measurement system is defined in terms of its effect upon SAR. The cumulative error associated with the overall measurement system is defined in terms of the residual sum of squares (RSS) of the individual accuracies.

Note.— Parameter accuracy need only be examined within the range of the parameter needed for showing compliance with the CO_2 *emissions standard.*

4.1.7 The absolute value of the cumulative error of the overall measurement system shall not be greater than 1.5 per cent.

4.1.8 If the absolute value of the cumulative error of the overall measurement system is greater than 1.5 per cent a penalty equal to the amount that the RSS value exceeds 1.5 per cent shall be applied to the SAR value corrected to reference conditions (see section 5).

5. CALCULATION OF REFERENCE SPECIFIC AIR RANGE FROM MEASURED DATA

5.1 Calculation of SAR

5.1.1 SAR is calculated from the following equation:

$$SAR = TAS/W_f$$

5.2 Corrections from test to reference conditions

5.2.1 Corrections shall be applied to the measured SAR values to correct to the reference conditions specified in 2.5 of Part II, Chapter 2. Corrections shall be applied for each of the following measured parameters that is not at the reference conditions:

Gravity. Acceleration caused by the force of gravity affects the test weight of the aeroplane. The force of gravity varies with latitude and altitude. The reference gravity is based on the acceleration of a body in free fall at sea level at a geodetic latitude of 45 degrees.

Coriolis force. Acceleration caused by Coriolis force affects the aeroplane's test weight. Coriolis force results from the effect on the aeroplane of the rotation of the Earth. The reference Coriolis force is based on the aeroplane travelling in the direction of true North.

Mass/δ. The lift coefficient of the aeroplane is a function of mass/δ and Mach number, where δ is the ratio of the atmospheric pressure at a given altitude to the atmospheric pressure at sea level. The lift coefficient for the test condition affects the drag of the aeroplane. The reference mass/δ is derived from the combination of the reference mass, reference altitude and atmospheric pressures determined from the ICAO standard atmosphere.

Acceleration/deceleration (energy). Drag determination is based on an assumption of steady, unaccelerated flight. Acceleration or deceleration occurring during a test condition affects the assessed drag level. The reference condition is steady, unaccelerated flight.

Reynolds number. The Reynolds number affects aeroplane drag. For a given test condition the Reynolds number is a function of the density and viscosity of air at the test altitude and temperature. The reference Reynolds number is derived from the density and viscosity of air from the ICAO standard atmosphere at the reference altitude and temperature.

CG position. The position of the aeroplane centre of gravity affects the drag due to longitudinal trim.

Mass (aeroelasticity effect). Aeroelasticity may cause a variation in drag as a function of aeroplane mass.

Fuel lower heating value. The fuel lower heating value defines the energy content of the fuel. The lower heating value directly affects the fuel flow at a given test condition.

Altitude. The altitude at which the aeroplane is flown affects the fuel flow.

Temperature. The ambient temperature affects the fuel flow. The reference temperature is the standard day temperature from the ICAO standard atmosphere at the reference altitude.

Engine deterioration level. Engines, when new, undergo a rapid deterioration in fuel efficiency. Thereafter the rate of deterioration significantly decreases. Engines with fewer take-offs or hours than specified in the reference conditions may be used. In such a case, and subject to the approval of the certificating authority, correction of the fuel flow to the reference engine deterioration level may be permitted. Engines with more take-offs or hours than specified in the reference conditions may be used. However in this case a correction to the reference condition shall not be permitted.

Electrical and mechanical power extraction and bleed flow. Electrical and mechanical power extraction and bleed flow affects the fuel flow.

Note 1.— Post-flight data analysis includes the correction of measured data for data acquisition hardware response characteristics (e.g. system latency, lag, offset, buffering, etc.).

Note 2.— If the applicant considers that a particular correction is unnecessary then acceptable justification must be provided to the certificating authority.

5.2.2 Correction methods are subject to the approval of the certificating authority.

5.3 Calculation of Specific Air Range and CO_2 emissions evaluation metric level

5.3.1 The SAR values for each of the three reference masses defined in 2.3 of Chapter 2, Part II, shall be calculated either directly from the measurements taken at each valid test point adjusted to reference conditions, or indirectly from a model validated by way of these test points. The final SAR value for each reference mass shall be the arithmetic average of all valid test points at the appropriate gross mass, or derived from a validated model. No data acquired from a valid test point shall be omitted unless agreed by the certificating authority.

Note.— Extrapolations consistent with accepted airworthiness practices to masses other than those tested may be allowed subject to the approval of the certificating authority.

5.3.2 The level of the CO_2 emissions evaluation metric shall be calculated from the average of the 1/SAR values for the three reference masses and the RGF value calculated according to the procedure defined in Appendix 2, using the following formula:

$$\text{Value of the } CO_2 \text{ emissions evaluation metric} = (1/SAR)_{AVG}/RGF^{0.24}.$$

6. VALIDITY OF RESULTS

6.1 The 90 per cent confidence interval shall be calculated for each of the SAR values at the three reference masses.

6.2 If clustered data is acquired independently for each of the three gross mass reference points, the minimum sample size acceptable for each of the three gross mass SAR values is six.

6.3 Alternatively SAR data may be collected over a range of masses. In this case the 90 per cent confidence interval shall be calculated for the mean regression line through the data.

6.4 The 90 per cent confidence interval associated with each of the three reference mass SAR values shall not exceed ±1.5 per cent.

Note 1.— Subject to the approval of the certificating authority the SAR value may be adjusted if the data results in a 90 per cent confidence interval greater than ±1.5 per cent. In such a case a penalty shall be applied to the mean SAR value equal to the amount that the 90 per cent confidence interval exceeds the 1.5 per cent limit. The adjusted mean value shall be used in the calculation of the CO_2 emissions evaluation metric.

Note 2.— Methods for calculating the 90 per cent confidence interval are given in Chapter 3 of Doc 9501 Volume I.

7. REPORTING OF DATA TO THE CERTIFICATING AUTHORITY

Note.— The information required is divided into three groups: 1) general information to identify the aeroplane characteristics and the method of data analysis; 2) the data obtained from the aeroplane test(s); and 3) the results derived from the test data.

7.1 General information

The following information shall be provided for each aeroplane type and model for which CO_2 certification is sought:

a) designation of the aeroplane type and model;

b) general characteristics of the aeroplane, including centre of gravity range, number and type designation of engines and, if fitted, propellers;

c) maximum certificated take-off mass;

d) the relevant dimensions needed for calculation of the reference geometric factor; and

e) serial number(s) of the aeroplane(s) tested for CO_2 certification purposes and, in addition, any modifications or non-standard equipment likely to affect the CO_2 characteristics of the aeroplane.

7.2 Test data

The following measured test data, including any corrections for instrumentation characteristics, shall be provided for each of the test measurement points. .

a) airspeed, ground speed and true airspeed;

b) fuel flow;

c) pressure altitude;

d) static air temperature;

e) aeroplane gross mass and centre of gravity for each test point;

f) levels of electrical and mechanical power extraction and bleed flow;

g) engine performance:

1) for jet aeroplanes, engine power setting (e.g. N_1, EPR);

2) for propeller-driven aeroplanes, shaft horsepower or engine torque and propeller rotational speed.

h) fuel lower heating value;

i) fuel specific gravity and kinematic viscosity if volumetric fuel flow meters are used (see 3.2.1d);

j) the cumulative error (RSS) of the overall measurement system (see 4.1.6);

k) heading, track and latitude;

l) stability criteria (see 3.2.4.1);

m) description of the instruments and devices used to acquire the parameters necessary for the determination of SAR, and their individual accuracies in terms of their effect on SAR (see 4.1.5 and 4.1.6);

7.3 Derived data

The following derived information shall be provided for each aeroplane tested for certification purposes:

a) the mass, altitude, and airspeed (or Mach number) at which the value of the CO_2 emissions evaluation metric is provided;

b) the specific air range (km/kg) for each reference aeroplane mass and the associated 90 per cent confidence interval;

c) the average of the inverse of the three reference mass specific air range values;

d) the reference geometric factor calculated according to Appendix 2; and

e) the value of the CO_2 emissions evaluation metric.

APPENDIX 2. REFERENCE GEOMETRIC FACTOR

1. The Reference Geometric Factor (RGF) is a measure of fuselage size. It is defined as follows:

a) for aeroplanes with a single deck the area of a surface bounded by the maximum width of the fuselage outer mould line (OML) projected to a flat plane parallel with the main deck floor; or

b) for aeroplanes with an upper deck it is the sum of the area of a surface bounded by the maximum width of the fuselage outer mould line (OML) projected to a flat plane parallel with the main deck floor, and the area of a surface bounded by the maximum width of the fuselage OML at or above the upper deck floor projected to a flat plane parallel with the upper deck floor.

2. The RGF includes all pressurised space on the main or upper deck including aisles, assist spaces, passage ways, stairwells and areas that can accept cargo and auxiliary fuel containers. It does not include permanent integrated fuel tanks within the cabin or any unpressurized fairings, nor crew rest/work areas or cargo areas which are not on the main or upper deck (e.g. 'loft' or under floor areas).

3. The rear boundary to be used for calculating RGF is the rear pressure bulkhead. The forward boundary is the forward pressure bulkhead except for the cockpit crew zone (the area of the aeroplane designated solely for crew use). Areas that are accessible to both crew and passengers are included in the calculation of RGF.

Note 1.— For aeroplanes with a cockpit door the forward boundary to be used for calculating RGF is the plane of the cockpit door. For aeroplanes having optional interior configurations which include different locations of the cockpit door the boundary shall be determined by the configuration that provides the largest value of RGF.

Note 2.— For aeroplanes without a cockpit door, such as aeroplanes capable of single pilot operation, the forward boundary to be used for calculating RGF is the forward pressure bulkhead for the non-crew zone. Areas not accessible to passengers in all interior arrangements shall be excluded from the RGF.

4. Figures A2-1 and A2-2 provide a notional view of the RGF boundary conditions.

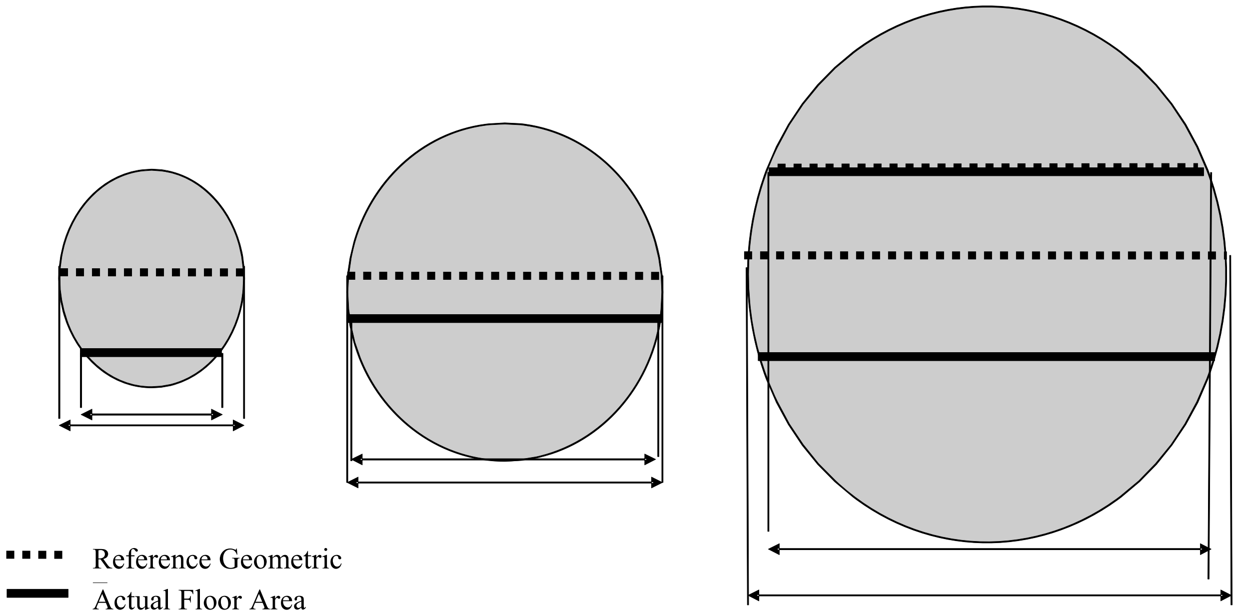


Figure A2-1. Cross-sectional View

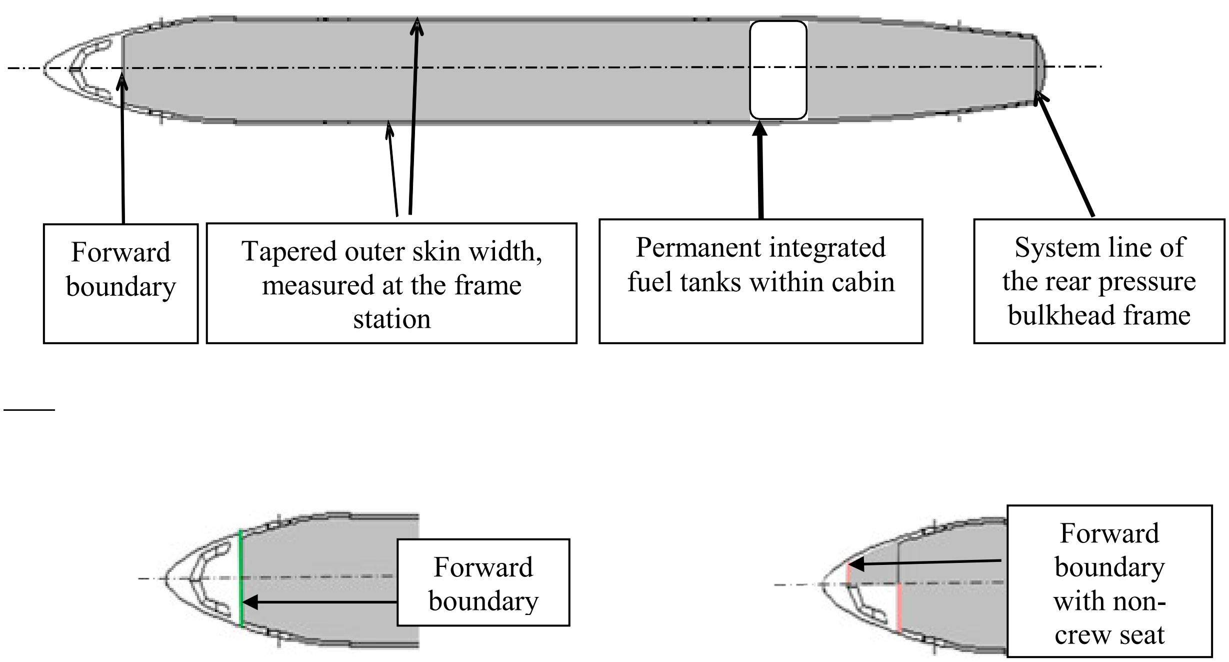


Figure A2-2. Longitudinal View

Agenda Item 3: Review of technical proposals relating to aircraft noise.

3.1 REPORT OF WG1 – NOISE TECHNICAL

3.1.1 The Co-Rapporteurs of Working Group 1 (WG1, Noise Technical) presented the group's work since CAEP/8. The main aim of WG1 is to keep ICAO noise certification standards (Annex 16, Vol. I) up to date and effective, while ensuring that the certification procedures are as simple and inexpensive as possible.

3.1.2 The Co-Rapporteurs informed CAEP on the progress on items regarding amendments to Annex 16, Volume I and the Environmental Technical Manual (ETM), Volume I. A summary of these amendments can be found in section 3.2.

3.1.3 During CAEP/9 the process for updating the ICAO noise certification database (NoisedB) was continuously monitored. In addition the NoisedB was updated and extended several times. The most recent update of the NoisedB has been publish as Version 2.13.

3.1.4 The WG1 Co-Rapporteurs reported that the Technology Task Group (TTG) organised the Second Noise Technology Independent Experts Review (IER2), which primarily investigated new advances in technology (N.04.03). An interim extended report was presented to the 2012 Steering Group and details on the final report presented to this meeting can be found in section 3.3.1.

3.1.5 A comprehensive overview of on-going worldwide aircraft noise efforts and associated goals was developed during the IER2. Since the IER2, updates have been made and further details are given in section 3.4, thus addressing work item N.04.01 "Monitor and report on the various national and international research programme goals and milestones".

3.1.6 The TTG also conducted the first assessment exercise to review progress towards achievement of Technology Goals (N.04.02) and a summary is provided in section 3.5.

3.1.7 The Supersonic Task group (SSTG) continued to advance work on the three supersonic aeroplane noise related work items assigned to WG1 by CAEP/8 (N.05.01 – N05.03). Research Focal Points (RFPs) continue to provide the SSTG with details on important research topics, and an update is given in section 3.3.7. Also industry efforts continue on several collaborative supersonic projects, however schedules for most programmes remain uncertain. The WG1 Co-Rapporteurs reported that the SSTG continues efforts on a Standard for future supersonic aircraft.

3.1.8 Following the completion of Project N.06.01, the range of stringency options up to 10-12dB cumulative margin relative to Chapter 4 was endorsed by the 2010 Steering Group meeting for use in the cost/effectiveness study. WG1 also continuously worked with WG3 to assess interdependency effects of noise stringency options with respect to CO_2 and NOx (N.06.02). Work on the interdependency effects of CO_2 emissions stringency options with noise (N.06.03) is on-going and is being coordinated through WMF. Concerning N.06.01.05, WG1 concluded that aircraft design changes made to meet new noise stringency, even when they include re-engining, do not necessarily require a new Type Certificate. WG1 completed its review and update the Growth and Replacement (G&R) database for use in the stringency analysis (N.06.04).

3.1.9 For the review of emerging technologies (N.06.05), WG1 created the Low Carbon Technology Noise Data summary Group (LoCaTNoise). The output of LoCaTNoise is a summary of relevant information to inform any CAEP/9 considerations on a new noise Standard that would not preclude low carbon technology. A summary is given in section 3.4.

3.1.10 The WG1 Co-Rapporteurs reported that WG1 considers it premature to determine the need for certification methodologies specific to new engine concepts (N.06.06) such as open rotor given that related new engine and aircraft designs that might be brought forward for certification are not yet well defined. Concerning N.06.01.03, N.06.07 and N.06.08, at the 2011 Steering Group meeting, WG1 presented a proposal to change the noise limits applicable to subsonic jet aeroplanes with take-off masses <8,618kg. The 2011 Steering Group endorsed the features of the proposal, and specifically approved a second "knee point" at 8,618kg, to use the same gradient of the limit line at lower masses as the higher masses and the constant limit line for aircraft with masses <2,000kg. The 2011 Steering Group agreed that this proposal would not be finalised until an increase in stringency proposal was formulated.

3.1.11 Concerning tasks N.06.09 – N.06.12, WG1 responded to requests from MDG/FESG in support of noise stringency analyses. This included participation in the Noise Stringency Ad Hoc Group (NoSAHG) that was established by the 2011 Steering Group, with representation from WG1, WG3, MDG and FESG, to address issues arising with the first round of stringency analysis. Further details on the noise stringency analysis can be found in section 3.7.

3.2 PROPOSED AMENDMENTS TO ANNEX16 , VOLUME I AND THE ENVIRONMENTAL TECHNICAL MANUAL, VOLUME I

3.2.1 N.02.01: Definitions, N.02.02: Modification of ETM figures & N.02.04: Nomenclature, symbols and units

3.2.1.1 Revisions to the ETM and Annex 16 to enhance the documents' utility and compatibility. Tasks were initiated in parallel with other N.02 technical tasks. Completion is expected during the CAEP/10 cycle following the conclusion of other on-going tasks.

3.2.2 N.02.03: ETM references

3.2.2.1 WG1 recommended changes to several references from the ETM to Amendment 10 of Volume I of Annex 16. The changes were endorsed by the 2012 Steering Group meeting. A similar task will be undertaken during CAEP/10 to update the references to Amendment 11.

3.2.3 N.02.05: Expansion of ETM Chapter 2

3.2.3.1 The 2012 Steering Group meeting endorsed the transfer of sections of the ETM generally applicable to all aircraft categories to ETM Chapter 2.

3.2.4 N.02.06: Annex 16/ETM improvements

3.2.4.1 Miscellaneous editorial changes to remedy typographical errors and improve utility of the ETM were developed by WG1 and endorsed by the 2012 Steering Group meeting.

3.2.5 **N.02.07: Static engine noise test methods**

3.2.5.1 Changes to the relevant ETM text associated with recent revisions to SAE ARP 1846A which reflect current industry practices have been developed by WG1 and endorsed by the 2012 Steering Group meeting.

3.2.6 **N.02.08, N.02.09: Flight path definition and measurement and adjustment to reference conditions**

3.2.6.1 Extensive new ETM guidance and procedures for the determination of aircraft flight path and geometry to support the implementation of the simplified and integrated methods of adjustment have been developed by WG1 and endorsed by the 2012 Steering Group meeting.

3.2.7 **N.02.10: Propagation path**

3.2.7.1 WG1 has investigated the need to improve the Annex 16 guidance concerning the effect of atmospheric absorption on the sound propagation path. WG1 has concluded that no change is necessary.

3.2.8 **N.02.11: Calibration guidance**

3.2.8.1 Extensive revisions to Annex 16 have been developed by WG1 to harmonise the sections concerning level calibrations and level sensitivity drift, and to update the specifications in the light of advances in audio recording technology. This was endorsed by the 2012 Steering Group meeting.

3.2.9 **N.02.12: Atmospheric absorption**

3.2.9.1 SAE work to revise the atmospheric absorption procedures of ARP 866 h as been monitored. WG1 does not recommend any associated revision for Annex 16 or the ETM at this time, but proposes to continue monitoring the situation during CAEP/10.

3.2.10 **N.02.13: Chapter 10 acoustical change guidance**

3.2.10.1 An extensive new ETM section concerning methods for the demonstration of no-acoustical changes for light propeller driven aeroplane has been developed. It was endorsed by the 2012 Steering Group meeting.

3.2.11 **N.02.14: Confidence interval interpolation**

3.2.11.1 The WG1 Co-Rapporteurs reported that no progress has been made on this topic.

3.2.12 **N.02.15: Lateral noise**

3.2.12.1 After careful consideration WG1 concluded that no change to the existing ETM text was needed.

3.2.13 **N.02.16: Helicopter land use planning**

3.2.13.1 Some progress has been made. It is expected that the task will be completed during CAEP/10.

3.2.14 **N.02.17: Calculation of maximum permitted noise levels**

3.2.14.1 WG1 has concluded that no change be made to the existing Annex 16 text or equations that define the noise limits. Though it has recommended that the equations for defining the limits of any future standard be expressed with sufficient precision so that the equations and text yield the same result when rounded to 1 decimal place.

3.2.14.2 The WG1 Co-Rapporteurs emphasised that the 2012 Steering Group meeting had previously approved the revisions of the ETM and this was published as a Steering Group Approved Revision (SGAR) on the ICAO public website in accordance with the wishes of the 2012 Steering Group.

3.2.15 The meeting noted information on amendments made to Annex 16, Volume I regarding the wind criteria for noise abatement.

Discussion and Conclusions

3.2.16 The Co-Rapporteurs confirmed that regarding the amendments proposed by WG1 to Annex 16 – other than those related to the new noise stringency and Tiltrotor considerations – have already been approved by the Steering Group meeting, and that what was being sought was the official recommendation of the CAEP on the amendment to Annex 16, Volume I.

3.2.17 Regarding the timescales for supersonic aircraft development, the WG1 Co-Rapporteur highlighted that it is crucial to have a prototype to prove that supersonic flight is possible without increased human annoyance. It was recently announced that such a prototype research project is underway.

3.2.18 The meeting congratulated WG1 on its achievements in keeping Annex 16, Volume I up to date and relevant. The meeting approved the amendments to Annex 16, Volume I as contained in Appendix A of this report. These amendments were previously approved by the 2012 CAEP Steering Group.

3.2.19 The meeting endorsed the Steering Group Approved Revision (SGAR) of the ETM, Volume I, which following the 2012 Steering Group meeting had been made available on the ICAO public website. This approval included an additional amendment to the forward of the ETM as requested by the 2012 Steering Group meeting, as shown in Appendix B.

3.2.20 **Recommendations**

3.2.20.1 In light of the foregoing discussion, the meeting developed the following recommendations:

RSPP

Recommendation 3/1 – Amendments to Annex 16 — Environmental Protection, Volume I — *Aircraft Noise*

That Annex 16, Volume I be amended as indicated in Appendix A to the report on this agenda item.

Recommendation 3/2 – Publication of the Environmental Technical Manual, Volume I — *Aircraft Noise*

That the ETM, Volume I (Doc 9501) be amended as soon as possible to include the material in Appendix B to the report as well as changes made by the CAEP 2012 Steering Group.

3.3 STATE OF THE ART AND EMERGING ISSUES

3.3.1 Independent Expert Review of Noise Technologies

3.3.1.1 An Independent Expert Panel (IEP2) has conducted a review for ICAO to evaluate expected commercial aircraft noise levels by 2020 and 2030. The specific tasks were to: 1) summarize the status of new novel aircraft and advanced engine concepts (e.g., open rotor, geared turbofan, blended wing body, etc.) that can be brought to market within 10 years from the date of the review, as well as the 20-year prospects; 2) assess the possibility of noise reduction for each concepts; 3) comment on the environmental efficiency, and other economic trade-offs resulting from adopting the candidate technologies; and 4) recommend updated mid-term and long-term technology goals for reducing aircraft noise. Additional tasks included Turboprop Mid-Term goals and en-route noise. The overall conclusions from the IEP2 review are as follows:

a) The IEP2 expects the evolution of conventional tube and wing aircraft to prevail over more aggressive aircraft designs where noise reduction is considered a primary design objective. Novel aircraft with noise reduction features are only feasible by 2030 with increased resources and investment. The Massachusetts Institute of Technology (MIT) "Double Bubble D8" concept aircraft is a good example.

b) Novel engine concepts, however, can be developed by 2030, i.e. Ultra High Bypass (UHB) engines, counter-rotating open rotors (CROR) and geared turbofans (GTF).

c) IEP2 studies show that UHB turbofans are quieter than current designs, but the noise reduction benefit diminishes with increased BPR, especially for values above 15. An IEP2 pilot study has suggested alternative noise correlations for turbofans based on specific thrust and other overall aircraft parameters. These have confirmed both the IEP1 long-term noise projections and recent NASA UHB estimates.

d) Short to medium range aircraft can be powered by CROR engines but are considerably noisier than the equivalent UHB turbofan, by 15 EPNdB cum or more for the aft-mounted pusher configuration. Wing mounted (tractor) CROR are expected to be about 6 EPNdB cum louder than aft mounted configurations. A skewed uncertainty distribution is recommended for the CROR cum noise margin.

e) The Realization Factor (RF) used by IEP1 cannot be applied to novel aircraft/engine concepts that have not been developed and tested beyond TRL6. Hence the Long-Term noise goals can only be specified at TRL6, not TRL8 as in the Mid-Term.

f) En route noise from CROR aircraft cruising at 35,000 feet is expected to be significantly quieter than Un-Ducted Fan (UDF) flight tests from the 1980's. Projections using TRL4 wind tunnel data predict ground noise levels to be 13 to 20 dBA quieter. Comparisons with 2009 background noise measurements in Europe show the CROR flyover noise levels would be near the upper band of the turbofan noise levels.

3.3.1.2 The IEP2 updated Mid-Term and Long-Term noise goals are summarized in the Tables 1 and 2.

Table 1 - Mid-Term (2020) Cumulative Noise Margin Goals Relative to Chapter 4

Aircraft Category	BPR Goal	NR TRL6	NR TRL8	Cum Ref	Cum Goal TRL6	Cum Goal TRL8
Regional Jet (RJ)						
40 tonnes (nominal)	**7±1**	**10**	**9**	**4**	**14**	**13±4**
50 tonnes (max)	**7±1**	**10**	**9**	**-0.5**	**9.5**	**8.5±4**
Large Turboprops						
45 tonnes (nominal)	**-**	**9.5**	**9**	**3**	**12.5**	**12±4**
53 tonnes (max)	**-**	**9.5**	**9**	**0.5**	**10**	**9.5±4**
Short Medium Range Twin (SMR2)						
Turbofans: 78 tonnes (nominal)	**9±1**	**17.5**	**16**	**5**	**22.5**	**21±4**
98 tonnes (max)	**9±1**	**17.5**	**16**	**1.5**	**19**	**17.5±4**
CROR: 78 tonnes (nominal)	**-**	**-**	**-**	**-**	**-**	**-**
91 tonnes (max)	**-**	**-**	**-**	**-**	**-**	**-**
Long Range Twin (LR2)						
230 tonnes (nominal)	**10±1**	**16**	**14.5**	**6**	**22**	**20.5±4**
290 tonnes (max)	**10±1**	**16**	**14.5**	**2.5**	**18.5**	**17±4**
Long Range Quad (LR4)						
440 tonnes (nominal)	**9±1**	**17.5**	**16**	**5**	**22.5**	**21±4**
550 tonnes (max)	**9±1**	**17.5**	**16**	**-1.5**	**16**	**14.5±4**

Table 2 - Long-Term (2030) Cumulative Noise Margin Goals Relative to Chapter 4

Aircraft Category	BPR Goal	NR TRL6	NR TRL8	Cum Ref	Cum Goal TRL6	Cum Goal TRL8
Regional Jet (RJ)						
40 tonnes (nominal)	9±1	17.5	-	4	21.5±4	-
50 tonnes (max)	9±1	17.5	-	-0.5	17±4	-
Large Turboprops						
45 tonnes (nominal)	-	-	-	-	-	-
53 tonnes (max)	-	-	-	-	-	-
Short Medium Range Twin (SMR2)						
Turbofans: 78 tonnes (nominal)	13±1	25	-	5	30±4	-
98 tonnes (max)	13±1	25	-	1.5	26.5±4	-
CROR: 78 tonnes (nominal)	-	8.5	-	5	* 13.5+2/-6	-
91 tonnes (max)	-	8.5	-	2	** 10.5+2/-6	-
Long Range Twin (LR2)						
230 tonnes (nominal)	13±1	22	-	6	28±4	-
290 tonnes (max)	13±1	22	-	2.5	24.5±4	-
Long Range Quad (LR4)						
440 tonnes (nominal)	11±1	22	-	5	27±4	-
550 tonnes (max)	11±1	22	-	-1.5	20.5±4	-

*** CROR cumulative margin with uncertainties range from 7.5 to 15.5 EPNdB for 78 tonne nominal weight aircraft.**
**** CROR cumulative margin with uncertainties range from 4.5 to 12.5 EPNdB for 91 tonne maximum weight aircraft .**

Discussion and Conclusions

3.3.1.3 Regarding the definition of project aircraft, and the margins used in the IE work, the IEP Chair clarified that, the work was based on a data driven exercise, and that these margins and uncertainties are a reflection on the IEP opinion on future technology which has not yet been certified. The IEP Chair added that the mid- and long- term goals include an assessment of the best technologies which will likely be available in the future.

3.3.1.4 The difference between technology goals and Standards was emphasized by a member and the importance of keeping the two separate was pointed out. The meeting agreed that the information presented by the Independent Experts can advise the future work of the CAEP on future noise related issues.

3.3.1.5 The meeting congratulated the IEP2 on their comprehensive and extremely valuable work on noise technology. The meeting agreed that the final report fulfills work item N.04.03.

3.3.1.6 The meeting endorsed the mid- and long-term goals developed by the noise technology independent experts panel as the CAEP/9 noise technology goals.

3.3.2 **Recommendations**

3.3.2.1 In light of the foregoing discussion, the meeting developed the following recommendations:

Recommendation 3/3 — Acceptance of the CAEP/9 noise technology goals

The CAEP/9 noise technology goals are endorsed by CAEP and should be used to inform ICAO noise activities.

Recommendation 3/4 — Publication of the report of the second Noise Technology Independent Expert Panel

The final report of the second Noise Technology Independent Expert Panel – '*Novel Aircraft Noise Technology Review and Medium and Long Term Noise Reduction Goals'* should be published by ICAO as soon as possible.

3.3.3 **Update on Sonic Boom knowledge**

3.3.3.1 The WG1 SSTG Research Focal Points (RFPs) provided a brief overview of many of the developments in supersonic technology during the CAEP/9 cycle. There have been important technical advances in creating low-boom sonic booms, ways to propagate the sonic booms to the ground, determining the signatures that will actually be heard outside and inside buildings, recreating those signatures in laboratory environments, and assessing those signatures in both lab and community response settings via subjective testing.

3.3.3.2 An important conclusion is that the technology is now ready for the production of a demonstration low-boom supersonic vehicle. Such a vehicle would serve as a useful test bed for validating the technology developed thus far and, thus, provide useful guidance for the future development of standards for civilian supersonic flight.

3.3.3.3 An additional conclusion is that there are still many unknowns related to effects of overland supersonic flight, and continued careful monitoring of the developments in supersonics within NASA, JAXA, industry, and other organisations would seem to be in the best interests of CAEP.

Discussion and Conclusions

3.3.3.4 A member asked whether research from the Russian Federation had been accounted for within current SSTG work. The SSTG co-lead clarified that currently this had not been accounted for but encouraged Russian Federation input into the work of the SSTG.

3.3.3.5 Two members emphasised the importance of researching supersonic flight, and that CAEP should be forward looking in order to understand what will come in the future.

3.3.3.6 The Chairperson asked about the timescales of future supersonic aircraft, and specifically about a demonstration aircraft being ready soon. The RFP stated that industry is interested in working on an aircraft, though nothing yet has been publically announced.

3.4 REVIEW OF DATA ON EMERGING TECHNOLOGIES

3.4.1 In response to WG1 Work Item N.06.05, "Review data on emerging technologies", WG1 considered the noise goals from the Independent Expert Panel 2 report; and the noise estimates provided by ICCAIA to the Independent Expert Review 2 when reviewing the following noise technologies:

— Second-generation Ultra High Bypass ratio Geared Turbo Fans (UHB/GTF)

— Aircraft equipped with Counter Rotating Open Rotor (CROR) propulsion systems

— Latest generation of large Turboprop aircraft

3.4.2 The WG1 Co-Rapporteurs reiterated the IEP2 noise goals making it clear that the IEP2 provided mid-term goals at both TRL 6 and TRL 8. The goals, the uncertainties and the growth limits were taken from IEP2's independent studies and from information provided by ICCAIA at the Independent Expert Reviews. An overview of the IEP2 final report is given in section 3.3.1.

3.4.3 The IEP2 long–term goals were limited to TRL6. Therefore to provide CAEP with estimates for long term novel aircraft configurations information was provided by ICCAIA based on its experience in estimation of noise levels to support product launch, considering Design and Test Margins and also Growth Margins

3.4.4 Ultra High Bypass Ratio / Geared Turbofans (UHB/GTF)

3.4.4.1 ICCAIA did not provide noise estimates for the second-generation UHB/GTF at IER2 because realizing the noise advantages of the UHB/GTF largely depends on the aircraft configurations. Those aircraft configurations are yet to be defined, so it has not been possible to finalize the noise benefits of such technologies to TRL8. If the aircraft configuration developed is conventional and allows the installation of the UHB/GTF engine, the 26.5EPNdB cumulative noise goal as predicted by the IEP2 at TRL6 for the highest weight version might be expected to be achieved with the 4EPNdB uncertainty assumed by the IEP2. If the aircraft configuration developed is not conventional (e.g. not tube and wing), because of the large margins to Chapter 4 a qualitative analysis for UHB/GTF concepts fits the purpose of task N.06.05 with no quantitative assessment necessary; this is because the noise margins to Chapter 4 are expected to be broadly maintained as 26.5EPNdB ± 4EPNdB such that the stringency levels being considered by CAEP are all met with margin.

3.4.5 Counter Rotating Open Rotor (CROR) Aircraft

3.4.5.1 ICCAIA estimated the noise levels of a study aircraft powered by a CROR pusher directly at TRL7 implicitly incorporating realization factors due to design trade-offs, by conducting a preliminary design of the aircraft that assessed all the aircraft attributes and included all the necessary trades. ICCAIA has also included both design and test margins and growth margins in its estimates (i.e. the cumulative estimated margin with uncertainties, for the highest weight version of the aircraft family). This process is consistent with project aircraft included in the Growth and Replacement Database used in the current MDG/FESG cost-effectiveness analysis, although the uncertainties are greater for the CROR because of the lower TRL. ICCAIA's estimates are shown in Table 2, including design and test margins and estimates for growth variants applicable after a Flight Demonstration has been completed.

Table 3 - ICCAIA TRL7 noise estimates of CROR pusher plus Design and Test Margins

	Passengers	Estimate (Cumulative margin to Chapter 4)	Design and Test Margins
SMR2 CROR pusher	190	12.6 EPNdB	+2/-6 EPNdB
	220	11.0 EPNdB	+2/-6 EPNdB

3.4.5.2 This noise level provided by ICCAIA for a CROR 'pusher' should be viewed only as an estimate and is being provided to CAEP for the express purpose of meeting CAEP remit of this specific task. This estimate should not be construed as certification levels in any manner whatsoever. Certification levels would be available only after relevant certification tests of a launched aircraft program are performed.

3.4.5.3 The WG1 Co-Rapporteurs made it clear that the purpose of this work item was to inform any CAEP/9 considerations given to a new noise standard so as not to preclude low-carbon technologies.

Discussion and Conclusions

3.4.6 A member asked for an explanation regarding the skewed uncertainty associated with the design and test margins for the SMR2 CROR pusher aircraft at TRL6. The IEP2 Chair clarified that this is a result of fewer noise mitigation opportunities being available for the design of this aircraft type, than risks associated with CROR integration and installation factors w hich will result in increased noise levels.

3.4.7 A member enquired on the reasons why small aircraft, such as regional jets, had comparable noise levels to heavier, larger aircraft. It was explained by the IEP2 chair that many of the noise reduction technologies that have been introduced into larger aircraft have not yet been incorporated into short and medium-range twin engine aircraft, including regional jets. It is more challenging, for instance, to introduce high By-Pass Ratio (BPR) technology, which has enabled some noise reductions on larger aircraft, on the smaller jets.

3.4.8 An observer enquired regarding the level of fuel burn benefit required to justify this noise difference between the open rotor and geared turbo fan. The meeting concurred that this was a policy discussion which lay outside the remit of the Noise Independent Experts presentation. Following a comment regarding the possible conflict between noise stringency and the introduction of open rotor technology, the meeting agreed that information on emerging technologies should be used to inform the CAEP noise stringency discussions.

3.4.9 The meeting expressed its appreciation for the continued work to keep the CAEP informed on emerging noise technology.

3.5 REVIEW OF PROGRESS TOWARDS ACHIEVEMENT OF CAEP/8 TECHNOLOGY GOALS

3.5.1 CAEP requested that WG1 "review progress towards achievement of Technology Goals" adopted in CAEP/8, and WG1 has completed its first assessment of progress with respect to the Mid-Term Noise Technology Goals.

3.5.2 To perform this first assessment of progress with respect to the Noise Technology Goals, new entries to Noise dB occurring since CAEP/8 were considered. They include new type certifications (Boeing 787, Boeing 747-8 and Sukhoi Superjet) as well as derivatives (Bombardier CRJ1000). Altogether, they cover a representative sample of situations (new products, re-engining, MTOW extensions) and cover the market segments originally considered in establishing the goals, with the exception of the Short Medium Range (SMR) category. For the sake of completeness and to support a first measure of trend analysis, the A380 has also been included as the only pre-CAEP/8 model meeting the Technology Goals. WG1 concluded that:

a) According to the proposed criterion, the Mid-Term Noise Technology Goals are now met for the two higher weight categories (LR4 and LR2).

b) In terms of trends, this CAEP cycle has allowed the noise goals to be met in a single additional category (LR2). From an overall perspective, recently certified products are either still short of reaching the goals or meeting them by a relatively small margin (one model variant). This is supporting the choice of IEP1 and IEP2 in establishing these set of goals as representative of the leading edge of technology by 2020.

c) The evolution of noise versus weight for new certifications is consistent with the noise-weight relationships used by IEP1 and IEP2 in setting up the goals bands.

d) Considering the planned certification dates for upcoming new aircraft programmes, it is anticipated that additional data will contribute to further progress assessment by CAEP/10 and that a full picture of progress across the board will be available for CAEP/11.

e) The meeting noted information provided by WG1 on Task N04.01 which was to "Monitor and report on the various national and international research programme goals and milestones" during the CAEP/9 cycle. The included an overview of the major noise technology research initiatives in the US, EU, Japan, Canada, Russia and Brazil. The meeting also noted information provided on research goals.

Discussion and Conclusions

3.5.3 The meeting thanked WG1 for the review of progress toward the achievement of technology goals and agreed to consider its results in their further discussions. They also supported conducting a similar assessment during the next CAEP cycle.

3.6 CONSIDERATION OF A PROPOSAL TO AMEND ANNEX 16, VOLUME I TO INCLUDE A NOISE STANDARD FOR TILTROTOR AIRCRAFT

3.6.1 The WG1 Co-Rapporteurs presented a proposal to form an Annex 16, Volume I Standard for Tilt-rotor aircraft. The background was given regarding the adoption of guidelines for incorporation into Annex 16, Vol. I, Chapter 13 and Attachment F before the Co-Rapporteurs gave details on the proposal for a noise Standard for Tilt-rotor aircraft, which dealt with:

a) **Noise-Technical issues**. Should the current noise guidance and stringency for Tilt-rotor aircraft (as is currently used in Annex 16, Vol. I, Attachment F) be used for an Annex 16 Standard for Tilt-rotor aircraft. The WG1 Co-Rapporteurs reported that the broad majority consensus of WG1 considered that a Standard for Tilt-rotor aircraft should be proposed to CAEP and that the procedures and technical detail in the guidance material should be used in the Standard along with the same Chapter 8, Paragraph 8.4.1 noise limits.

b) **Technical issues in relation to other Annexes**. Whether an Annex 16 Standard can be proposed for adoption without adaptations to other Standards in ICAO Annexes. The WG1 Co-Rapporteurs reported that three Annexes were identified that are relevant in this context, they are: Annex 8 — Airworthiness of Aircraft, Annex 7 – Aircraft Nationality and Registration Marks, and Annex 6 — Operations of Aircraft. These broad Standards provide a basis for the development of national regulations and rules which would specify the (minimum) scope and detail considered necessary by individual Contracting States for the certification, the continuing airworthiness and operation of individual aircraft. Overall, WG1 did not find any major barriers to forming a Tilt-rotor aircraft Standard, however, with respect to the lack of a definition of a Tilt-rotor aircraft, several issues were raised which could not be resolved before the CAEP meeting.

c) **Legal issues**. If there are any possible legal issues, and implications to other Annexes, should a noise Standard for Tilt-rotor aircraft be proposed for adoption in Annex 16. The WG1 Co-Rapporteurs reported (on advice from the ICAO Secretariat) that while there may be no legal impediment to developing a new noise Standard to be incorporated into Annex 16, without specific Standards for Tilt-rotor aircraft being in existence in Annexes 6, 7 and 8, practical and technical difficulties may arise in its implementation as it relates to the aircraft certification and operational requirements set out in those Annexes.

Discussion and Conclusions

3.6.2 A member referred to the definition in Annex 1 for Powered-Lift aircraft, suggesting that some coordination is required within ICAO on the definition for a Tilt-rotor aircraft. The WG1 Co-Rapporteur referred to the Annex 16, Volume I, Appendix F, Note. 1 which includes a definition for a Tiltrotor aircraft, and it was highlighted that the US FAA has a definition based on Powered-Lift aircraft. The Co-Rapporteurs suggested that there will be a lengthy delay in the formation of an Annex 16 Standard if the group waits for a fully coordinated definition, adding that an aircraft is due to enter service in 2016 and that there would be benefit in having an agreed international Standard by then.

3.6.3 The Secretary highlighted that the CAEP must be cautious in deliberating on tilt-rotors. There was a clear need to harmonize at an international level, but at the same time care must be taken to avoid unintended consequences in relation to other Annexes. The Secretary also brought to the attention of the group Annex 1 which includes the definition for powered-lift aircraft.

3.6.4 A member made it clear that an Annex 16 noise Standard should not result in any unsafe operational procedures, to which the Co-Rapporteurs and Chairperson responded that this is a certification technology Standard for Noise and should not affect day-to-day operational procedures as it only defines procedures for the noise certification.

3.6.5 The Secretariat provided background information on the Powered-lift aircraft definition (developed in 2005), under which a future Tilt-rotor aircraft would be a subgroup. The Secretariat gave an overview of how Annexes 1, 7 and 8 allow aircraft, on a multilateral basis, to operate internationally.

3.6.6 Following substantial discussion with the ICAO Secretariat experts on airworthiness, operations and legal aspects on the possible implications for Annexes 1, 6, 7, and 8, the meeting agreed on the following definition and spelling of tilt-rotor: ***Tilt-rotor.*** *A powered-lift capable of vertical take-off, vertical landing, and sustained low-speed flight, which depends principally on engine-driven rotors mounted on tiltable nacelles for the lift during these flight regimes and on non-rotating aerofoil(s) for lift during high-speed flight.*

3.6.7 The meeting agreed that this definition would be fully compatible with existing ICAO definitions and did not foresee unintended consequences resulting from this definition. The meeting further noted that when reviewed by the ANC, the definition may need to refer to "aerodynamic reactions on non-rotating aerofoil(s)…" to ensure precise agreement with the definition of aeroplane in Annex 1. The meeting is not opposed to this change, if it is determined to be necessary.

3.6.8 The meeting recommended that Annex 16, Volume I be update to include this definition for tilt-rotor along with the definition of ***powered-lift*** that is provided in Annex 1. In completing their consideration of implication on the other Annexes, the meeting also asked that the following recommendations be brought along with the proposed amendments to Annex 16, Volume I for the consideration of the Council:

3.6.9 **Annex 1 Amendment (Personnel Licensing)**

3.6.9.1 That the validity period of the transitional type rating for powered lift specified in Annex 1, paragraph 2.1.1.4 from 2015 be extended to a suitable future date, to be determined, nominally 2022. This recommendation was based on the anticipated 2016 entry into service of tilt-rotor aircraft and the need to gain operational experience with the aircraft prior to amending Annex 1. This would allow for a personnel licensing Standard to be developed in 2020. The meeting noted that input from ICCAIA would be required to advance this work.

3.6.10 **Annex 7 Amendment (Nationality and Registration Marks)**

3.6.10.1 That the definition of powered-lift to be added to Annex 7 to coincide with update to Annex 1, nominally in 2022. This would use the existing definition included in Annex 1.

3.6.11 **Annex 8 (Airworthiness)**

3.6.11.1 That work has not yet been initiated on an update Annex 8 to add powered-lift. The meeting recommended that ICCAIA review Annex 8 for helicopters and aeroplanes to identify gaps, if any. The group further noted Assembly Resolution 37-15, Appendix G in which the Assembly resolved "that pending the coming into force of international Standards respecting particular categories, classes or types of aircraft, certificates issued or rendered valid, under national regulations, by the Contracting State in which the aircraft is registered shall be recognized by other Contracting States for the purposes of flight over their territories, including landings and take-offs."

3.6.12 **Annex 6 (Operation of Aircraft)**

3.6.12.1 That the prospective operator(s)/those with operational experience be consulted in developing an amendment to Annex 6. Based on this input Annex 6 could be amended to address powered-lift. The timeline for this amendment would be based on resource availability and needs and priorities identified by States. In the interim, the meeting recommended that the possible applicability of bi-lateral agreements / national regulations be explored.

3.6.13 **Other Work**

3.6.13.1 That the Secretariat conduct a review of other annexes to assess any changes required related to the suitability of landing facilities and specific procedure design requirements.

3.6.14 **Recommendations**

3.6.14.1 In light of the foregoing discussion, the meeting developed the following recommendations:

RSPP

Recommendation 3/5 — Amendments to Annex 16 — Environmental Protection, Volume I — *Aircraft Noise*

That Annex 16, Volume I be amended as indicated in Appendix C to the report on this agenda item.

Recommendation 3/6 — Consideration of Amendments to Annex 1

That the Council amend Annex 1 to extend the validity period of the transitional type rating for powered-lift as recommended by CAEP, as soon as possible.

Recommendation 3/7 — Consideration of Amendments to Annexes 1, 6, 7 and 8

That the Council request a review of Annexes requiring amendment for tilt-rotor aircraft, in particular Annexes 1, 6, 7, and 8, noting the specific recommendations provided by CAEP.

3.7 MODELLING OF NEW NOISE STRINGENCY OPTIONS

3.7.1 The Co-Rapporteurs of MDG and FESG presented the modelling results for the environmental and economic assessment of the noise stringency options under consideration for CAEP/9.

3.7.2 For the noise stringency assessment, areas and population counts within the 55, 60 and 65 dB Day-Night Average Sound Level (DNL) contours were computed by airport and aggregated by region and for the globe. In all instances, noise results exhibit an expected trend of increasing benefits with increasing stringency. For analysis year 2036 the percentage reduction in area exposed to DNL 55 dB increases by: (1) 1.6% when moving from -5 to -7 EPNdB; (2) 4.3% when moving from -7 to -9 EPNdB; and (3) 3.5% when moving from -9 to -11 EPNdB.

3.7.3 For the greenhouse gas emissions portion of the analysis, full-flight performance-based fuel burn was developed using AEDT and AEM . It was explained that the change in fuel burn for all stringency cases is below 1.0 per cent of global fuel burn. That is to say the overall magnitude of the fuel burn reductions is very small and potentially within the models' uncertainty range . For the -3, -5 and -7 EPNdB stringency scenarios the fuel burn behaves similarly and as expected for both AEDT and AEM, i.e., to the extent the modelling suggests that as quieter, more fuel efficient, aircraft are introduced into the fleet to meet the noise stringency levels, the fuel burn benefit increases along with increasing noise stringency.

3.7.4 For AEDT this trend of increasing fuel benefit for increasing noise stringency does not hold true for the -9 EPNdB stringency scenario, which actually shows a fuel penalty; and for the -11 EPNdB stringency scenario the benefit is slightly less than that observed for the -7 EPNdB scenario. Modelling seat demand and an examination of the evolved fleet helps to explain this somewhat counter-intuitive behaviour in the -9 and -11 EPNdB scenarios for AEDT. In the case of AEM, the -9 EPNdB shows a similar, somewhat counter-intuitive behaviour relative to the -7 EPNdB scenario, i.e., there is a slight reduction in the fuel benefit at -9 EPNdB relative to -7 EPNdB. But, for the -11 EPNdB scenario AEM shows a fuel burn benefit on the order of 1% relative to total global fuel burn, whereas it is on the order of 0.4% for AEDT.

3.7.5 FESG modelled the recurring and non-recurring cost implications of each of the stringency scenarios against the baseline. The recurring direct operating costs reflect costs that would be incurred by aircraft operators, including changes in fuel costs, other direct costs (i.e., crew, maintenance, route, landing charges) and capital costs (i.e., aircraft financing and depreciation costs). The recurring costs results were calculated using the APMT-Economics model and confirmed by the FESG Noise Cost Model. While the fuel cost component mirrors the trend of the input MDG AEDT fuel burn results, the total recurring cost results show negative costs for -3 and -5 EPNdB and increasing costs for -7, -9 and -11 EPNdB, with undiscounted values from $-8.68B for -5 EPNdB to $100.2B for -11EPNdB. The MDG estimated results using AEM fuel burn showed the same trend for total recurring costs; though, a smaller range in cost values

3.7.6 The non-recurring costs were modelled to include the additional economic impacts that could be incurred by manufacturers, aircraft owners and aircraft operators as a result of the noise stringency scenarios. As there were different perspectives regarding whether such costs should be factored into the global cost effects, the non-recurring cost values were considered to be part of a range from zero to the values calculated. The values calculated for non-recurring manufacturer costs begin with $1.69B for -3 EPNdB and reach $18.82B for -11 EPNdB. The values for non-recurring aircraft operators and owners costs begin with $0.95B for -3 EPNdB and reach $9.09B for -11 EPNdB.

3.7.7 The ranking of the cost-effectiveness results shows -5 EPNdB as having the lowest cost per person or area removed from noise through all discount rates and scenarios tested. FESG also assessed the effects stringency-related cost increases may have on consumers (passengers and freight dispatchers), airports and air navigation service providers.

3.7.8 Another sensitivity test was run to assess the potential impacts of the announcement date. This resulted in a slight change to the non-recurring manufacturer costs ($1.69B for -3 EPNdB to $24.59B for -11 EPNdB) and the non-recurring aircraft operator and owner costs ($0.43B for -3 EPNdB to $3.87B for -11 EPNdB), thereby reducing the non-recurring costs for the -3, -5 and -7 EPNdB scenarios, and increasing the non-recurring costs for the -9 and -11 EPNdB scenarios (undiscounted).

Discussion and Conclusions

3.7.9 The meeting noted the information presented on the MDG/FESG results and recognised that the limited number of noise compliant aircraft types meeting the -9 and -11 EPNdB scenarios had presented challenges for MDG/FESG. The meeting then accepted the MDG and FESG noise stringency results. The meeting also noted that additional work would not improve the outcome of the analysis or add to further understanding of the stringency options.

3.7.10 An observer referred to the limited number of compliant aircraft at -9 and -11 EPNdB and postulated that this might reflect a lack of technically feasible aircraft at these options, questioning how this impacts the uncertainty of the presented results. The MDG Co-Rapporteur referred to the technical interchange between WG1, MDG and FESG through the Growth and Replacement database which is populated only with aircraft that are considered to respond to the criteria of technological feasibility. A WG1 Co-Rapporteur highlighted that in each seat class there was an aircraft that meets all the stringency options. Adding to this, two observers suggested that the assumptions used (e.g. the market driven cut-off) did arguably impact the modeled results. The MDG Co-Rapporteur agreed that the limited number of compliant aircraft at the -9 and -11 EPNdB scenarios has arguably added to the uncertainties in the analysis.

3.8 CONSIDERATION OF NEW NOISE STRINGENCY OPTIONS

3.8.1 An observer presented the joint opinion of several members and observers that a decision on a new noise stringency is necessary to ensure that ICAO meets its responsibility to provide a noise standard that ensures that state of the art technology is incorporated, thus providing one of the four elements of the balanced approach. Taking a decision now is important to give clear direction to the industry. It will also allow the working and support groups of CAEP to concentrate on the other two important strategic tasks of the CAEP, namely the CO_2 and PM standard setting processes. The group pointed out that the analysis shows that at -7, -9 and -11 EPNdB cumulative, the cost effectiveness results are of similar magnitude. But the environmental benefits achieved by larger stringencies are much higher than with -7 EPNdB. The group of members and observers consider that the highest possible technologically feasible and economically reasonable stringency level should be set. Whatever regulatory level is decided, the change needs to be significant and noticeable. It also has to be environmentally effective in a significant way. It is a condition to tackle effectively the noise problem that is already constraining many airports and even more so in the future. The data and analysis has clearly shown that none of the lower options being studied would meet these conditions.

3.8.2 Taking into new technological developments, and in order to decide on a Standard that is sufficiently ambitious, the group of members and observers suggested that it is reasonable to decide on a new noise stringency level reflecting a similar level of improvement as that which was agreed between the Chapters 3 and 4 Standards. Additionally, they proposed that 1 January 2020 at the latest should be the introduction date of the new noise standard.

3.8.3 A member presented a point of view on the noise stringency work developed over the CAEP/9 cycle. After a thorough analysis of all the aspects involved with the adoption of a noise stringency, the member concluded that the Chapter 4, -5 EPNdB scenario is the most reasonable to be recommended by CAEP at this point, when taking into consideration the CAEP principles of technical feasibility, economical reasonableness and environmental benefit. The member added that, based on IEP2 conclusions (shown in section 3.3), stringency scenarios higher than -5 EPNdB might violate the “not preclude low carbon technologies” remit of the noise stringency analysis task, since counter-rotating open rotor (CROR) powered aircraft might be impacted by these higher stringency levels. Additionally it was suggested that Chapter 4 stringency is still pushing air framers to implement the available noise reduction technologies in new aircraft designs whenever the economic and technical aspects allow. This indicates that the -5 EPNdB stringency option is more than enough to make the industry keep the implementation of noise reduction technologies whenever possible. Given the level of detail of the analysis performed in this cycle, the member also considered it to be unnecessary to postpone the decision of a new noise standard to the CAEP/10 cycle, adding that there is also a good argument to conduct stringency option analysis more frequently.

3.8.4 An observer made reference to the more frequent evaluations and questioned whether this meant that if, the CAEP agrees to a noise Standard now, the next evaluation should be conducted sooner. The member presenting its position stated that the CAEP should go for -5 EPNdB now and agreed that noise stringency evaluations should be more frequent.

3.8.5 A member asked whether it would be better to have a different Standard that accounts for the various aircraft types. It was suggested that a differentiated application of the noise Standard by aircraft size could be considered in the future. Following up on this, another member asked whether WG1 had considered the concept of dual limit lines during this phase of noise analysis. The WG1 Co-Rapporteurs stated that this had not been considered by WG1.

3.8.6 A member expressed the opinion that the work of WG1, WG3, MDG and FESG, through tasks N.06.01, E.09, M.02 and F.02, respectively, can guide CAEP in considering a more stringent noise Standard for subsonic jet and heavy propeller-driven aeroplanes. Following an overview of technical feasibility and economic reasonableness, which included details on the technology goals for aircraft categories (regional jet, large turboprop and pusher CROR), the member suggested that the -3 or -5 EPNdB options to be technically feasible and economically reasonable for use in a more stringent noise Standard. The member pointed out that both of these options should not preclude low carbon technologies such as the large turboprop and open rotor aircraft.

3.8.7 Regarding environmental benefit, the member highlighted that -5 EPNdB offers greater noise reduction and emissions benefits, and appears to be the most cost-effective option. The member suggested that the CAEP should recommend an increase in stringency of no more than 5 EPNdB cumulative margin below Chapter 4, with an applicability date in 2020.

3.8.8 Following a question from a member, it was clarified by the presenting member that -9 EPNdB should be ruled out, and -5 EPNdB is the most appropriate option that is environmentally beneficial, economically reasonable and technically feasible.

3.8.9 A member presented a view on the noise stringency analysis. Based on both the results of the CAEP analysis (shown in section 3.7) and the cost-benefit analysis presented by the member, support was given for an increase in noise stringency to a cumulative margin of Chapter 4, -5 EPNdB with an implementation in 2020. The member suggested that considering the environmental benefits and costs shown by the noise stringency analysis, potential unintended effects on low carbon technologies, and other factors, such as the role of project aircraft in the analysis, a stringency increase above Chapter 4, -5 EPNdB could not be supported. The member stated that if there is a desire to consider a stringency level higher than Chapter 4, -5 EPNdB, then the decision on noise stringency should be postponed.

3.8.10 In support of the member's position, the member highlighted a detailed and comprehensive cost benefit assessment of environmental impacts compared against economic costs for the CAEP/9 noise stringency options, with explicit consideration of interdependencies and uncertainties among impacts in that State. The analysis took into consideration the environmental impacts of the stringency options, including assessing the health and welfare impacts; and, quantified interdependencies in terms of physical and monetary impacts for aircraft-related noise, fuel burn and emissions, following a similar approach to that used by this member State to conduct a cost-benefit analysis of the stringency options for the CAEP/8 NO_X Stringency Analysis. The fundamental methodologies have been extensively vetted through peer review. The analysis built upon the analysis of MDG and FESG and was meant to further inform decision making. The analysis clearly found Stringency 2 (Chapter 4, -5 EPNdB) to be the most cost-beneficial option under a broad set of assumptions.

3.8.11 In response to a question on the feasibility of the -7EPNdB noise stringency option, the member encouraged the group to review the cost benefit analysis conducted by the United States. The member reminded that group that the United States cost benefit analysis is a supplementary tool and the stringency decision should be based on the MDG/FESG analysis. Two members agreed that time should be taken to come to an appropriate decision at this meeting on Noise Stringency.

3.8.12 An observer highlighted that the cost effective analysis does not include sound insulation for housing. The member suggested that, while this is quite an expense, it is a different order of magnitude to the resulting cost of adopting certain noise stringency options. The member added the opinion that an assessment of housing insulation cost effectiveness is more of a qualitative analysis. The member also highlighted that the largest noise reduction benefits come from aircraft operations and technology.

3.8.13 An observer presented views on the noise stringency analysis, agreeing with the conclusions of the MDG/FESG analysis (section 3.7). The observer mentioned that the CAEP terms of reference require standards to be environmentally beneficial, technologically feasible, economically reasonable and consider interdependencies. The observer suggested that the analyses performed by the working groups demonstrated that only the Chapter 4, -5 EPNdB and Chapter 4, -7 EPNdB scenarios are suitable for a CAEP/9 decision on noise Standard, and that the Chapter 4, -5 EPNdB scenario provides the most cost-effective option with a new applicability date of 2020.

3.8.14 The observer offered the opinion that WG1 had not discussed or agreed fully on the technical feasibility of all the stringency options. The observer highlighted that the low and high stringency options were apparently introduced to stretch the modelling analysis.

3.8.15 A member asked for clarification of the observer's position that the -5 EPNdB and -7 EPNdB noise stringency options captured the significant advances in noise technology developed by industry. The observer responded by stating that the -5 EPNdB is the most cost effective option and this should be taken forward by the CAEP. The observer added that any option greater than -7EPNdB is not acceptable to the industry because this would exceed the predicted capability of some of the in-development aircraft noise performance.

3.8.16 An observer urged CAEP to agree to a significant new noise standard which will be to the benefit of the long-term improvement of noise emissions of the global fleet. Furthermore, it would be an important component of the vital message to communities near airports that the aviation industry needs permission to grow and that local concerns regarding noise impacts continue to be addressed.

3.8.17 The observer also sought the incorporation of proposed modifications to the noise standard for aircraft below 10 tonnes as agreed by the CAEP Steering Group and the inclusion of a supplementary requirement of a minimum margin at all three noise certification locations. The observer also proposed a new CAEP work item on Open Rotor aircraft and their noise characteristics and another on a technical examination of impacts and benefits of a future phase-out of noisy aircraft. The observer proposed that a new noise standard should be based on Chapter 4, -9 EPNdB (cumulative) or better.

3.8.18 The observer did present new information showing the relationship of aircraft noise levels in relation to Chapter 2, 3, 4 and future noise Standards. Regarding this, a member voiced a concern that this was last minute information and questioned the assumptions used. It was clarified that project aircraft represented in this study were introduced at the observer's own discretion and that the manufacturers had not been consulted on this.

3.8.19 ICAO SARPs have been, and are, an important means for securing technological improvements and reduction of noise at source. An observer suggested that noise certification Standards are increasingly being used by States to restrict operations and impose noise-related charges on aircraft which do not meet the most stringent requirements. As CAEP considers whether to recommend that ICAO adopt a new noise certification Standard, the observer suggested that it also should consider the proper application of any such Standard. The observer highlighted industry concern that adopting a new Standard would lead to the introduction of further operating restrictions on in-service aircraft, undermining the role of ICAO's Standards, the ICAO balanced approach to aircraft noise management and the regulatory stability needed by operators. The observer suggested that should CAEP recommend the adoption of a new noise stringency Standard, it should make a corresponding recommendation that the ICAO States should be urged not to place any operating restrictions on aircraft meeting the noise certification Standards in Annex 16, Vol. I, Chapter 4 or the new certification Standard, and be encouraged to adhere strictly to the balanced approach to aircraft noise management.

3.8.20 Another observer fully supported the position as presented and encouraged states to fully apply the balanced approach to noise management, highlighting that access to airports should not be limited by a noise stringency decision.

3.8.21 Noise remains a significant issue at many airports around the world and the numbers of people exposed globally is forecast to increase in the future. Based on the environmental need to protect communities and contribute to the long-term objective of reducing aircraft noise, an observer supported making a recommendation to introduce a new noise standard at the CAEP/9 meeting. The observer emphasised that the level of stringency should be ambitious, noting the fact that there is likely to be a longer than usual period before the Standard takes effect in 2020. Based on this, the observer supported the introduction of a new noise standard that is a minimum of -9 EPNdB below the existing Chapter 4 Standard.

Discussion and Conclusions

3.8.22 The meeting heard many opinions from members and observers on their positions on a new Stringency for the noise Standard. There was a general consensus that the CAEP should try its utmost to reach a noise stringency decision at this meeting. While in agreement, some members did stress that we should take the necessary period of time to come to an agreement.

3.8.23 The meeting heard a range of views on the appropriateness of the various stringency options from -5 EPNdB to -9 EPNdB, and that the CAEP must reach a consensus considering the pillars of the balanced approach, while balancing the interests of the various stakeholders. Several members and observers supported the options of -5 EPNdB and -7 EPNdB, while a smaller number of members and observers supported -9 EPNdB and above, as their preferred options which are, according to them, the most reasonable given the technical feasibility, costs and environmental benefits.

3.8.24 The meeting heard many interpretations of the technical analysis conducted by MDG and FESG on the noise stringency options. The meeting did agree that, while other analyses had been supplied for information, the decision is to be based on the comprehensive MDG/FESG analysis.

3.8.25 A member raised a specific proposal which highlighted concerns connected to the current form of the noise stringency limit line, and suggested that smaller aircraft should be treated differently to larger aircraft under a new Standard. The member suggested that the stringency increase should be smaller for lighter aircraft and greater for heavier aircraft. An observer stated that the information presented to the meeting by the member was new and that the manufacturing community was uncomfortable with the proposal.

3.8.26 The Chairman summarised, stating that the meeting had heard several positions form the members and observers and highlighted that the meeting needed to reach a consensus on the future noise Standard. This included the selection of a noise stringency option, an applicability date, the margin at each certification point, and perhaps an option for modifying the noise Standard limit line slope. The meeting was reminded that if a decision is made on noise stringency then the noise limits applicable to subsonic jet aeroplanes with take-off masses <8,618kg should be incorporated into the new Standard as agreed to the 2011 Steering Group.

3.8.27 The ICAO Balanced Approach to noise management is an approach to managing noise at an airport that consists of identifying the noise problem at an airport and then analysing the various measures available to reduce noise through the exploration of four principal elements, namely, reduction at source, land-use planning and management, noise abatement operational procedures and operating restrictions, with the goal of addressing the noise problem in the most cost-effective manner. In fulfilling the ICAO environmental objectives, progress is expected in all elements.

3.8.28 The selection of a new, more stringent, noise Standard addresses a key element of the balanced approach, namely the reduction of noise at source. Following an extensive discussion amongst the CAEP Members, a consensus was reached regarding the question of which new Noise Stringency option should be applicable to aircraft in the future. The members converged on a new noise Standard of -7EPNdB with respect to Chapter 4 with an applicability date of 2017 for all types with MTOW equal to or higher than 55tonnes and with an applicability date of 2020 for MTOW lower than 55tonnes. The meeting agreed that these new noise Standards be included as Chapter 14 of Annex 16 Volume I. In addition to the stringency level, the following points were agreed:

a) That a supplementary condition be included in addition to the cumulative stringency options requiring a margin of not less than 1.0 EPNdB below Chapter 3 limits at each certification point.

b) To change the noise limits applicable to subsonic jet aeroplanes with take-off masses <8,618kg, and specifically a second "knee point" at 8,618kg, to use the same gradient of the limit line at lower masses as the higher masses and the constant limit line for aircraft with masses <2,000kg, as agreed during the 2011 Steering Group.

c) That the noise stringency increase should be implemented by 31 December 2017 and 2020 respectively.

d) That there is more potential for the introduction of noise reduction technologies for the heavier jet aircraft as compared to lighter aircraft, and it was agreed that any future noise Standard analysis would have to take this factor into account when looking into possible increases of the noise stringency levels.

e) That the meeting should recommend to the Council to propose to the 38th Session of the ICAO Assembly text urging States not to introduce operational restrictions on aircraft that comply with the noise certification Standard of Annex 16 Volume I, Chapter 4 and 14.

3.8.29 An observer referred to the very thorough analysis conducted by CAEP which showed the -5EPNdB option as the most cost-effective option. The observer also highlighted the need to emphasise that operational restrictions and phase-outs should not be implemented based on the Chapter 4 or new noise Standard.

3.8.30 The Chairman reminded the group about the nature of the decisions made by CAEP, highlighting that the decision had been taken unanimously by the members and represented their view that this was the best compromise amongst the options discussed. The Chairman congratulated the meeting on making such an important decision on a new noise Standard.

3.8.31 Following a full discussion of all the issues involved, the meeting agreed to recommend an amendment to Annex 16, Volume I involving an increase in stringency of 7 EPNdB (cumulative) relative to the current Chapter 4 cumulative levels. Applicability would be to new aeroplane types submitted for certification on or after 31 December 2017 (31 December 2020 for aircraft <55 tonnes). This includes a supplementary condition, included in addition to the cumulative stringency requirement, requiring a margin of not less than 1.0 dB below Chapter 3 limits at each certification point. The meeting also agreed to change the noise limits applicable to subsonic jet aeroplanes with take-off masses <8,618kg, and specifically the introduction of a second "knee point" at 8,618kg, to use the same gradient of the limit line at lower masses as the higher masses and the constant limit line for aircraft with masses <2,000kg, as agreed during the 2011 Steering Group.

3.8.32 **Recommendations**

3.8.32.1 The meeting consequently developed the following recommendations:

RSPP **Recommendation 3/8 — Amendment to Annex 16, Volume I - Aircraft Noise**

That Annex 16, Volume I be amended as indicated in Appendix A to this part of the report to include the new Chapter 14.

Recommendation 3/9 — Refrain from the introduction of operational restrictions

That States be urged not to introduce operational restrictions on aircraft that comply with the noise certification Standard of Annex 16, Volume I, Chapter 4 and/or 14.

— — — — — — — —

APPENDIX A

PROPOSED AMENDMENT TO ANNEX 16, VOLUME I

The text of the amendment is arranged to show deleted text with a line through it and new text highlighted with grey shading, as shown below:

1. ~~Text to be deleted is shown with a line through it.~~	text to be deleted
2. New text to be inserted is highlighted with grey shading.	new text to be inserted
3. ~~Text to be deleted is shown with a line through it~~ followed by the replacement text which is highlighted with grey shading.	new text to replace existing text

TEXT OF PROPOSED AMENDMENT TO THE

INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES

ENVIRONMENTAL PROTECTION

ANNEX 16
TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME I
AIRCRAFT NOISE

. . .

FOREWORD

. . .

Applicability

Part I of Volume I of Annex 16 contains definitions and Part II contains Standards, Recommended Practices and guidelines for noise certification applicable to the classification of aircraft specified in individual chapters of that part, where such aircraft are engaged in international air navigation.

Note.— Chapters 2 ~~and~~, 3, 4 and 14 exclude jet aeroplanes having short take-off and landing (STOL) capabilities which, pending the development by ICAO of a suitable definition, are described for the purpose of this Annex as those requiring a runway (with no stopway or clearway) of 610 m or less at the maximum certificated mass for airworthiness.

. . .

See Work Item N.02.17

PART II. AIRCRAFT NOISE CERTIFICATION

. . .

CHAPTER 1. ADMINISTRATION

1.1 The provisions of 1.2 to 1.6 shall apply to all aircraft included in the classifications defined for noise certification purposes in Chapters 2, 3, 4, 5, 6, 8, 10, 11 ~~and~~, 12 and 14 of this part where such aircraft are engaged in international air navigation.

. . .

1.5 The documents attesting noise certification for an aircraft shall provide at least the following information:

. . .

Item 9. Maximum take-off mass in kilograms.

Item 10. Maximum landing mass, in kilograms, for certificates issued under Chapters 2, 3, 4, 5 ~~and~~, 12 and 14 of this Annex.

Item 11. The chapter and section of this Annex according to which the aircraft was certificated.

Item 12. Additional modifications incorporated for the purpose of compliance with the applicable noise certification Standards.

Item 13. The lateral/full-power noise level in the corresponding unit for documents issued under Chapters 2, 3, 4, 5 ~~and~~, 12 and 14 of this Annex.

Item 14. The approach noise level in the corresponding unit for documents issued under Chapters 2, 3, 4, 5, 8 ~~and~~, 12 and 14 of this Annex.

Item 15. The flyover noise level in the corresponding unit for documents issued under Chapters 2, 3, 4, 5 ~~and~~, 12 and 14 of this Annex.

Item 16. The overflight noise level in the corresponding unit for documents issued under Chapters 6, 8 and 11 of this Annex.

Item 17. The take-off noise level in the corresponding unit for documents issued under Chapters 8 and 10 of this Annex.

Item 18. Statement of compliance, including a reference to Annex 16, Volume I.

Item 19. Date of issuance of the noise certification document.

Item 20. Signature of the officer issuing it.

CHAPTER 2.

. . .

2.4 Maximum noise levels

. . .

Note.— See Attachment A for equations for the calculation of maximum permitted noise levels as a function of take-off mass.

. . .

See Work Item N.02.06

CHAPTER 3.

1.— SUBSONIC JET AEROPLANES — Application for Type Certificate submitted on or after 6 October 1977 and before 1 January 2006

2.— ~~PROPELLER-DRIVEN AEROPLANES OVER 8 618 kg — Application for Type Certificate submitted on or after 1 January 1985 and before 1 January 2006~~ PROPELLER-DRIVEN AEROPLANES OVER 8 618 kg — Application for Type Certificate submitted on or after 1 January 1985 and before 1 January 2006

. . .

See Work Item N.02.17

3.4 Maximum noise levels

. . .

Note.— See Attachment A for equations for the calculation of maximum permitted noise levels as a function of take-off mass.

. . .

CHAPTER 4.

1.— SUBSONIC JET AEROPLANES AND PROPELLER-DRIVEN AEROPLANES WITH MAXIMUM CERTIFICATED TAKE-OFF MASS 55 000 kg AND OVER — Application for Type Certificate submitted on or after 1 January 2006 and before 31 December 2017

2.— SUBSONIC JET AEROPLANES WITH MAXIMUM CERTIFICATED TAKE-OFF MASS LESS THAN 55 000 kg — Application for Type Certificate submitted on or after 1 January 2006 and before 31 December 2020

~~2.~~3.—PROPELLER-DRIVEN AEROPLANES WITH MAXIMUM CERTIFICATED TAKE-OFF MASS LESS THAN 55 000 kg AND OVER 8 618 kg — Application for Type Certificate submitted on or after 1 January 2006 and before 31 December 2020

4.1 Applicability

Note. — See also Chapter 1, 1.10, 1.11, 1.12 and 1.13.

4.1.1 The Standards of this chapter shall, with the exception of those subsonic jet aeroplanes which require a runway[1] length of 610 m or less at maximum certificated mass for airworthiness or propeller-driven aeroplanes specifically designed and used for agricultural or fire-fighting purposes, be applicable to:

[1] With no stopway or clearway.

a) all subsonic jet aeroplanes and propeller-driven aeroplanes, including their derived versions, ~~other than aeroplanes which require a runway length of 610 m or less at maximum certificated mass for airworthiness~~ with a maximum certificated take-off mass of 55 000 k g and over for which the application for a Type Certificate was submitted on or after 1 January 2006 and before 31 December 2017;

b) all subsonic jet aeroplanes, including their derived versions, with a maximum certificated take-off mass of less than 55 000 kg for which the application for a Type Certificate was submitted on or after 1 January 2006 and before 31 December 2020;

~~b)~~ c) all propeller-driven aeroplanes, including their derived versions, ~~of~~ with a maximum certificated take-off mass of less than 55 000 kg and over 8 618 kg ~~maximum certificated take-off mass~~, for which the application for a Type Certificate was submitted on or after 1 January 2006 and before 31 December 2020; and

~~c)~~ d) all subsonic jet aeroplanes and all propeller-driven aeroplanes certificated originally as satisfying Annex 16, Volume 1, Chapter 3 or Chapter 5, for which recertification to Chapter 4 is requested.

Note.— Guidance material on applications for recertification is provided in the Environmental Technical Manual *(Doc 9501), Volume I —* Procedures for the Noise Certification of Aircraft.

. . .

4.4 Maximum noise levels

. . .

4.4.1.2 The sum of the differences at any two measurement points between the maximum noise levels and the corresponding maximum permitted noise levels specified in Chapter 3, 3.4.1.1, 3.4.1.2 and 3.4.1.3, shall not be less than 2 EPNdB.

Note.— See Attachment A for equations for the calculation of maximum permitted noise levels as a function of take-off mass.

. . .

CHAPTER 5.

. . .

5.4 Maximum noise levels

. . .

Note.— See Attachment A for equations for the calculation of maximum permitted noise levels as a function of take-off mass.

. . .

CHAPTER 6.

. . .

6.3 Maximum noise levels

. . .

Note 1.— Where an aeroplane comes within the provisions of Chapter 10, 10.1.2, the limit of 80 dB(A) applies up to 8 618 kg.

Note 2.— See Attachment A for equations for the calculation of maximum permitted noise levels as a function of take-off mass.

. . .

CHAPTER 8.

. . .

8.4 Maximum noise levels

. . .

Note.— See Attachment A for equations for the calculation of maximum permitted noise levels as a function of take-off mass.

. . .

See Work Item N.02.06

. . .

8.6.2 Take-off reference procedure

. . .

f) the reference take-off path is defined as a straight line segment inclined from the starting point (500 m prior to the centre microphone location and 20 m (65 ft) above ground level) at an angle defined by best rate of climb ~~(BRC)~~ and V_y for minimum specification engine performance.

. . .

8.7.5 During the test the average rotor rpm shall not vary from the normal maximum operating rpm by more than ±1.0 per cent during the 10 dB-down ~~time~~ period.

8.7.6 The helicopter airspeed shall not vary from the reference airspeed appropriate to the flight demonstration by more than ±9 km/h (±5 kt) throughout the 10 dB-down ~~time~~ period.

. . .

8.7.8 The helicopter shall fly within ±10° or ±20 m, whichever is greater, from the vertical above the reference track throughout the 10 dB-down ~~time~~ period (see Figure 8-1).

8.7.9 The helicopter height shall not vary during overflight from the reference height at the overhead point by more than ±9 m (±30 ft).

. . .

See Work Item N.02.17

CHAPTER 10.

. . .

10.4 Maximum noise levels

. . .

b) for aeroplanes specified in 10.1.4, a 70 dB(A) constant limit up to an aeroplane mass of 570 kg increasing linearly from that point with the logarithm of aeroplane mass until at 1 500 kg the limit of 85 dB(A) is reached after which the limit is constant up to 8 618 kg.

Note.— See Attachment A for equations for the calculation of maximum permitted noise levels as a function of take-off mass.

. . .

CHAPTER 11.

. . .

11.4 Maximum noise level

. . .

11.4.2 For helicopters specified in 11.1.4, the maximum noise levels, when determined in accordance with the noise evaluation method of Appendix 4, shall not exceed 82 decibels SEL for helicopters with maximum certificated take-off mass, at which the noise certification is requested, of up to 1 417 kg and increasing linearly with the logarithm of the helicopter mass at a rate of 3 decibels per doubling of mass thereafter.

Note.— See Attachment A for equations for the calculation of maximum permitted noise levels as a function of take-off mass.

. . .

See Work Item N.02.06

11.5.2 Reference procedure

11.5.2.1 The reference procedure shall be established as follows:

a) the helicopter shall be stabilized in level flight overhead the flight path reference point at a height of ~~150 m (492 ft) ± 15 m (50 ft)~~ 150 m ± 15 m (492 ft ± 50 ft);

. . .

11.6.6 During the test, the average rotor rpm shall not vary from the normal maximum operating rpm by more than ±1.0 per cent during the 10 dB-down ~~time~~ period.

11.6.7 The helicopter airspeed shall not vary from the reference airspeed appropriate to the flight demonstration as described in Appendix 4 by more than ±5.5 km/h (±3 kt) throughout the 10 dB-down ~~time~~ period.

. . .

Editorial note.— Insert new Chapter 14 as follows:

CHAPTER 14

1.— SUBSONIC JET AEROPLANES AND PROPELLER-DRIVEN AEROPLANES WITH MAXIMUM CERTIFICATED TAKE-OFF MASS 55 000 kg AND OVER — Application for Type Certificate submitted on or after 31 December 2017

2.— SUBSONIC JET AEROPLANES WITH MAXIMUM CERTIFICATED TAKE-OFF MASS LESS THAN 55 000 kg — Application for Type Certificate submitted on or after 31 December 2020

3.— PROPELLER-DRIVEN AEROPLANES WITH MAXIMUM CERTIFICATED TAKE-OFF MASS LESS THAN 55 000 kg AND OVER 8 618 kg — Application for Type Certificate submitted on or after 31 December 2020

14.1 Applicability

Note. — See also Chapter 1, 1.10, 1.11, 1.12 and 1.13

14.1.1 The Standards of this chapter shall, with the exception of those subsonic jet aeroplanes which require a runway[1] length of 610 m or less at maximum certificated mass for airworthiness or propeller-driven aeroplanes specifically designed and used for agricultural or fire-fighting purposes, be applicable to:

a) all subsonic jet aeroplanes and propeller-driven aeroplanes, including their derived versions, with a maximum certificated take-off mass of 55 000 kg and over for which the application for a Type Certificate was submitted on or after 31 December 2017;

b) all subsonic jet aeroplanes, including their derived versions, with a maximum certificated take-off mass of less than 55 000 kg for which the application for a Type Certificate was submitted on or after 31 December 2020;

c) all propeller-driven aeroplanes, including their derived versions, with a maximum certificated take-off mass of less than 55 000 kg and over 8 618 kg for which the application for a Type Certificate was submitted on or after 31 December 2020; and

[1] With no stopway or clearway.

d) all subsonic jet aeroplanes and all propeller-driven aeroplanes certificated originally as satisfying Annex 16, Volume I, Chapter 3, Chapter 4 or Chapter 5, for which recertification to Chapter 14 is requested.

Note.— Guidance material on applications for recertification is provided in the Environmental Techincal Manual *(Doc 9501), Volume I* – Procedures for Noise Certification of Aircraft.

14.1.2 Notwithstanding 14.1.1, it may be recognized by a Contracting State that the following situations for jet aeroplanes and propeller-driven heavy aeroplanes on its registry do not require demonstration of compliance with the provisions of the Standards of Annex 16, Volume I:

a) gear down flight with one or more retractable landing gear down during the entire flight;

b) spare engine and nacelle carriage external to the skin of the aeroplane (and return of the pylon or other external mount); and

c) time-limited engine and/or nacelle changes, where the change in type design specifies that the aeroplane may not be operated for a period of more than 90 days unless compliance with the provisions of Annex 16, Volume I, is shown for that change in type design. This applies only to changes resulting from a required maintenance action.

14.2 Noise measurements

14.2.1 Noise evaluation measure

The noise evaluation measure shall be the effective perceived noise level in EPNdB as d escribed in Appendix 2.

14.3 Reference noise measurement points

14.3.1 An aeroplane, when tested in accordance with these Standards, shall not exceed the maximum noise level specified in 14.4 of the noise measured at the points specified in Chapter 3, 3.3.1 a), b) and c).

14.3.2 Test noise measurement points

The provisions of Chapter 3, 3.3.2, relating to test noise measurement points shall apply.

14.4 Maximum noise levels

14.4.1 The maximum noise levels, when determined in accordance with the noise evaluation method of Appendix 2, shall not exceed the following:

14.4.1.1 *At the lateral full-power reference noise measurement point*

103 EPNdB for aeroplanes with maximum certificated take-off mass, at which the noise certification is requested, of 400 000 kg and over, decreasing linearly with the logarithm of the mass down to 94 EPNdB at 35 000 kg, after which the limit is constant to 8 618 kg, where it decreases linearly with the logarithm of the mass down to 88.6 EPNdB at 2 000 kg, after which the limit is constant.

14.4.1.2 *At the flyover reference noise measurement point*

a) *Aeroplanes with two engines or less*

101 EPNdB for aeroplanes with maximum certificated take-off mass, at which the noise certification is requested, of 385 000 kg and over, decreasing linearly with the logarithm of the mass at the rate of 4 EPNdB per halving of mass down to 89 EPNdB, after which the limit is constant to 8 618 kg, where it decreases linearly with the logarithm of the mass at a rate of 4 EPNdB per halving of mass down to 2 000 kg, after which the limit is constant.

b) *Aeroplanes with three engines*

As a) but with 104 EPNdB for aeroplanes with maximum certificated take-off mass of 385 000 kg and over.

c) *Aeroplanes with four engines or more*

As a) but with 106 EPNdB for aeroplanes with maximum certificated take-off mass of 385 000 kg and over.

14.4.1.3 *At the approach reference noise measurement point*

105 EPNdB for aeroplanes with maximum certificated take-off mass, at which the noise certification is requested, of 280 000 kg and over, decreasing linearly with the logarithm of the mass down to 98 EPNdB at 35 000 kg, after which the limit is constant to 8 618 kg, where it decreases linearly with the logarithm of the mass down to 93.1 EPNdB at 2 000 kg, after which the limit is constant.

14.4.1.4 The sum of the differences at all three measurement points between the maximum noise levels and the maximum permitted noise levels specified in 14.4.1.1, 14.4.1.2 and 14.4.1.3, shall not be less than 17 EPNdB.

14.4.1.5 The maximum noise level at each of the three measurement points shall not be less than 1 EPNdB below the corresponding maximum permitted noise level specified in 14.4.1.1, 14.4.1.2 and 14.4.1.3.

Note.— See Attachment A for equations for the calculation of maximum permitted noise levels as a function of take-off mass.

14.5 Noise certification reference procedures

The noise certification reference procedures shall be as specified in Chapter 3, 3.6.

14.6 Test procedures

The test procedures shall be as specified in Chapter 3, 3.7.

14.7 Recertification

For aeroplanes specified in 14.1.1 d), recertification shall be granted on the basis that the evidence used to determine compliance with Chapter 14 is as satisfactory as the evidence associated with aeroplanes specified in 14.1.1 a), b) and c).

. . .

End of new Chapter 14

See Work Item N.02.04

APPENDIX 1.

. . .

2.2 General test conditions

. . .

2.2.3 The tests shall be carried out under the following atmospheric conditions:

. . .

d) average wind not above ~~5~~ 5.1 m/s (10 kt) and average crosswind component not above ~~2.5~~ 2.6 m/s (5 kt) at 10 m (33 ft) above ground. A 30-second averaging period spanning the 10 dB-down time interval is recommended; and

. . .

3.3.6 A windscreen shall be employed with the microphone during all measurements of aeroplane noise when the wind speed is in excess of ~~11 km/h~~ 3 m/s (6 kt). Corrections for any insertion loss produced by the windscreen, as a function of frequency, shall be applied to the measured data and the corrections applied shall be reported.

. . .

See Work Item N.02.06

APPENDIX 2. EVALUATION METHOD FOR NOISE CERTIFICATION OF:

1.— SUBSONIC JET AEROPLANES — Application for Type Certificate submitted on or after 6 October 1977

2.— PROPELLER-DRIVEN AEROPLANES OVER 8 618 kg — Application for Type Certificate submitted on or after 1 January 1985

3.— HELICOPTERS

Note.— See Part II, Chapters 3, 4 ~~and~~, 8 and 14.

. . .

2.2.2.1 *Definitions and specifications*

For the purposes of noise certification in this section the following specifications apply:

. . .

Average wind speed shall be determined ... Pythagorean Theorem and ~~“arctan(u/v)”~~ “arctan(v/u)”.

Distance constant (or response length) is the passage of wind (in metres) required for the output of a wind speed sensor to indicate ~~100*(1-1/e)~~ $100\times(1-1/e)$ per cent (about 63 per cent) of a step-function increase of the input speed.

Maximum crosswind component. The maximum value within the series of individual values of the “cross track” (v) component of the wind samples recorded every second over a ~~period that spans the 10 dB-down time interval~~ time interval that spans the 10 dB-down period.

Maximum wind speed. The maximum value within the series of individual wind speed samples recorded every second over a ~~period that spans the 10 dB-down time interval~~ time interval that spans the 10 dB-down period.

. . .

Time constant (of a first order system) is the time required for a device to detect and indicate ~~100*(1-1/e)~~ $100\times(1-1/e)$ per cent (about 63 per cent) of a step function change. (The mathematical constant, e, is the base number of the natural logarithm, approximately 2.7183 – also known as Euler’s number, or Napier’s constant.)

Wind direction sample (at a certain moment) is the value obtained at that moment from a wind direction sensor/system with characteristics as follows:

Wind speed operating range:	1 m/s (2 kt) to more than 10 m/s (20 kt);
Linearity:	~~+/-~~ ± 5 degrees over the specified range; and
Resolution:	5 degrees.

. . .

Wind speed sample (at a certain moment) is the value measured at that moment for wind speed using a sensor/system with characteristics as follows:

Range:	1 m/s (2 kt) to more than 10 m/s (20 kt);
Linearity:	~~+/-~~ ± 0.5 m/s (± 1 kt) over the specified range; and

. . .

See Work Item N.02.04

2.2.2.4 *Test window*

2.2.2.4.1 For aircraft test runs to be acceptable, they shall be carried out under the following atmospheric conditions, except as provided in 2.2.2.4.2:

. . .

e) for aeroplanes the average wind speed at 10 m (33 ft) above the ground shall not exceed ~~6~~ 6.2 m/s (12 kt) and the maximum wind speed at 10 m (33 ft) above the ground shall not exceed ~~7.5~~ 7.7 m/s (15 kt);

f) for aeroplanes the average crosswind component at 10 m (33 ft) above the ground shall not exceed ~~3.5~~ 3.6 m/s (7 kt) and the maximum crosswind component at 10 m (33 ft) above the ground shall not exceed ~~5~~ 5.1 m/s (10 kt);

g) for helicopters the average wind speed at 10 m (33 ft) above the ground shall not exceed ~~5~~ 5.1 m/s (10 kt);

h) for helicopters the average crosswind component at 10 m (33 ft) above the ground shall not exceed ~~2.5~~ 2.6 m/s (5 kt); and

. . .

See Work Item N.02.06

3.7.6 The instant in time by which a SLOW time weighted sound pressure level is characterized shall be 0.75 seconds earlier than the actual readout time.

Note.— The definition of this instant in time is required to correlate the recorded noise with the aircraft position when the noise was emitted and takes into account the averaging period of the SLOW weighting. For each one-half second data record this instant in time may also be identified as 1.25 seconds after the start of the associated ~~2 seconds~~ 2-second averaging period.

. . .

See Work Item N.02.11

~~3.8 Calibration systems~~

~~The acoustical sensitivity of the measurement system shall be determined using a sound calibrator generating a known sound pressure level at a known frequency. The sound calibrator shall at least conform to the class 1L requirements of IEC 60942[3] as amended.~~

3.8 Calibration instrumentation

3.8.1 All instrumentation used for calibration and determination of corrections shall be approved by the certificating authority.

3.8.2 The sound calibrator shall at least conform to the class 1 requirements of IEC 609423. The sound pressure level produced in the cavity of the coupler of the sound calibrator shall be calculated for the test environmental conditions using the manufacturer's supplied information on the influence of atmospheric air pressure and temperature. The output of the sound calibrator shall be determined within six months of each aircraft noise measurement by a method traceable to a national standards laboratory. Tolerable changes in output from the previous calibration shall be not more than 0.2 dB.

3.8.3 If pink noise is used to determine the corrections for system frequency response in 3.9.7, then the output of the noise generator shall be determined within six months of each aircraft noise measurement by a method traceable to a national standards laboratory. Tolerable changes in the relative output from the previous calibration in each one-third octave band shall be not more than 0.2 dB.

Editorial note.— Delete paragraph 3.9 in toto and replace by the following new text:

3.9 Calibration and checking of system

3.9.1 Calibration and checking of the measurement system and its constituent components shall be carried out to the satisfaction of the certificating authority by the methods specified in 3.9.2 to 3.9.9. All calibration corrections and adjustments, including those for the environmental effects on sound calibrator output level, shall be reported to the certificating authority and applied to the measured one-third octave sound pressure levels determined from the output of the analyser. Aircraft noise data collected during an overload condition of any measurement system components in the signal path prior to and including the recorder are invalid and shall not be used. If the overload condition occurred during analysis or at a point in the signal path after the recorder, the analysis shall be repeated with reduced sensitivity to eliminate the overload.

3.9.2 The acoustical sensitivity of the measurement system shall be established using a sound calibrator generating a known sound pressure level at a known frequency. Sufficient sound pressure level calibrations shall be recorded during each test day to ensure that the acoustical sensitivity of the measurement system is known for the prevailing environmental conditions corresponding with each aircraft noise measurement. Measured aircraft noise data shall not be considered valid for certification purposes unless preceded and succeeded by valid sound pressure level calibrations. The measurement system shall be considered satisfactory if the difference between the acoustical sensitivity levels recorded immediately before and immediately after each group of aircraft noise measurements on a given day is not greater than 0.5 dB. The 0.5 dB limit applies after any atmospheric pressure corrections have been applied to the calibrator output level. The arithmetic mean of the preceding and succeeding calibrations shall be used to represent the acoustical sensitivity level of the measurement system for each group of aircraft noise measurements. The calibration corrections shall be reported to the certificating authority and applied to the measured one-third octave band sound pressure levels determined from the output of the analyser.

3.9.3 For analogue (direct or FM) magnetic tape recorders each volume of recording medium, such as a reel, cartridge, or cassette, shall carry a sound pressure level calibration of at least 10 seconds duration at its beginning and end.

3.9.4 The free-field frequency response of the microphone system may be determined by using an electrostatic actuator in combination with the manufacturer's data or by testing in an anechoic free-field facility. The corrections for frequency response shall be determined within 90 days of each aircraft noise measurement and shall be reported to the certificating authority. They shall be applied to the measured one-third octave band sound pressure levels determined from the output of the analyser.

3.9.5 When the angles of incidence at the microphone of sound emitted from the aircraft are within ±30º of grazing incidence (see Figure A2-1), a single set of free-field corrections based on grazing incidence is considered sufficient for the correction of directional response effects. Otherwise appropriate corrections for incidence effects shall be determined at the angle of incidence for each one-half second sample. Such corrections shall be reported to the certificating authority and applied to the measured one-third octave band sound pressure levels determined from the output of the analyser.

3.9.6 The free-field insertion effects of the windscreen for each one-third octave nominal midband frequency from 50 Hz to 10 kHz inclusive shall be determined with sinusoidal sound signals at appropriate incidence angles on the inserted microphone. For a windscreen which is undamaged and uncontaminated, the insertion effects may be taken from the manufacturer's data. In addition, the insertion effects of the windscreen may be determined within six months of each aircraft noise measurement by a method traceable to a national standards laboratory. Tolerable changes in the insertion effects from the previous calibration at each one-third octave frequency band shall be not more than 0.4 dB. The corrections for the free-field insertion effects of the windscreen shall be reported to the certificating authority and applied to the measured one-third octave sound pressure levels determined from the output of the analyser.

3.9.7 The frequency response of the entire measurement system, exclusive of the microphone and windscreen, but otherwise configured as deployed in the field during the aircraft noise measurements, shall be established. Corrections shall be determined for each one-third octave nominal midband frequency from 50 Hz to 10 kHz inclusive. The determination shall be made at a level within 5 dB of the level corresponding to the calibration sound pressure level on the reference level range, and shall utilize pink random or pseudo-random noise or alternatively discrete sine or swept sine signals. The corrections for frequency response shall be reported to the certificating authority and applied to the measured one-third octave sound pressure levels determined from the output of the analyser. If the system frequency response corrections are determined away from the field then frequency response testing shall be performed in the field to ensure the integrity of the measurement system.

3.9.8 For analogue (direct or FM) magnetic tape recorders, each volume of recording medium such as a reel, cartridge, or cassette shall carry at least 30 seconds of pink random or pseudo-random noise at its beginning and end. Aircraft noise data obtained from analogue tape-recorded signals shall be accepted as valid only if level differences in the 10 kHz one-third octave band are not more than 0.75 dB for the signals recorded at the beginning and end. For systems using analogue (direct or FM) magnetic tape recorders frequency response corrections shall be determined from pink noise recordings performed in the field during deployment for aircraft noise measurements.

3.9.9 The performance of switched attenuators in the equipment used during noise certification measurements and calibration shall be checked within six months of each aircraft noise measurement to ensure that the maximum error does not exceed 0.1 dB. The accuracy of gain-changes shall be tested or determined from manufacturers specifications to the satisfaction of the certificating authority.

End of new paragraph 3.9.

. . .

See Work Item N.02.06

4.2 Perceived noise level

. . .

Step 3. Convert the total perceived noisiness, N(k), into perceived noise level, PNL(k), by the following formula:

$$\text{PNL}(k) = 40.0 + \frac{10}{\log 2}\log N(k)$$

$$\text{PNL} = 40.0 + \frac{10}{\log 2}\log N(k)$$

. . .

4.7 Mathematical formulation of noy tables

. . .

4.7.3 The equations are as follows:

. . .

c) SPL(e) ≤ SPL < SPL(b)
$n = 0.3 \text{ antilog}_{10} \{M(e) [\text{SPL} - \text{SPL}(e)]\}$
$n = 0.3 \text{ antilog } \{M(e) [\text{SPL} - \text{SPL}(e)]\}$

. . .

See Work Item N.02.04

APPENDIX 3.

. . .

2.2 General test conditions

. . .

2.2.2 The tests shall be carried out under the following atmospheric conditions:

. . .

c) at 1.2 m (4 ft) above ground, instantaneous wind speed shall not exceed ~~5~~ 5.1 m/s (10 kt) and instantaneous crosswind speed shall not exceed ~~2.5~~ 2.6 m/s (5 kt). Flights shall be made in equal numbers with tailwind and headwind components; and

. . .

See Work Item N.02.06

4.2.3 Performance correction

. . .

4.2.3.2 The performance correction shall be calculated by using the following formula:

~~$$\Delta dB = 49.6 - 20 \log_{10} \left[(3\,500 - D_{15}) \frac{R/C}{V_y} + 15 \right]$$~~

$$\Delta \mathrm{dB} = 49.6 - 20 \log \left[(3\,500 - D_{15}) \frac{\mathrm{R/C}}{\mathrm{V}_y} + 15 \right]$$

. . .

See Work Item N.02.04

APPENDIX 4.

. . .

2.2.2 The tests shall be carried out under the following atmospheric conditions:

. . .

c) at a height between 1.2 m (4 ft) and 10 m (33 ft) above ground, average wind speed shall not exceed ~~5~~ 5.1 m/s (10 kt) and the average crosswind component shall not exceed ~~2.5~~ 2.6 m/s (5 kt); and

. . .

See Work Item N.02.06

3.3 The above integral can be approximated from periodically sampled measurement as:

$$L_{AE} = 10 \log \frac{1}{T_0} \sum_{k_F}^{k_L} 10^{0.1 L_A(k)} \Delta t$$

$$\mathrm{L}_{\mathrm{AE}} = 10 \log \frac{1}{T_0} \sum_{k_F}^{k_L} 10^{0.1 L_{\mathrm{A}}(k)} \Delta t$$

where $L_A(k)$ is the time varying A-frequency-weighted S-time-weighted sound level measured at the k^{th} k^{th} instant of time, k_F and k_L are the first and last increment of k, and Δt is the time increment between samples.

3.4 The integration time ($t2 - t1$) in practice shall not be less than the 10 dB-down time interval period during which $L_A(t)$ first rises to 10 dB(A) below its maximum value and last falls below 10 dB(A) of its maximum value.

. . .

4.3 Sensing, recording and reproducing equipment

. . .

4.3.2 The SEL may be directly determined from an integrating sound level meter. Alternatively, with the approval of the certificating authority the sound pressure signal produced by the helicopter may be stored on an analog analogue magnetic tape recorder or a digital audio recorder for later evaluation using an integrating sound level meter. The SEL may also be calculated from one-third octave band data obtained from measurements made in conformity with Section 3 of Appendix 2 and using the equation given in 3.3. In this case each one-third octave band sound pressure level shall be weighted in accordance with the A-weighting values given in IEC Publication 61672-1[1].

. . .

See Work Item N.02.11

~~4.3.4 The overall sensitivity of the measuring system shall be checked before tests start, after testing has ended, and at intervals during testing using a sound calibrator generating a known sound pressure level at a known frequency. The sound calibrator should conform to the class 1 requirements of IEC60942[2]. The output of the sound calibrator shall have been checked by a standardizing laboratory within 6 months of the test series; tolerable changes in output shall be not more than 0.2 dB. The equipment shall be considered satisfactory if the variation over the period immediately prior to and immediately following each test series within a given test day is not greater than 0.5 dB.~~

[1] IEC 61672-1: 2002 entitled “Electroacoustics – Sound level metres meters – Part I: Specifications”. This IEC publication may be obtained from the Bureau central de la Commission électrotechnique internationale, 3 rue de Varembé, Geneva, Switzerland.

~~*Note.— The certificating authority may approve the use of calibrators compliant with class 2 of the current IEC standard, or the use of calibrators compliant with class 1 of an earlier standard, if the applicant can show that the calibrator had previously been approved for noise certification use by a certificating authority.*~~

4.3.4 The overall sensitivity of the measurement system shall be checked before the start of testing, after testing has ended and at intervals during testing using a sound calibrator generating a known sound pressure level at a known frequency. The sound calibrator shall conform to the class 1 requirements of IEC 60942[1]. The output of the sound calibrator shall have been checked by a standardizing laboratory within 6 months of each aircraft noise measurement. Tolerable changes in output shall be not more than 0.2 dB. Measured aircraft noise data shall not be considered valid for certification purposes unless preceded and succeeded by valid sound pressure level calibrations. The measurement system shall be considered satisfactory if the difference between the acoustical sensitivity levels recorded immediately before and immediately after each group of aircraft noise measurements on a given day is not greater than 0.5 dB.

Note.—The certificating authority may approve the use of calibrators compliant with class 2 of the current IEC standard, or the use of calibrators compliant with class 1 of an earlier standard, if the applicant can show that the calibrator had previously been approved for noise certification use by a certificating authority.

. . .

See Work Item N.02.06

4.4.3 Where an ~~analog~~ analogue magnetic tape recorder forms part of the measuring chain, each reel of magnetic tape shall carry 30 s of this electrical calibration signal at its beginning and end for this purpose. In addition, data obtained from tape-recorded signals shall be accepted as reliable only if the level difference in the 10 kHz one-third octave band filtered levels of the two signals is not more than 0.75 dB.

. . .

5.2.2 The adjustments for spherical spreading and duration may be approximated from:

~~$\Delta_1 = 12.5 \log_{10} (H/150)$ dB~~

$$\Delta_1 = 12.5 \log (H/150) \text{ dB}$$

where H is the height, in metres, of the test helicopter when directly over the noise measurement point.

[1] IEC 60942: 2003 entitled "Electroacoustics – Sound calibrators". This IEC publication may be obtained from the Bureau central de la Commission électrotechnique internationale, 3 rue de Varembé, Geneva, Switzerland.

5.2.3 The adjustment for the difference between reference airspeed and adjusted reference airspeed is calculated from:

$$~~\Delta_2 = 10 \log_{10}\left(\frac{V_{ar}}{V_r}\right) dB~~$$

$$\Delta_2 = 10 \log\left(\frac{V_{ar}}{V_r}\right) dB$$

. . .

See Work Item N.02.04

APPENDIX 6.

. . .

2.2.2 The tests shall be carried out under the following atmospheric conditions:

. . .

c) average wind speed shall not exceed ~~5~~ 5.1 m/s (10 kt) and crosswind average wind speed shall not exceed ~~2.5~~ 2.6 m/s (5 kt);

. . .

See Work Item N.02.06

2.3.3 The flight test shall be conducted at V_y ± 9 km/h (V_y ± 5 kt) indicated airspeed.

. . .

4.3 Sensing, recording and reproducing equipment

. . .

See Work Item N.02.11

~~4.3.3 The overall sensitivity of the measuring system shall be checked before tests start, after testing has ended, and at intervals during testing using a sound calibrator generating a known sound pressure level at a known frequency. The sound calibrator should conform to the class 1 requirements of IEC 60942[2].~~

~~*Note.— The certificating authority may approve the use of calibrators compliant with the class 2 specifications of the current IEC standard, or the use of calibrators compliant with class 1 of an earlier standard, if the applicant can show that the calibrator had p reviously been approved for noise certification use by a certificating authority.*~~

4.3.3 The overall sensitivity of the measurement system shall be checked before the start of testing, after testing has ended, and at intervals during testing using a sound calibrator generating a known sound pressure level at a known frequency. The sound calibrator shall conform to the class 1 requirements of IEC 60942[1]. The output of the sound calibrator shall have been checked by a standardizing laboratory within 6 months of each aircraft noise measurement. Tolerable changes in output shall be not more than 0.2 dB. Measured aircraft noise data shall not be considered valid for certification purposes unless preceded and succeeded by valid sound pressure level calibrations. The measurement system shall be considered satisfactory if the difference between the acoustical sensitivity levels recorded immediately before and immediately after each group of aircraft noise measurements on a given day is not greater than 0.5 dB.

Note.—The certificating authority may approve the use of calibrators compliant with class 2 of the current IEC standard, or the use of calibrators compliant with class 1 of an earlier standard, if the applicant can show that the calibrator had previously been approved for noise certification use by a certificating authority.

See Work Item N.02.06

4.3.4 When the sound from the aeroplane is tape recorded, the maximum A-frequency-weighted and S-time-weighted sound level may be determined by playback of the recorded signals into the electrical input facility of an approved sound level meter that conforms to the class 1 performance requirements of ~~IEC 61672-1[3]~~ IEC 61672-1[2]. The acoustical sensitivity of the sound level meter shall be established from playback of the associated recording of the signal from the sound calibrator and knowledge of the sound pressure level produced in the coupler of the sound calibrator under the environmental conditions prevailing at the time of the recording of the sound from the aeroplane.

. . .

See Work Item N.02.06

4.4 Noise measurement procedures

. . .

4.4.3 Where a magnetic tape recorder forms part of the measuring chain, each reel of magnetic tape shall carry 30 s of this electrical calibration signal at its beginning and end for this purpose. In addition, data obtained from tape recorded signals shall be accepted as reliable only if the level difference in the 10 kHz one-third octave band filtered levels of the two signals is not more than 0.75 dB.

Note.— Digital audio recorders typically do not exhibit substantial variation in frequency response or level sensitivity, therefore the pink noise testing described in 4.4.3 is not necessary for digital audio recorders. Design characteristics for digital audio recorders should be compliant with class 1 performance specifications of ~~IEC 61672-1[4]~~ IEC 61672-1[3].

. . .

[1] IEC 60942: 2003 entitled "Electroacoustics – Sound calibrators". This IEC publication may be obtained from the Bureau central de la Commission électrotechnique internationale, 3 rue de Varembé, Geneva, Switzerland.

[2] IEC 61672-1: 2002 entitled "Electroacoustics – Sound level meters – Part I: Specifications". This IEC publication may be obtained from the Bureau central de la Commission électrotechnique internationale, 3 rue de Varembé, Geneva, Switzerland.

See Work Item N.02.17

ATTACHMENTS TO ANNEX 16, VOLUME I

ATTACHMENT A. EQUATIONS FOR THE CALCULATION OF MAXIMUM PERMITTED NOISE LEVELS AS A FUNCTION OF TAKE-OFF MASS

Note.— See Part II, 2.4.1, 2.4.2, 3.4.1, 4.4, 5.4, 6.3, 8.4.1, 8.4.2, 10.4, 11.4.1 ~~and~~, 11.4.2 and 14.4.1.

. . .

11. CONDITIONS DESCRIBED IN CHAPTER 11, 11.4.2

M = Maximum take-off mass in 1 000 kg	0	1.417	3.175
Noise level in dB SEL	82	80.49 + 9.97 log M	

12. CONDITIONS DESCRIBED IN CHAPTER 14, 14.4.1

<table>
<tr><th colspan="2">M = Maximum take-off mass in 1 000 kg</th><th>0</th><th>2</th><th>8.618</th><th>20.234</th><th>28.615</th><th>35</th><th>48.125</th><th>280</th><th>385</th><th>400</th></tr>
<tr><td colspan="2">Lateral full-power noise level (EPNdB)
All aeroplanes</td><td>88.6</td><td>86.03754 + 8.512295 log M</td><td colspan="3">94</td><td colspan="4">80.86511 + 8.50668 log M</td><td>103</td></tr>
<tr><td colspan="2">Approach noise level (EPNdB)
All aeroplanes</td><td>93.1</td><td>90.77481 + 7.72412 log M</td><td colspan="3">98</td><td colspan="2">86.03167 + 7.75117 log M</td><td colspan="3">105</td></tr>
<tr><td rowspan="3">Flyover noise levels (EPNdB)</td><td>2 engines or less</td><td rowspan="3">80.6</td><td rowspan="3">76.57059 + 13.28771 log M</td><td colspan="4">89</td><td colspan="2">66.64514 + 13.28771 log M</td><td colspan="2">101</td></tr>
<tr><td>3 engines</td><td colspan="2">89</td><td colspan="4">69.64514 + 13.28771 log M</td><td colspan="2">104</td></tr>
<tr><td>4 engines or more</td><td>89</td><td colspan="5">71.64514 + 13.28771 log M</td><td colspan="2">106</td></tr>
</table>

Note.— The slope of the limit lines in the lower and higher weight regions are essentially the same. The observed minor differences between the coefficients of the equations defining the slopes of the lateral and approach lines are a consequence of the limits in Chapter 14, Sections 14.4.1.1 and 14.4.1.3 being defined with fixed end points. For all practical purposes the minor differences between the coefficients are considered to be insignificant.

Each of the following conditions shall apply:

$(LIMIT_L - EPNL_L) \geq 1$; $(LIMIT_A - EPNL_A) \geq 1$; and $(LIMIT_F - EPNL_F) \geq 1$;

$[(LIMIT_L - EPNL_L) + (LIMIT_A - EPNL_A) + (LIMIT_F - EPNL_F)] \geq 17$

where

$EPNL_L$, $EPNL_A$ and $EPNL_F$ are respectively the noise levels at the lateral, approach and flyover reference noise measurement points when determined, to one decimal place, in accordance with the noise evaluation method of Appendix 2; and

$LIMIT_L$, $LIMIT_A$, and $LIMIT_F$ are respectively the maximum permitted noise levels at the lateral, approach and flyover reference noise measurement points determined, to one decimal place, in accordance with the equations for the conditions described in Chapter 14, 14.4.1.

See Work Item N.02.04

ATTACHMENT C.

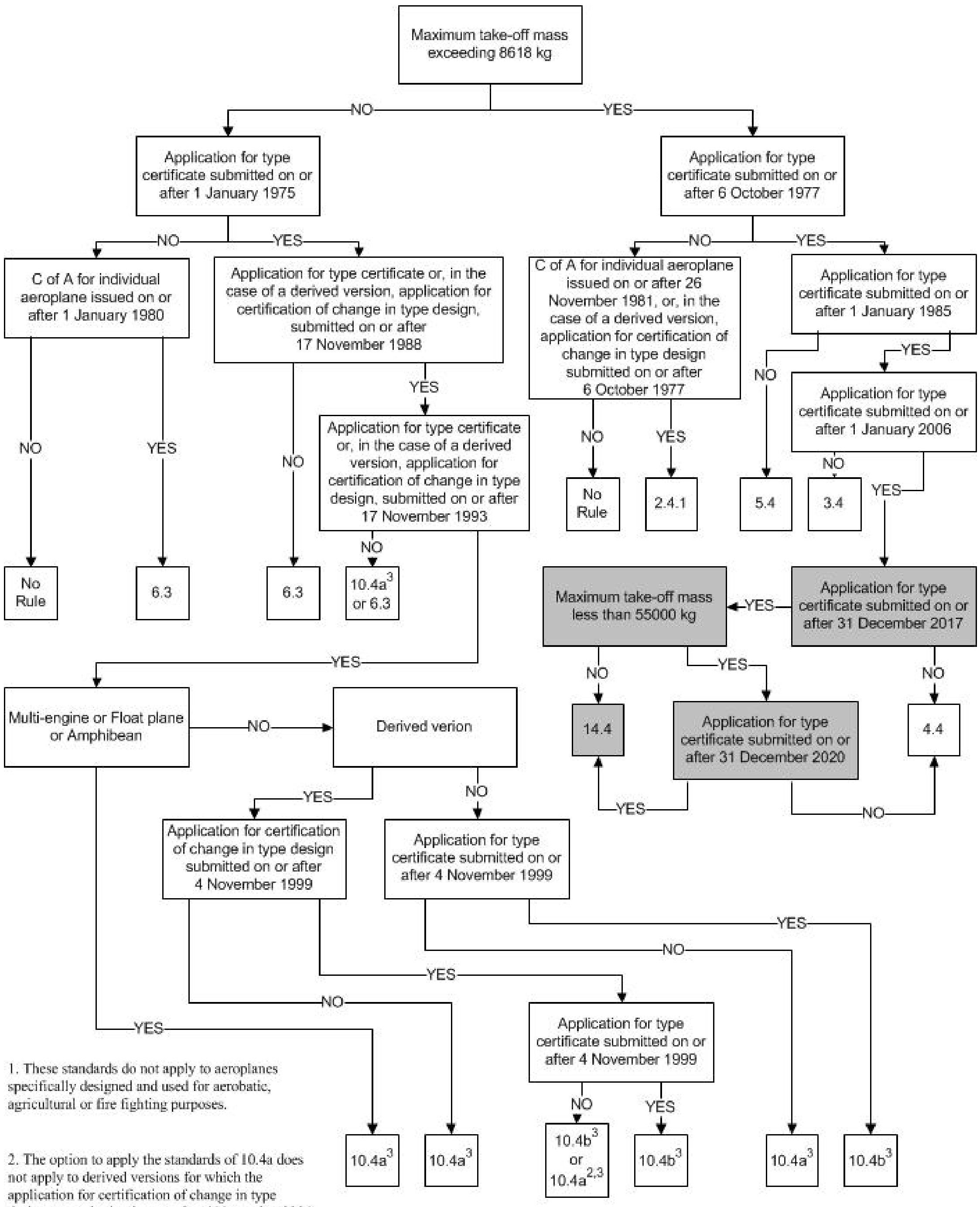
. . .

4.2.1 Meteorological conditions

Wind: not more than ~~5~~ 5.1 m/s (10 kt).

. . .

ATTACHMENT E. APPLICABILITY OF ANNEX 16 NOISE CERTIFICATION STANDARDS FOR PROPELLER-DRIVEN AEROPLANES[1]



1. These standards do not apply to aeroplanes specifically designed and used for aerobatic, agricultural or fire fighting purposes.

2. The option to apply the standards of 10.4a does not apply to derived versions for which the application for certification of change in type design was submitted on or after 4 November 2004.

3. These standards do not apply to self-sustaining powered sailplanes.

See Work Item N.02.06

ATTACHMENT G. GUIDELINES FOR THE ADMINISTRATION OF NOISE CERTIFICATION DOCUMENTATION

. . .

2. NOISE CERTIFICATION DOCUMENTATION

2.1 Information to be provided

. . .

2.1.11 *Item 10. Maximum landing mass and unit for certificates issued under Chapters 2, 3, 4, 5 ~~and~~, 12 and 14*

The maximum landing mass, in kilograms, associated with the certificated noise levels of the aircraft. The unit (kg) should be specified explicitly in order to avoid misunderstanding. If the primary unit of mass of the State of Design of the aircraft is different from kilograms, the conversion factor used should be in accordance with Annex 5. This item is included only in the noise certification documentation for documents issued under Chapters 2, 3, 4, 5 ~~and~~, 12 and 14.

. . .

2.1.14 *Item 13. The lateral/full-power noise level in the corresponding unit for documents issued under Chapters 2, 3, 4, 5 ~~and~~, 12 and 14*

The lateral/full-power noise level as defined in the relevant chapter. It should specify the unit (e.g. EPNdB) of the noise level, and the noise level should be stated to the nearest tenth of a dB. This item is included only in the noise certification documentation for aircraft certificated to Chapters 2, 3, 4, 5 ~~and~~, 12 and 14.

2.1.15 *Item 14. The approach noise level in the corresponding unit for documents issued under Chapters 2, 3, 4, 5, 8 ~~and~~, 12 and 14*

The approach noise level as defined in the relevant chapter. It should specify the unit (e.g. EPNdB) of the noise level, and the noise level should be stated to the nearest tenth of a dB. This item is included only in the noise certification documentation for aircraft certificated to Chapters 2, 3, 4, 5, 8 ~~and~~, 12 and 14.

2.1.16 *Item 15. The flyover noise level in the corresponding unit for documents issued under Chapters 2, 3, 4, 5 ~~and~~, 12 and 14*

The flyover noise level as defined in the relevant chapter. It should specify the unit (e.g. EPNdB) of the noise level, and the noise level should be stated to the nearest tenth of a dB. This item is included only in the noise certification documentation for aircraft certificated to Chapters 2, 3, 4, 5 ~~and~~, 12 and 14.

. . .

ATTACHMENT H. GUIDELINES FOR OBTAINING HELICOPTER NOISE DATA FOR LAND-USE PLANNING PURPOSES

. . .

3.1 All data provided for land-use planning purposes should be submitted to the ~~certification~~ certificating authority for approval. The approved data and the corresponding flight procedures should be presented as supplementary information in the helicopter flight manual.

. . .

— — — — — — — —

APPENDIX B

PROPOSED AMENDMENT OF THE ENVIRONMENTAL TECHNICAL MANUAL (VOL. I)

The text of the amendment is arranged to show deleted text with a line through it and new text highlighted with grey shading, as shown below:

1.	~~Text to be deleted is shown with a line through it.~~	text to be deleted
2.	New text to be inserted is highlighted with grey shading.	new text to be inserted
3.	~~Text to be deleted is shown with a line through it~~ followed by the replacement text which is highlighted with grey shading.	new text to replace existing text

TEXT OF PROPOSED AMENDMENT OF THE ENVIRONMENTAL TECHNICAL MANUAL (VOL. I)

FOREWORD

This revision of Doc. 9501, Volume I, First Edition, includes material which has been approved by the ICAO Committee on Aviation Environmental Protection (CAEP) Steering Group during their third meeting of the CAEP/9 cycle in July 2012. This revision is intended to make the most recent information available to certificating authorities, noise certification applicants and other interested parties in a timely manner, aiming at achieving the highest degree of harmonisation possible. The technical procedures and equivalent procedures described in this Steering Group approved revision of the ETM are consistent with currently accepted techniques and modern instrumentation. In this respect this Steering Group approved revision of the ETM is compatible with Amendment 10 of Annex 16, Volume I and the changes endorsed by the CAEP Steering Group for Amendment 11 of Annex 16, Volume I. This revision and subsequent revisions that may be approved by the CAEP Steering Group will be posted on the ICAO website (http://www.icao.int/) under “publications” until the latest approved revision is submitted to CAEP for formal endorsement and subsequent publication by ICAO.

— — — — — — — —

APPENDIX C

PROPOSED AMENDMENT TO ANNEX 16, VOLUME I

The text of the amendment is arranged to show deleted text with a line through it and new text highlighted with grey shading, as shown below:

1. ~~Text to be deleted is shown with a line through it.~~	text to be deleted
2. New text to be inserted is highlighted with grey shading.	new text to be inserted
3. ~~Text to be deleted is shown with a line through it~~ followed by the replacement text which is highlighted with grey shading.	new text to replace existing text

PROPOSED AMENDMENT TO

ANNEX 16
TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME I
AIRCRAFT NOISE

. . .

PART I. DEFINITIONS

. . .

Powered-lift. A heavier-than-air aircraft capable of vertical take-off, vertical landing, and low-speed flight, which depends principally on engine-driven lift devices or engine thrust for the lift during these flight regimes and on non-rotating aerofoil(s) for lift during horizontal flight.

. . .

Tilt-rotor. A powered-lift capable of vertical take-off, vertical landing, and sustained low-speed flight, which depends principally on engine-driven rotors mounted on tiltable nacelles for the lift during these flight regimes and on non-rotating aerofoil(s) for lift during high-speed flight.

. . .

PART II. AIRCRAFT NOISE CERTIFICATION

CHAPTER 1. ADMINISTRATION

1.1 The provisions of 1.2 to 1.6 shall apply to all aircraft included in the classifications defined for noise certification purposes in Chapters 2, 3, 4, 5, 6, 8, 10, 11 ~~and~~, 12, 13 and 14 of this part where such aircraft are engaged in international air navigation.

. . .

1.5 The documents attesting noise certification for an aircraft shall provide at least the following information:

. . .

Item 14. The approach noise level in the corresponding unit for documents issued under Chapters 2, 3, 4, 5, 8 ~~and~~, 12, 13 and 14 of this Annex.

. . .

Item 16. The overflight noise level in the corresponding unit for documents issued under Chapters 6, 8 ~~and~~, 11 and 13 of this Annex.

Item 17. The take-off noise level in the corresponding unit for documents issued under Chapters 8 ~~and~~, 10 and 13 of this Annex.

. . .

~~ATTACHMENT F. GUIDELINES FOR NOISE CERTIFICATION OF~~ CHAPTER 13. TILT-ROTOR AIRCRAFT

~~*Note.— See Part II, Chapter 13.*~~

~~*Note 1.— These guidelines are applicable to heavier-than-air aircraft that can be supported in flight chiefly by the reactions of the air on two or more power-driven rotors on axes which can be changed from substantially vertical to horizontal.*~~

Note ~~2~~ 1.— These ~~guidelines~~ Standards are not intended to be used for tilt-rotor aircraft that have one or more configurations that are certificated for airworthiness for STOL only. In such cases, different or additional ~~guidelines~~ procedures/conditions would likely be needed.

~~1.~~ 13.1 APPLICABILITY

Note. — See also Chapter 1, 1.10, 1.11, 1.12 and 1.13.

13.1.1 ~~The following guidelines should be applied~~ The Standards of this chapter shall be applicable to all tilt-rotor aircraft, including their derived versions, for which the application for a Type Certificate was submitted on or after 13 May 1998.

~~*Note.—*~~ 13.1.2 Certification of tilt-rotor aircraft which are capable of carrying external loads or external equipment ~~should~~ shall be made without such loads or equipment fitted.

~~2.~~ 13.2 NOISE EVALUATION MEASURE

The noise evaluation measure ~~should~~ shall be the effective perceived noise level in EPNdB as described in Appendix 2 of this Annex. The correction for spectral irregularities shall start at 50 Hz (see 4.3.1 of Appendix 2).

Note.— Additional data in SEL and L_{Amax} as defined in Appendix 4, and one-third octave SPLs as defined in Appendix 2 corresponding to L_{Amax} should be made available to the certificating authority for land-use planning purposes.

~~3.~~ 13.3 NOISE MEASUREMENT REFERENCE POINTS

A tilt-rotor aircraft, when tested in accordance with the reference procedures of Section 6 and the test procedures of Section 7, ~~should~~ shall not exceed the noise levels specified in ~~Section 4~~ 13.4 at the following reference points:

a) *Take-off reference noise measurement points*:

1) a flight path reference point located on the ground vertically below the flight path defined in the take-off reference procedure (see 13.6.2) and 500 m (1 640 ft) horizontally in the direction of flight from the point at which transition to climbing flight is initiated in the reference procedure;

2) two other points on the ground symmetrically disposed at 150 m (492 ft) on both sides of the flight path defined in the take-off reference procedure and lying on a line through the flight path reference point.

b) *Overflight reference noise measurement points*:

1) a flight path reference point located on the ground 150 m (492 ft) vertically below the flight path defined in the overflight reference procedure (see 13.6.3);

2) two other points on the ground symmetrically disposed at 150 m (492 ft) on both sides of the flight path defined in the overflight reference procedure and lying on a line through the flight path reference point.

c) *Approach reference noise measurement points*:

1) a flight path reference point located on the ground 120 m (394 ft) vertically below the flight path defined in the approach reference procedure (see 13.6.4). On level ground, this corresponds to a position 1 140 m (3 740 ft) from the intersection of the ~~6.0 degree~~ 6.0° approach path with the ground plane;

2) two other points on the ground symmetrically disposed at 150 m (492 ft) on both sides of the flight path defined in the approach reference procedure and lying on a line through the flight path reference point.

~~4.~~ 13.4 MAXIMUM NOISE LEVELS

13.4.1 For tilt-rotor aircraft specified in ~~Section 1~~ 13.1, the maximum noise levels, when determined in accordance with the noise evaluation method of Appendix 2 for helicopters, ~~should~~ shall not exceed the following:

~~a) *At the take-off flight path reference point:*~~

13.4.1.1 *For take-off*: 109 EPNdB for tilt-rotor aircraft in VTOL/conversion mode with maximum certificated take-off mass, at which the noise certification is requested, of 80 000 kg and over and decreasing linearly with the logarithm of the tilt-rotor aircraft mass at a rate of 3 EPNdB per halving of mass down to 89 EPNdB after which the limit is constant.

~~b) *At the overflight path reference point*:~~

13.4.1.2 *For overflight*: 108 EPNdB for tilt-rotor aircraft in VTOL/conversion mode with maximum certificated take-off mass, at which the noise certification is requested, of 80 000 kg and over and decreasing linearly with the logarithm of the tilt-rotor aircraft mass at a rate of 3 EPNdB per halving of mass down to 88 EPNdB after which the limit is constant.

Note 1.— For the tilt-rotor aircraft in aeroplane mode, there is no maximum noise level.

Note 2.— VTOL/conversion mode is all approved configurations and flight modes where the design operating rotor speed is that used for hover operations.

~~c) *At the approach flight path reference point*:~~

13.4.1.3 *For approach:* 110 EPNdB for tilt-rotor aircraft in VTOL/conversion mode with maximum certificated take-off mass, at which the noise certification is requested, of 80 000 kg and over and decreasing linearly with the logarithm of the tilt-rotor aircraft mass at a rate of 3 EPNdB per halving of mass down to 90 EPNdB after which the limit is constant.

Note.— The equations for the calculation of noise levels as a function of take-off mass presented in Section ~~8~~ 7 of Attachment A, for Conditions Described in Chapter 8, 8.4.1 are consistent with the maximum noise levels defined in ~~these guidelines~~ 13.4.

~~5.~~ 13.5 TRADE-OFFS

If the maximum noise levels are exceeded at one or two measurement points:

a) the sum of excesses ~~should~~ shall not be greater than 4 EPNdB;

b) any excess at any single point ~~should~~ shall not be greater than 3 EPNdB; and

c) any excess ~~should~~ shall be offset by corresponding reductions at the other point or points.

~~6.~~ 13.6 NOISE CERTIFICATION REFERENCE PROCEDURES

13.6.1 General conditions

13.6.1.1 The reference procedures ~~should~~ shall comply with the appropriate airworthiness requirements.

13.6.1.2 The reference procedures and flight paths ~~should~~ shall be approved by the certificating authority.

13.6.1.3 Except in conditions specified in 13.6.1.4, the take-off, overflight and approach reference procedures ~~should~~ shall be those defined in 13.6.2, 13.6.3 and 13.6.4, respectively.

13.6.1.4 When it is shown by the applicant that the design characteristics of the tilt-rotor aircraft would prevent a flight from being conducted in accordance with 13.6.2, 13.6.3 or 13.6.4, the reference procedures ~~should~~ shall:

a) depart from the reference procedures defined in 13.6.2, 13.6.3 or 13.6.4 only to the extent demanded by those design characteristics which make compliance with the reference procedures impossible; and

b) be approved by the certificating authority.

13.6.1.5 The reference procedures ~~should~~ shall be established for the following reference atmospheric conditions:

a) sea level atmospheric pressure of 1 013.25 hPa;

b) ambient air temperature of 25°C, i.e. ISA + 10°C;

c) relative humidity of 70 per cent; and

d) zero wind.

13.6.1.6 In 13.6.2 d), 13.6.3 d) and 13.6.4 c), the maximum normal operating rpm ~~should~~ shall be taken as the highest rotor speed for each reference procedure corresponding to the airworthiness limit imposed by the manufacturer and approved by the certificating authority. Where a tolerance on the highest rotor speed is specified, the maximum normal operating rotor speed ~~should~~ shall be taken as the highest rotor speed about which that tolerance is given. If the rotor speed is automatically linked with the flight condition, the maximum normal operating rotor speed corresponding with the reference flight condition ~~should~~ shall be used during the noise certification procedure. If the rotor speed can be changed by pilot action, the maximum normal operating rotor speed specified in the flight manual limitation section for the reference conditions ~~should~~ shall be used during the noise certification procedure.

13.6.2 Take-off reference procedure

The take-off reference flight procedure ~~should~~ shall be established as follows:

a) a constant take-off configuration, including nacelle angle, selected by the applicant ~~should~~ shall be maintained throughout the take-off reference procedure;

b) the tilt-rotor aircraft ~~should~~ shall be stabilized at the maximum take-off power corresponding to minimum installed engine(s) specification power available for the reference ambient conditions or gearbox torque limit, whichever is lower, and along a path starting from a point located 500 m (1 640 ft) prior to the flight path reference point, at 20 m (65 ft) above the ground;

c) the nacelle angle and the corresponding best rate of climb speed, or the lowest approved speed for the climb after take-off, whichever is the greater, ~~should~~ shall be maintained throughout the take-off reference procedure;

d) the steady climb ~~should~~ shall be made with the rotor speed stabilized at the maximum normal operating rpm certificated for take-off;

e) the mass of the tilt-rotor aircraft ~~should~~ shall be the maximum take-off mass at which noise certification is requested; and

f) the reference take-off path is defined as a straight line segment inclined from the starting point (500 m (1 640 ft) prior to the centre noise measurement point and 20 m (65 ft) above ground level) at an angle defined by best rate of climb (BRC) and the best rate of climb speed corresponding to the selected nacelle angle and for minimum specification engine performance.

13.6.3 Overflight reference procedure

13.6.3.1 The overflight reference procedure ~~should~~ shall be established as follows:

a) the tilt-rotor aircraft ~~should~~ shall be stabilized in level flight overhead the flight path reference point at a height of 150 m (492 ft);

b) a constant configuration selected by the applicant ~~should~~ shall be maintained throughout the overflight reference procedures;

c) the mass of the tilt-rotor aircraft ~~should~~ shall be the maximum take-off mass at which noise certification is requested;

d) in the VTOL/conversion mode, the nacelle angle at the authorized fixed operation point that is closest to the lowest nacelle angle certificated for zero airspeed, a speed of $0.9V_{CON}$ and a rotor speed stabilized at the maximum normal operating rpm certificated for level flight ~~should~~ shall be maintained throughout the overflight reference procedure;

Note.— For noise certification purposes, V_{CON} is defined as the maximum authorized speed for VTOL/conversion mode at a specific nacelle angle.

e) in the aeroplane mode, the nacelles ~~should~~ shall be maintained on the down-stop throughout the overflight reference procedure, with:

1) rotor speed stabilized at the rpm associated with the VTOL/conversion mode and a speed of $0.9V_{CON}$; and

2) rotor speed stabilized at the normal cruise rpm associated with the aeroplane mode and at the corresponding $0.9V_{MCP}$ or $0.9V_{MO}$, whichever is lesser, certificated for level flight.

Note ~~1~~.— For noise certification purposes, V_{MCP} is defined as the maximum operating limit airspeed for aeroplane mode corresponding to minimum engine installed, maximum continuous power (MCP) available for sea level pressure (1 013.25 hPa), 25°C (77°F) ambient conditions at the relevant maximum certificated mass; and V_{MO} is the maximum operating (MO) limit airspeed that may not be deliberately exceeded.

~~*Note 2.—*~~ 13.6.3.2 The values of V_{CON} and V_{MCP} or V_{MO} used for noise certification ~~should~~ shall be quoted in the approved flight manual.

13.6.4 Approach reference procedure

The approach reference procedure ~~should~~ shall be established as follows:

a) the tilt-rotor aircraft ~~should~~ shall be stabilized and follow a ~~6.0 degree~~ 6.0° approach path;

b) the approach ~~should~~ shall be in an airworthiness approved configuration in which maximum noise occurs, at a stabilized airspeed equal to the best rate of climb speed corresponding to the nacelle angle, or the lowest approved airspeed for the approach, whichever is the greater, and with power stabilized during the approach and over the flight path reference point, and continued to a normal touchdown;

c) the approach ~~should~~ shall be made with the rotor speed stabilized at the maximum normal operating rpm certificated for approach;

d) the constant approach configuration used in airworthiness certification tests, with the landing gear extended, ~~should~~ shall be maintained throughout the approach reference procedure; and

e) the mass of the tilt-rotor aircraft at touchdown ~~should~~ shall be the maximum landing mass at which noise certification is requested.

~~7.~~ 13.7 TEST PROCEDURES

13.7.1 The test procedures ~~should~~ shall be acceptable to the airworthiness and noise certificating authority of the State issuing the certificate.

137.2 The test procedures and noise measurements ~~should~~ shall be conducted and processed in an approved manner to yield the noise evaluation measure designated in ~~Section 2~~ 13.2.

13.7.3 Test conditions and procedures ~~should~~ shall be similar to reference conditions and procedures or the acoustic data ~~should~~ shall be adjusted, by the methods outlined in Appendix 2 for helicopters, to the reference conditions and procedures specified in this attachment.

13.7.4 Adjustments for differences between test and reference flight procedures ~~should~~ shall not exceed:

a) ~~for take-off~~ *for take-off:* 4.0 EPNdB, of which the arithmetic sum of ~~delta 1~~ Δ1 and the term −7.5 log ~~(QK/Q_rK_r)~~ QK/Q_rK_r from ~~delta 2 should~~ Δ2 shall not in total exceed 2.0 EPNdB; and

b) ~~for overflight or approach~~ *for overflight or approach:* 2.0 EPNdB.

13.7.5 During the test the average rotor rpm ~~should~~ shall not vary from the normal maximum operating rpm by more than ±1.0 per cent ~~during~~ throughout the 10 dB-down ~~time~~ period.

13.7.6 The tilt-rotor aircraft airspeed ~~should~~ shall not vary from the reference airspeed appropriate to the flight demonstration by more than ±9 km/h (±5 kt) throughout the 10 dB-down ~~time~~ period.

13.7.7 The number of level overflights made with a headwind component ~~should~~ shall be equal to the number of level overflights made with a tailwind component.

13.7.8 The tilt-rotor aircraft ~~should~~ shall fly within ~~±10 degrees~~ ±10° or ±20 m (±65 ft), whichever is greater, from the vertical above the reference track throughout the 10 dB-down ~~time~~ period (see Figure 8-1 ~~of Part II, Chapter 8~~).

13.7.9 The tilt-rotor aircraft height ~~should~~ shall not vary during overflight from the reference height ~~at the overhead point~~ throughout the 10 dB-down period by more than ±9 m (±30 ft).

13.7.10 During the approach noise demonstration the tilt-rotor aircraft ~~should~~ shall be established on a stabilized constant speed approach within the airspace contained between approach angles of ~~5.5 degrees~~ 5.5° and ~~6.5 degrees~~ 6.5° throughout the 10 dB-down period.

13.7.11 Tests ~~should~~ shall be conducted at a tilt-rotor aircraft mass not less than 90 per cent of the relevant maximum certificated mass and may be conducted at a mass not exceeding 105 per cent of the relevant maximum certificated mass. For each of the flight conditions, at least one test must be completed at or above this maximum certificated mass.

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APPENDIX 2. EVALUATION METHOD FOR NOISE CERTIFICATION OF:

1.— SUBSONIC JET AEROPLANES — Application for Type Certificate submitted on or after 6 October 1977

2.— PROPELLER-DRIVEN AEROPLANES OVER 8 618 kg — Application for Type Certificate submitted on or after 1 January 1985

3.— HELICOPTERS

4.— TILT-ROTORS

Note.— See Part II, Chapters 3, 4 ~~and~~, 8, 13 and 14.

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ATTACHMENT A. EQUATIONS FOR THE CALCULATION OF MAXIMUM PERMITTED NOISE LEVELS AS A FUNCTION OF TAKE-OFF MASS

Note.— See Part II, 2.4.1, 2.4.2, 3.4.1, 4.4, 5.4, 6.3, 8.4.1, 8.4.2, 10.4, 11.4.1 and 11.4.2 ,13.4 and 14.4.1.

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7. CONDITIONS DESCRIBED IN CHAPTER 8, 8.4.1 AND CHAPTER 13, 13.4

M = Maximum take-off mass in 1 000 kg	0	0.788	80.0
Take-off noise level (EPNdB)	89	90.03 + 9.97 log M	109
Approach noise level (EPNdB)	90	91.03 + 9.97 log M	110
Overflight noise level (EPNdB)	88	89.03 + 9.97 log M	108

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ATTACHMENT F. GUIDELINES FOR NOISE CERTIFICATION OF TILT-ROTOR AIRCRAFT

Note.— See Part II, Chapter 13.

[Reserved]

Editorial note.— Delete the remainder of Attachment F.

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ATTACHMENT G. GUIDELINES FOR THE ADMINISTRATION OF NOISE CERTIFICATION DOCUMENTATION

Note.— See Part II, Chapter 1.

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2. NOISE CERTIFICATION DOCUMENTATION

2.1 Information to be provided

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2.1.15 *Item 14. The approach noise level in the corresponding unit for documents issued under Chapters 2, 3, 4, 5, 8 ~~and~~, 12, 13 and 14*

The approach noise level as defined in the relevant chapter. It should specify the unit (e.g. EPNdB) of the noise level, and the noise level should be stated to the nearest tenth of a dB. This item is included only in the noise certification documentation for aircraft certificated to Chapters 2, 3, 4, 5, 8 ~~and~~, 12, 13 and 14.

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2.1.17 *Item 16. The overflight noise level in the corresponding unit for documents issued under Chapters 6, 8 ~~and~~, 11 and 13*

The overflight noise level as defined in the relevant chapter. It should specify the unit (e.g. EPNdB or dB(A)) of the noise level, and the noise level should be stated to the nearest tenth of a dB. This item is included only in the noise certification documentation for aircraft certificated to Chapters 6, 8 ~~and~~, 11 and 13.

Note.— For tilt-rotor aircraft certificated according to Chapter 13 only the overflight noise level established in VTOL/conversion mode need be stated.

2.1.18 *Item 17. The take-off noise level in the corresponding unit for documents issued under Chapters 8 ~~and~~, 10 and 13*

The take-off noise level as defined in the relevant chapter. It should specify the unit (e.g. EPNdB or dB(A)) of the noise level, and the noise level should be stated to the nearest tenth of a dB. This item is included only in the noise certification documentation for aircraft certificated to Chapters 8 ~~and~~, 10 and 13.

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Agenda Item 4: Alternative Fuels

4.1 ICAO ACTIVITIES RELATED TO SUSTAINABLE ALTERNATIVE FUELS

4.1.1 The Secretariat has continued its efforts to promote and further facilitate the development and deployment of sustainable alternative fuels for aviation, through the convening of the ICAO Aviation and Sustainable Alternative Fuels (SUSTAF) Workshop in October 2011. A summary of this workshop is available from www.icao.int/sustaf.

4.1.2 Building on the outcomes of the SUSTAF Workshop in 2011 and on the discussions of the 194th Session of the ICAO Council, the Sustainable Alternative Fuels for Aviation Expert Group (SUSTAF) was established in June 2012 to develop recommendations to further facilitate the global development and deployment of sustainable alternative fuels for aviation.

4.1.3 With the target to present its recommendations at the 38th Session of the Assembly after approval by the Council, the experts group has focused its work on a nalysing the possible options to overcome the near-term challenges attendant to the deployment of sustainable alternative fuels in aviation. In particular economics aspects and sustainability were considered. In its analysis, the group aimed at building on the existing background, practices and initiatives in order to evidence guidance for States and stakeholders.

4.1.4 In the course of its work, the group developed an intermediate report, presented to CAEP for information and comments, with its preliminary findings and recommendations. Among the main outcomes, the group agreed that creating a long-term stable market perspective is critical in order to attract investments in the production of alternative fuels for aviation. In addition, support for research in processes technology and feedstock production is needed in order to decrease production cost and achieve price parity with conventional jet fuel. The group also agreed that it is fundamental to ensure that alternative aviation fuels are produced and used in a sustainable way. Therefore, the group encourages States to develop policies that create a long-term stable market perspective and that ensure aviation biofuel sustainability. The latter should be based on principles and approaches already developed for bioenergy and transportation biofuels. Additional measures and works under ICAO are also recommended. Last, the group agreed that increasing harmonization or interoperability of regional policies would be an asset.

4.1.5 The group will continue its work up to the 38th Session of the ICAO Assembly, where its conclusions and recommendations will be presented and where future directions for work on sustainable alternative fuels will be defined by Member States.

Discussion and conclusions

4.1.6 The meeting congratulated ICAO for its substantial work on sustainable alternative fuels for aviation. The initiatives undertaken by ICAO since the 2009 Conference on Aviation and Alternative Fuels were found to be valuable. The meeting recognised the work achieved by the SUSTAF group in a short period of time and the substantial information gathered in the paper. The meeting also had particular appreciation for the facilitation of information exchange through workshops and the Global Framework for Aviation Alternative Fuels. Many Sates expressed the importance of alternative fuels for their country and the meeting expressed its general support to the continuation of ICAO's effort to facilitate the development and deployment of alternative fuels.

4.1.7 The meeting noted that interest is growing rapidly in alternative fuels and identified many connections to related activities that ICAO should support, including action plans on CO_2 emissions reductions, support to States, and dissemination of information and best practices. In addition, MDG and WG3 require technical input on alternative fuels, which could be facilitated in the future through ICAO.

4.1.8 **A Member's View on Sustainable Alternative Fuels for Aviation and the Role of CAEP**

4.1.8.1 In general, a member supported the work put in by the SUSTAF Group to prepare the report summarised in section 4.1, but the member also noted that the work could have benefited from an improved process with clearer objectives and deliverables. The member noted her resource constraints, along with the resource constraints of others, and emphasized the need to prioritize limited resources toward efforts that could provide the most value. She noted that she would be reluctant to devote resources to this type of effort in the future without clearer objectives and greater potential benefits. In terms of future work on the subject, the member was supportive of ICAO's role in information sharing and technical work to assess potential emissions benefits of alternative aviation fuels She recommended that any future technical work should be conducted under the auspices of CAEP in order to more efficiently manage the process with appropriate levels of expertise, resources, and coordination.

4.1.9 A member presented the considerable efforts which are underway within the United States to advance the development and deployment of sustainable alternative drop-in jet fuels. To support the ASTM certification process, the member and its industry partners are conducting testing of drop-in alternative jet fuels covering the development of bio-based aromatics, of biofuel from oligomerization of alcohols as well as catalytic conversion of sugars. A "bottom up" projection of the potential production of alternative aviation (jet) fuels in North America[1] was conducted showing that the production could to be between 2.5 billion gallons per year (BGY) and 9 BGY by 2020. For some sets of assumptions, this could allow the U.S. to meet its 2020 carbon neutral growth from a 2005 baseline goal. In addition an analysis of the long-term technical potential for alternative jet fuels from lignocellulose and algae feedstocks showed the potential to supply many multiples of the current worldwide demand for jet fuel. The Environment Team of CAAFI has developed environmental sustainability guidance and an environmental progression for alternative jet fuels to support fuel producers to evaluate sustainability. Research within the PARTNER Center of Excellence and the CLEEN program also confirmed that with appropriate technologies, a 66-90% reduction in life cycle GHG emissions was possible with algae, while freshwater use can be similar to today's petroleum-based jet fuel. Cost analysis showed that the use of a rotation crop, grown on otherwise fallow land, has the potential to achieve the U.S. goal of a cost below US$4.00 per gallon of HEFA fuel without subsidies. To advance the development and deployment of alternative jet fuels, the member supports CAAFI, a public-private coalition and collaborates internationally at ICAO and also via formal and informal bilateral partnerships. As a conclusion, it was underlined that, without the tools and conditions needed for the price competitiveness, the degree of market penetration suggested by the bottom up projection will not happen and the potential production of alternative jet fuel will not be realized.

Discussion and conclusions

4.1.9.1 The meeting noted that as alternative fuels for aviation are relatively new, all involved are experiencing a steep learning curve and that the related discussions in ICAO and within CAEP are very important.

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[1] Comprising the United States, Canada and Mexico. The analyses also considered European production potential to a more limited extent

4.1.9.2 An observer explained that the development and deployment of sustainable alternative fuels is a priority in his region with a plan to deliver 2 million tonnes of sustainably-product alternative fuels for aviation by 2020.

4.1.9.3 An observer noted the need for States to create favourable political and legislative conditions for large-scale development and production of alternative fuels. The observer also noted issues related to alternative fuels that are particularly apt for international coordination, such as sustainability standards. The observer noted the substantial role ICAO can play in facilitation and information exchange in the field of alternative fuels

4.1.9.4 The meeting agreed that CAEP should stay focused on the technical aspects of alternative fuels and not become involved in political discussions. Information sharing on alternative fuels is the key to facilitating their development and deployment and the Secretariat had a clear role in that area. The meeting urged States to share their initiatives in this field through their action plans and other means. The meeting, also noting the scarce resources available in this subject area to the CAEP work, urged that ICAO activities complement those underway in other fora. The meeting expressed significant support for refining the CAEP trends assessment to include improved estimates of the effects of alternative fuels on global aviation CO_2 trends. Again noting resource limitations, the meeting agreed that proposed tasks should be properly scoped before initiating work on them.

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Agenda Item 5: Future work

5.1 ADMINISTRATIVE

5.1.1 Participation in CAEP meetings

5.1.1.1 The CAEP Secretary presented an update on CAEP participation and membership, highlighting the high level of expertise present in the working groups. She pointed out that the Council had approved the CAEP directives which included rules on participation. It was stated that the working group participants mostly came from the same group of States, and the importance of others to contribute was highlighted. The Secretary emphasized the importance of engaging all members and observers. It was suggested that the use of e-mail and teleconferences can help, and WG2 was used an example where through the use of different schedules for the conference calls, the different time zones had been accommodated.

5.1.1.2 The Secretariat will be closely monitoring the membership of the groups, with a view to supporting wider participation, and will be informing the ICAO Council on this matter on an annual basis.

5.2 CAEP STRUCTURE

5.2.1 The meeting agreed to the following structure for CAEP/10:

a) Working Group 1 (WG1) – Noise Technical;

b) Working Group 2 (WG2) – Airports and Operations;

c) Working Group 3 (WG3) – Emissions Technical;

d) Forecasting and Economic Analysis Support Group (FESG);

e) Modelling and Databases Group (MDG);

f) Impacts and Science Group (ISG); and

g) Aviation Carbon Calculator Support Group (ACCS).

5.2.2 The Chair explained that subgroups could be created within the above groups as required. Building upon t his basic structure and guidance, the working groups need to further establish the appropriate WG structure to address the their work programmes. The member from Canada registered interest in offering resources to lead task groups in WG2.

5.2.3 The meeting agreed that the WMF Liaison group and the associated Chaperone group (consisting of France, Netherlands, UK and US) should continue as this will allow CAEP members to further guide and monitor progress on the CO_2 Standard development.

5.2.4 The meeting agreed to the following Co-Rapporteurs:

a) WG1 – Mr. Willem Franken (EASA) and Mr. Jim Skalecky (United States);

b) WG2 – Mr. Andrew Watt (EUROCONTROL) and Ms. Julie Marks (United States);

c) WG3 – Mr. Ralph Iovinelli (United States) and Mr. Roger Worth (UK) and as CO_2 Standard Task Group Leaders – Mr. Mike Samulski (United States) and Mr. Steve Arrowsmith (EASA)

d) FESG – Ms. Sylvie Mallet (Canada) and Mr. Kevin Guittet (France);

e) MDG – Mr. Gregg Fleming (United States) and Dr. Urs Ziegler (Switzerland);

f) ISG – Dr. Jim Hileman (United States) and Prof. David Lee (UK);

g) ACCS – Mr. Tim Johnson (ICSA) and Mr. Alexandre Filizola (Brazil).

5.2.5 The meeting agreed that Mr. Shigehiko Yamaguchi will continue to be the Focal Point on Voluntary Measures.

5.2.6 The meeting requested that members and observers propose participants for ISG as soon as possible.

5.2.7 The meeting agreed that CAEP will consider how to tackle issues related to alternative fuels following the 38th session of the Assembly, recognising that until then ICAO has the SUSTAF group on this subject.

5.3 CAEP/10 WORK PROGRAMME

5.3.1 The CAEP Secretary presented a general work programme that reflected the input from the Working Groups along with the items recommended by the ICAO Secretariat and requested from other UN bodies.

5.3.2 Noting the importance of planning and identifying priorities for the CAEP/10 work programme, the Secretariat began planning the CAEP future work programme during the 2012 Steering Group meeting. The CAEP Secretary recognized the increasing workload in the environmental area and this pre-planning should permit better consideration by CAEP participants of schedules and budgets for undertaking CAEP-related activities.

5.3.3 The Working Group Co-Rapporteurs presented the proposed CAEP/10 tasks associated with their specific Working Group. Additionally, a number of Members and observers presented proposals for future work. Only fully scoped proposals were agreed by the CAEP/9 meeting. Members and observers who presented tasks to the meeting, that were of interest but not fully scoped, were asked to provide proposals to a future meeting of the CAEP or its Steering Group.

5.3.4 The approved work programme items are shown in the Appendix at the end of the report on this agenda item.

5.3.5 The meeting was reminded that in developing the new work programme, special attention needed to be given to the resources available, the priority and relevance of tasks, and a clear definition of the end products envisaged.

5.3.6 **Recommendation**

5.3.6.1 The meeting developed the following recommendation:

Recommendation 5/1 —Revised CAEP work programme

That the Council approve the revised work programme of CAEP contained in the Appendix to the report on this agenda item.

5.3.7 The Secretary clarified that, following the outcome of the 38th Session of the ICAO Assembly, adjustments would be made to the CAEP/10 work programme at the first CAEP/10 Steering Group Meeting in November 2013.

5.4 CALENDAR

5.4.1 The meeting agreed to hold the following Steering Group meetings prior to CAEP/10:

a) Dubai, United Arab Emirates, 3 to 7 November 2013;

b) TBC, Durban, South Africa, 15 to 19 September 2014; and

c) Singapore, Singapore, 22 to 26 June 2015.

5.4.2 The full calendar leading to CAEP/10 will be agreed by the first Steering Group meeting. The CAEP/10 meeting is planned for February 2016.

5.5 CLOSING REMARKS

5.5.1 In her closing remarks, the Secretary thanked the meeting for their dedication to the work of CAEP. She congratulated the members and observers for the true spirit of cooperation present throughout the meeting to achieving consensus and for the development of a future work programme that will meet the needs of the Organization.

5.5.2 The Chair also thanked CAEP members and observers for their diligent efforts and formally closed the meeting.

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APPENDIX

CAEP/10 WORK PROGRAMME

Task Number	Short Title	Description	Timeframe	Deliverable
Working Group 1 (WG1 – Noise Technical) Tasks				
N.01.01	Technology, operations and goals coordination	Coordinate with other working group Rapporteurs on interdependencies related to technology, operational issues, and goals as well as harmonizing the goal setting process.	Ongoing	Coordination
N.01.02	Databases coordination	Coordinate with other working group Rapporteurs on interdependencies related to management and update of noise and emissions databases.	Ongoing	Coordination
N.01.03	Environmental impacts coordination	Coordinate with other working group Rapporteurs on interdependencies related to environmental impacts, including stringency.	Ongoing	Coordination
N.01.04	SST CAEP coordination	Coordinate with other working group Rapporteurs on programmes for development of both noise and emissions SARPs for future supersonic aeroplanes.	Ongoing	Coordination
N.02	Annex and ETM maintenance	Maintain and update Annex 16, Vol. I and ETM, Vol. I.	SG2014/ SG2015/ CAEP/10	Updates to Annex 16 and ETM
N.03	NoisedB	Ensure process integrity and data currency of the ICAO noise certification database.	Ongoing	Up-to-date ICAO NoisedB
N.04.01	Monitor research	Monitor and report on the various national and international research programme goals and milestones.	SG2015 or CAEP/10	Report
N.04.02	Technology goals bench-marking	Review progress towards achievement of Technology Goals recommended by IEs for 2020 and 2030.	SG2015 or CAEP/10	Report

Task Number	Short Title	Description	Timeframe	Deliverable
N.05.01	Monitoring Sonic Boom research	Monitor and report on research to characterize, quantify and measure (including metric) sonic boom and their acceptability while also assisting in promoting and defining such research.	CAEP/10	Report
N.05.02	SST standards development (subsonic and supersonic regime)	Continue to work on noise certification standards for supersonic aircraft: 1) based on subsonic noise standards for local airport noise that may include the use of Variable Noise Reduction System (VNRS) technology as "acceptable means of compliance." and 2) a new scheme for supersonic flight, as informed by developments under N.05.01.	CAEP/10	Progress report
N.05.03	SST coordination	Update Air Navigation Commission with SSTG Report on progress of SST noise activities.	TBD	Coordination
N.05.04	Monitoring SST	Monitor, and report on, status of SST projects and expectations for their operation (nature, frequency etc.).	CAEP/10	Report
N.06.01	Respond concerning Interdependencies	Respond to WG3 requests to assess interdependency effects of CO_2 emissions stringency options with respect to noise.	SG2013/ SG2014/ SG2015/ CAEP/10, if and when WG3 has provided request.	Interdependency effects
N.06.02	Monitor emerging technologies	Review data on emerging technologies as it becomes available.	CAEP/10	Report

Task Number	Short Title	Description	Timeframe	Deliverable
Working Group 2 (WG2 – Airports and Operations) Tasks				
O.01	Airport community engagement	Develop a document on best practice case studies and lessons learned to assist States and the aviation industry, in particular airports, airlines and ANSPs, to engage local communities and address their concerns regarding aircraft operational noise and emissions, and aviation operations in general.	CAEP/10	Circular with case studies
O.02	Operational Interdependencies	CAEP has already carried out work on interrelationships / interdependences / trade-offs, but it is spread around a number of documents. It is really difficult to find, and there may be gaps that require to be identified and addressed. Other CAEP groups are also doing work on these from various points of view, and it would be beneficial to be able to identify and collate them together in one document or webpage on the ICAO website. This task would develop additional information on operational interdependencies for the CAEP Operations web page. To consider O.03.	SG2015	Information for CAEP Operations web page
O.03	“Best practice” environmental assessment.	Develop a compendium of illustrated “best practice” environmental assessment case studies that demonstrate the application of "Environmental Assessment Guidance For Proposed Air Traffic Management Operational Changes“. To consider O.02 and O.05.	CAEP/10 (to begin, ensuring synergies with ASBU task)	Report
O.04	Support to ANB	To be defined. Interaction with panels (e.g. OPSP).		
O.05	ASBU Analysis	As defined in the ASBU environmental analysis TOR.	Phase II: May 2013, Phase IV: July 2013, Phase V: SG2014	

Task Number	Short Title	Description	Timeframe	Deliverable
O.06	Update to Airport Planning Manual Part 2	Update the Airport Planning Manual (APM), Part 2. Incorporate eco-friendly airport planning (e.g. infrastructure decisions that facilitate environmentally-friendly airports) and best practices in land-use planning and management.	CAEP/10	WP to CAEP/10 + Appendix with the updated APM, Part 2
Working Group 3 (WG3 – Emissions Technical) Tasks				
E.01	Interdependencies	Coordinate with other working group Rapporteurs on interdependencies related to (a) technology, operational issues and goals (b) management and update of noise and emissions databases (c) environmental impacts (d) SARPs for future SST aircraft.	Ongoing	Coordination report for each SG
E.02	Aircraft Fuel Efficiency Technology Advances	Provide assessment of advances in aircraft and engine design technologies for subsonic aircraft and the degree to which these technologies could influence the fuel burn of the aircraft including the potential interdependencies and tradeoffs with emissions and noise, and the likely timescales for introduction. Consider these in the context of the existing CAEP goals.	CAEP/10	Stand-alone Report
E.03	Combustion Technology Advances	Provide assessment of advances in engine combustor design technologies for subsonic aircraft and the degree to which these technologies could influence gaseous emissions, and particulate matter, including the potential interdependencies and tradeoffs with emissions and noise, and the likely timescales for introduction. Consider these in the context of the existing CAEP goals.	CAEP/10	Stand-alone Report

Task Number	Short Title	Description	Timeframe	Deliverable
E.04	Fuel composition and emissions	Monitor trends in aviation kerosene fuel supply composition and assess consequences for emissions. Including a global survey of fuel sulphur content to support the estimation of global and regional SOx emissions.	During CAEP/10	Report
E.05.01	CO_2 - Certification requirements (aircraft)	Complete an aircraft based CO_2 emissions certification requirement.	SG2013	Standard Annex 16, Vol. III
E.05.02	CO_2 – Standard Stringency assessment for new types	Develop pass/fail stringency options, including TRL≥8[1] technology responses, for new aircraft type applicability requirements and dates of 2020 and 2023 for evaluation of cost effectiveness and market impacts by FESG and MDG.	SG2013 SG2014 CAEP/10	Report
E.05.03	CO_2 - Standard Stringency assessment for in-production types	Develop proposals for in-production aircraft type applicability requirements and dates for evaluation of cost effectiveness and market impacts by FESG and MDG. This should include consideration of pass/fail stringency options including TRL≥8 technology responses, reporting requirements , and transition periods.	SG2013 SG2014 CAEP/10	Report
E.05.04	CO_2 - Regulatory standard	Recommend an aircraft CO_2 standard including regulatory levels and applicability in accordance with the CAEP principles of being technically feasible[2], economically reasonable, environmentally beneficial and taking into account interdependencies.	CAEP/10	New standard; change to Annex 16, Vol. III.
E.05.05	CO_2 - Off-optimum performance monitoring	Low priority: Review the performance of current and emerging aircraft technology at off-optimum but relevant points in the flight envelope.	SG2015	Report

[1] Technology Readiness Level 8 – flight qualified through test and demonstration.
[2] Building on NO_x and Noise definitions of technically feasible.

Task Number	Short Title	Description	Timeframe	Deliverable
E.05.06	ICAO Aeroplane CO_2 Emissions Metric Databank	Develop and maintain the ICAO Aeroplane CO_2 Emissions Metric Databank.		
E.06	Interdependencies	Coordinate with other groups to assess the interdependency effects of CO_2 emissions stringency options.	Ongoing	Coordination report for each SG
E.07	Annex 16, Vol. II maintenance	Maintain Annex 16, Vol. II, taking account of updates to SAE-E31 documentation.	CAEP/10	Proposed Annex changes
E.08	ETM maintenance	Maintain the emissions Environmental Technical Manual.	CAEP/10	Proposed ETM changes
E.09	Emissions Database maintenance	Maintain the ICAO engine emissions certification databank.	Ongoing	up-to-date databank
E.10	G&R database maintenance	Review and update a "Growth & Replacement" database in order to support development of models used to populate future fleets and the replacement of retired aircraft. Coordinate with CO2TG, WG1 and support groups to ensure consistency in assumptions.	During CAEP/10	up-to-date G&R databank
E.11	NOx cruise - Climb relationship	Review the LTO NOx - cruise climb NOx relationship for staged combustion and future engine technologies, to quantify control of mission emissions of NOx, and identify any methodology issues with respect to the correlation between LTO and climb/cruise and to quantify interdependencies with other emissions.	During CAEP/10	Report
E.12	Certification Requirements - SST	Monitor trends in supersonic technology and assess consequences for emissions and certification standards.	CAEP/10	Proposed change to Annex 16
E.13	Certification requirements - new engine concepts	Monitor developments in new engine concepts such as open-rotor, etc. and develop methodologies for emissions certification.	During CAEP/10	Report

Task Number	Short Title	Description	Timeframe	Deliverable
E.14.01	PM - Non-volatile	Develop an aircraft engine based non-volatile PM mass and number metric and methodology for application as a non-volatile PM mass and number emissions certification requirement for turbofan/turbojet engines >26.7kN. Note input from SAE-International E-31 Committee.	During CAEP/10	Annex 16, Vol. II
E.14.02	PM - Non-volatile	Develop an aircraft engine based non-volatile PM mass and number standard for turbofan/turbojet engines >26.7kN.	During CAEP/10	Annex 16, Vol. II
E.14.03	PM - Non-volatile	Develop representative engine data for assessing the nvPM emissions contribution from (1) turbofans/turbojets ≤26.7kN, (2) turboprops, (3) turboshaft and (4) APU engines.	During CAEP/10	Report
E.14.04	PM - Non-volatile	Develop improved nvPM model inputs to both local air quality models and, as required, global climate models per advice from ISG. Consider collaborative work with MDG. Note input from ISG on nvPM impacts.	During CAEP/10	WG3 Report and MDG improved CAEP models
		Modelling and Databases Group (MDG) Tasks		
M.01	Interdependencies	Coordinate with other working group Rapporteurs on interdependencies related to technology, operational issues, goals, environmental impacts and management and update of noise and emissions databases.	CAEP/10	Coordinated WP to SG meetings and CAEP/10
M.02	CO_2 Standard	Conduct sample problem and policy option analyses of the environmental benefits and interdependencies of a potential CO_2 standard as directed by CAEP and SG.	CAEP/10	Sample problem WP; Analysis: Joint MDG/FESG WP to CAEP/10 or as requested by SG

Task Number	Short Title	Description	Timeframe	Deliverable
M.03	ICAO Environmental Trends Projection	Conduct an updated trends projection, for the 2010 baseline case and forecasts to 2050, and for various cases which consider technology, operational improvements and alternative fuels life cycle. The projection will consider incorporation of information from state action plans as interpreted and provided to MDG by the ICAO Secretariat. Updated trends projection for Noise and Local Air Quality.	CAEP/10	WP to SG2013 on fuel burn; Full analysis WP to CAEP/10 Fuel burn trends by April 2013 CAEP/10 for Noise and LAQ Trends
M.04	Update to CAEP/10 ICAO environmental trends	The input from I.11 would be applied to the fuel burn trends prepared in Task M.03 to constitute the updated fuel burn trends for CAEP/10.	CAEP/10	
M.05	Existing Model and Database Management	Maintain version control of models and databases to be used in support of specific CAEP analyses. Determine if updates to models or databases require a re-evaluation.	CAEP/10	WP to CAEP/10
M.06	New Model Evaluation	If new models are introduced to support CAEP/10, continue the candidate model evaluation process, which calls for sensitivity tests, comparisons with "gold standard data, and sample problems. Refine the process as appropriate on the basis of relevant criteria, to better inform CAEP which tools are sufficiently robust, rigorous and transparent, and appropriate for which analysis, and why there might be differences in modelling results.	CAEP/10	WP to CAEP/10
M.07	Document 9911	Review and update ICAO Document 9911, as appropriate.	CAEP/10	Updated Document 9911
M.08	Fuel Burn Reporting	Seek to improve modelling and State reporting of fuel burn data by conducting a comparative assessment of modelled and reported data from member states, as reported data becomes available.	CAEP/10	WP to CAEP/10

Task Number	Short Title	Description	Timeframe	Deliverable
M.09	ICAO Support	Provide support to ICAO Secretariat in dissemination of MDG results.	CAEP/10	As required
M.10	PM Standard	Conduct sample problem and policy option analyses of the environmental benefits and interdependencies of a potential PM standard as directed by CAEP and SG. In cooperation with other CAEP WG's.	CAEP/10	As required / directed by SG
M.11	ASBU Analysis	Note: WG2 has the lead on this task. As defined in the ASBU environmental analysis TOR.	Phase III: June 2013 Phase IV: July 2013 Phase V: SG2014	
M.12	COD Improvement(s)	Broaden the scope of the Common Operations Database (COD) and manage the acquisition and treatment of the additional data		
M.13	Feasibility of ICAO climate change goals	Provide support to ICAO Secretariat in the assessment of the feasibility of ICAO climate change goals.	Refined scope to SG2013	
Forecasting and Economic Analysis Support Group (FESG) Tasks				
F.01	Review of Economic Models	Review of economic models as needed for the CAEP/10 analyses.	During CAEP/10	Report
F.02	Review of FESG CAEP/9 forecast	Review of the CAEP/9 forecast to address potential issues and facilitate its implementation in support of the CAEP/10 analyses.	During CAEP/10	Report
F.03	Cost-effectiveness analysis of potential CO_2 policy options	Conduct the cost-effectiveness analysis of the potential CO_2 policy options under consideration for CAEP/10.	During CAEP/10	Report
F.04	Cost-effectiveness analysis of potential PM policy options under consideration for CAEP/10	Conduct the cost-effectiveness analysis of the potential particulate matter (PM) policy options under consideration for CAEP/10 (and a sample problem). (See task M.10).	During CAEP/10	Report

Task Number	Short Title	Description	Timeframe	Deliverable
Impacts and Science Group (ISG) Tasks				
I.01.01	Coordination (internal group)	Coordination on activities.	Ongoing	Coordination
I.01.02	Coordination (internal ICAO)	Coordination with other WGs, TFs, RFPs, etc. Rapporteurs and ICAO Secretariat on activities.	Ongoing	Coordination
I.02	Environmental impact seminar	ISG to hold an ICAO seminar to build upon outcomes of the 2007 Impacts Workshop. Exact topics are yet to be determined. Potential topics that respond to other WG issues could include: climate impacts of aviation NOx emissions, PM emissions and their impact, and simplified approaches to quantifying climate benefits of system improvements (e.g. technologies that improve fuel efficiency); noise impacts.	CAEP/10	WP to CAEP
I.03	Climate context (non-CO_2) Coordinate with MDG as needed	ISG to summarize and critique ongoing research on contrail avoidance, including predicting contrail prone areas and routing to avoid them.	CAEP/10	WP to CAEP
I.04	Local and surface air quality context	ISG to provide an update to the current White Paper under development for CAEP/9 on air quality, with a focus on particulate matter.	CAEP/10	WP to CAEP
I.05	Climate context	ISG to provide an update to the current White Paper under development for CAEP/9 on aviation impacts on climate.	CAEP/10	WP to CAEP
I.06	Climate context	ISG to develop a new White Paper for CAEP/10 summarizing knowledge regarding the impacts of climate on aviation operations, from a science perspective.	CAEP/10	WP to CAEP
I.07	Support the ICAO Secretariat in requesting an IPCC update	Support the ICAO Secretariat in requesting that the IPCC update their figures regarding the distribution of global CO_2 emissions by Sector.		

Task Number	Short Title	Description	Timeframe	Deliverable
I.08	Estimation of global peer-reviewed CO_2 emissions by Sector	Compile peer-reviewed estimates of global CO_2 emissions by sector that can be used by ICAO, in the interim, pending updated IPCC figures and present their results to the first Steering Group meeting of the CAEP/10 cycle.		
I.09	Effects of aviation noise	Include the effects of aviation noise in ISG study topics during the CAEP/10 cycle. Only a review of peer-reviewed studies, not undertaking new studies.	CAEP/10	
I.10	Assessment of Climate Change Risk	Consider including the monitoring and communication of climate change risk and resilience in the CAEP/10 Work Programme.	CAEP/10	
I.11	GHG reductions from alternative fuels	Proposed approach for the analysis of the range of potential GHG reductions from alternative fuels up to the year 2050. Based on an agreed approach from SG2013, analyze the range of potential GHG reductions from alternative fuels up to the year 2050.	SG2013 SG2014	
Aviation Carbon Calculator Support Group (ACCS) Tasks				
C.01	Offset Accounting Methodology	Develop a methodology to estimate the amount of emissions on an airport-pair basis that would have been offset by the operator as the result of exceeding their emissions allowances within a cap and trade system or other offsetting schemes.	Delivery (if feasible) – June 2013.	Methodology to be implemented in the carbon calculator by the ICAO Secretariat
C.02	Enhancements to Passenger Carbon Calculator			
C.03	Estimating CO_2 Emissions from Air Freight			

Task Number	Short Title	Description	Timeframe	Deliverable
C.04	Methodology to Account for Carbon Offsets in the ICAO Carbon Calculator	Assist the ICAO Secretariat in developing a methodology consistent with the recommendations from Task C.01 and define the precise requirements for obtaining data.		
WG1, WG2, WG3, MDG and FESG (WMF) Tasks				
WMF.01	CO_2 Standard Technical Liaison	Coordinate across all relevant groups to clarify key assumptions, define analysis requirements, and identify database and modelling needs to support policy option analysis of a CO_2 standard.	CAEP/10	Report to CAEP/10
WMF.02	Progress reports	Report on progress being achieved toward delivering the CO_2 Standard.	Each Steering Group until CAEP/10	Regular reports
All Working Groups Tasks				
A.01	Support liaison activities with other UN bodies.	Provide the support required by liaison activities held in cooperation with other UN bodies.	CAEP/10	
A.02	Support to ICAO Secretariat	Provide support to the ICAO Secretariat activities in the fulfillment of tasks stemming from the relevant Assembly resolutions.	CAEP/10	
A.03	WG coordination	Coordination will need to continue throughout the CAEP/10 work cycle on existing and future work items.	CAEP/10	

— END —

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