Volpe Acoustics

Atmospheric Absorption Standard ARP 5534
FAA DER Seminar 2014

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John A. Volpe National Transportation Systems Center

Atmospheric Absorption Standard ARP 5534

FAA Acoustic DER Seminar – 24 September, 2014

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New SAE Absorption Standard

- **Final Version of SAE ARP 5534 was published in August 2013.**
  - Provides an empirically-determined method for applying the pure-tone absorption algorithms of ANSI S1-26/ISO 9613-1 to one-third octave band SPLs;
- Result of decades of research and development to improve calculations for sound attenuation effects of atmospheric absorption
  - Based on algorithms developed by Lou Sutherland, published in ANSI S1-26/ISO 9613-1
  - Algorithms address weaknesses identified in SAE ARP 866A methodology currently incorporated into Annex 16 and Part 36 specifications for aircraft noise certification ;
- ICAO WG1 has been monitoring development of ARP 5534 and upon publication initiated efforts to evaluate for noise certification

Federal Aviation Administration

SAE International

Recent ICAO WG1 Efforts 1 of 2

- N.02.12 AHG (ad hoc group) formed during CAEP/10 work cycle
- AHG begins investigating – initial data gathering indicates that there will be a small but significant increase in noise levels calculated using the new method;
- AHG designs a formal study to compare the new method to the current method – solicits organizations to voluntarily participate;
    - ARP 5534 vs. ARP 866A comparison study will evaluate differences – or deltas – between noise levels (EPNLs, PNLs, SPLs) obtained using the two methods;
- FAA provides support to WG1 study by participating in AHG and funding support by Volpe;
    - Volpe develops standalone executable calculator and portable code module that can be incorporated into participants' own code for calculation of EPNL – also provides validation data tables for participants to confirm that their code is operating properly;
- Difficulty of implementing new method into existing software → minimal data from participants;
    - FAA (Volpe) and EASA agree to process some sanitized applicant data sets so that there will be some data for WG1 to consider;
- Current data-providing participants: Dassault; Volpe; EASA; Boeing; Gulfstream; Bell;
- Results evaluated to date indicate that cumulative EPNLs obtained using the new method are typically 1 to 2 dB higher than those obtained using the current method;

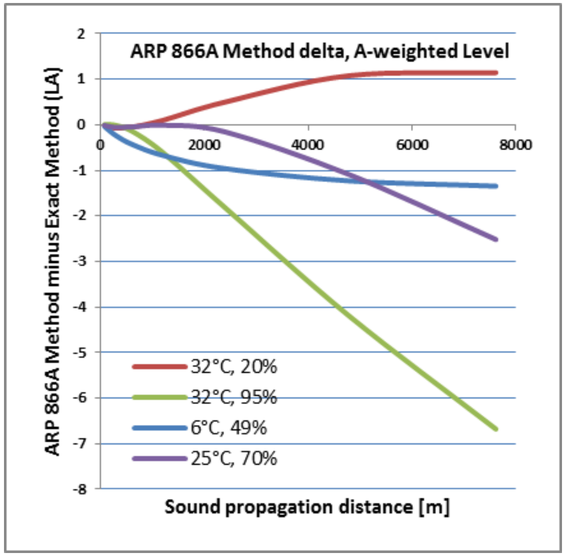
Recent ICAO WG1 Efforts 2 of 2

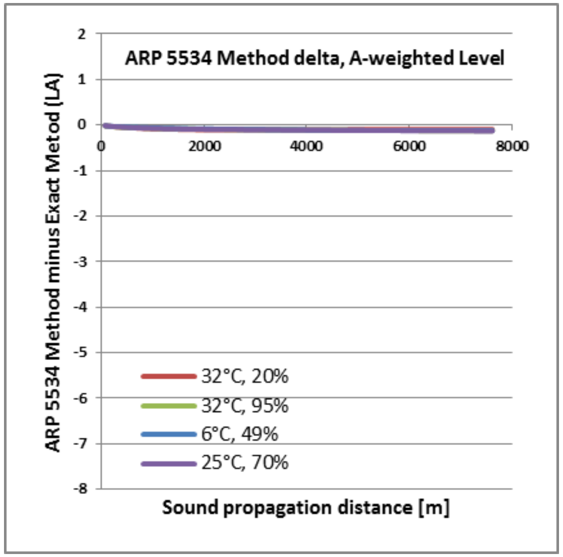
- Concurrent with formal comparison study, AHG members investigated related issues and concerns:
  - Sensitivity of both methods to specific test-day meteorological conditions;
  - Sensitivity of ARP 5534 to pressure;
  - Differences in the rate of change in absorption with frequency;
  - Ways in which both methods represent the physical mechanisms of sound absorption;
  - Issues related to implementation of the new method into Annex 16 specifications;
  - Identification of areas of effort required before ARP 5534 could be incorporated into the Annex
- At the June 2014 WG1 meeting in Tokyo, WG1 agreed that it would be desirable to incorporate the improved absorption methodology of ARP 5534 into the Annex, but that substantial additional work is required before that can happen;
- WG1 is recommending to Steering Group that this additional work be authorized – SG meets in Indonesia during the week of September 15th, 2014, so additional information may be available during the 2014 DER Seminar.

Why is a new absorption standard needed?

- Current ARP 866A method is known to have several weaknesses:
  - Sensitivity to meteorological conditions during measurement (corrected EPNLs for a particular aircraft could differ, based only on the conditions under which it was measured)
  - High-frequency absorption characteristics are less “accurate” than desired;
  - Absorption values calculated for long sound propagation distances are less “accurate” than desired

  Note: the 3 previous items were proven during Aérospatiale physical experimentation several years ago, using balloons and transmission of acoustical tones through varying atmosphere;
  - ARP 866A method of adapting pure-tone absorption algorithms to one-third octave band SPLs can cause spurious tone corrections around 5 kHz;

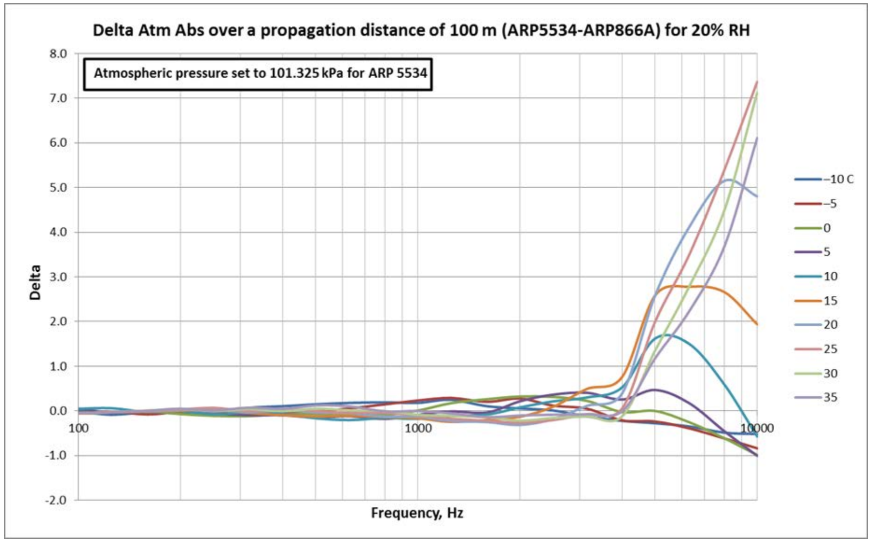


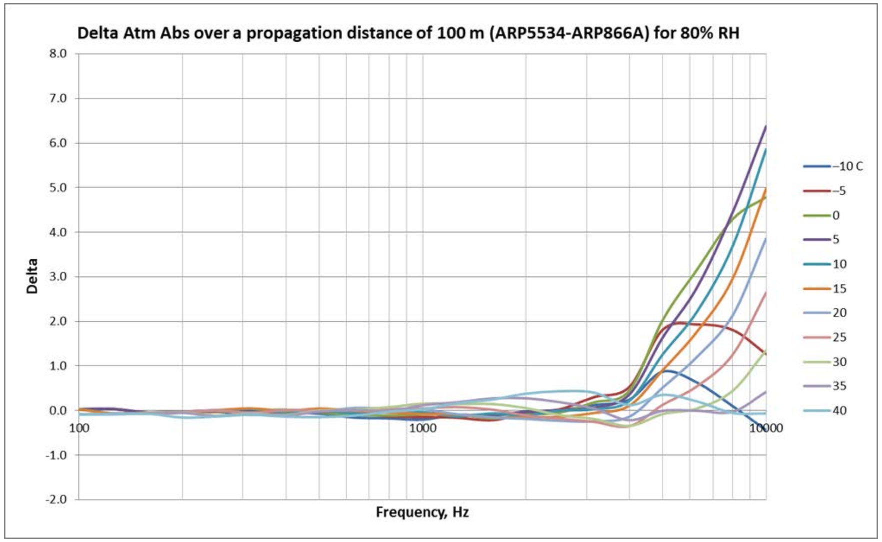


Figures developed by USDOT Volpe Center

Differences in the pure-tone absorption algorithms used in ARP 866A and ARP 5534

- Pure-tone absorption is greater at higher frequencies for ARP 5534 relative to ARP 866A:





Figures developed by M. Marsan

How ARP 5534 works

- Starts with improved pure-tone absorption algorithms;
  - Algorithms validated during Aérospatiale physical experimentation using balloons and transmission of acoustic tones through varying atmosphere;
  - In addition to temperature and relative humidity, ARP 5534 also uses barometric pressure as an input;
- “Exact Method” of ANSI S1-26 / ISO 9613-1 requires narrow-band calculation of absorption effects at many frequencies within each one-third octave band:
  - Computationally intensive;
  - Requires knowledge of aircraft source spectrum shape, as well as shape of one-third octave band filters;
- ARP 5534 applies empirically-derived regressions to adapt the pure-tone algorithms to one-third octave band data;
- Regressions simulate shifting “critical frequency” over propagation distance:
  - For shorter propagation distances and lower frequency bands, nominal midband frequency adequately represents absorption characteristics for all sound energy contained within one-third octave band;
  - With increasing propagation distance and frequency, the critical frequency that best represents the overall absorption within the band shifts downward toward the lower band-edge
- The ARP 5534 method has been shown to have good agreement with the Exact Method of ANSI S1-26 / ISO 9613-1

Critical Frequency Concept

A. Elements of 1/3 octave band filter:

1) filter response curve
2) Geometrical midband frequency
3) Lower band-edge frequency

B. 1/3 O.B. filter effect on zero-slope noise

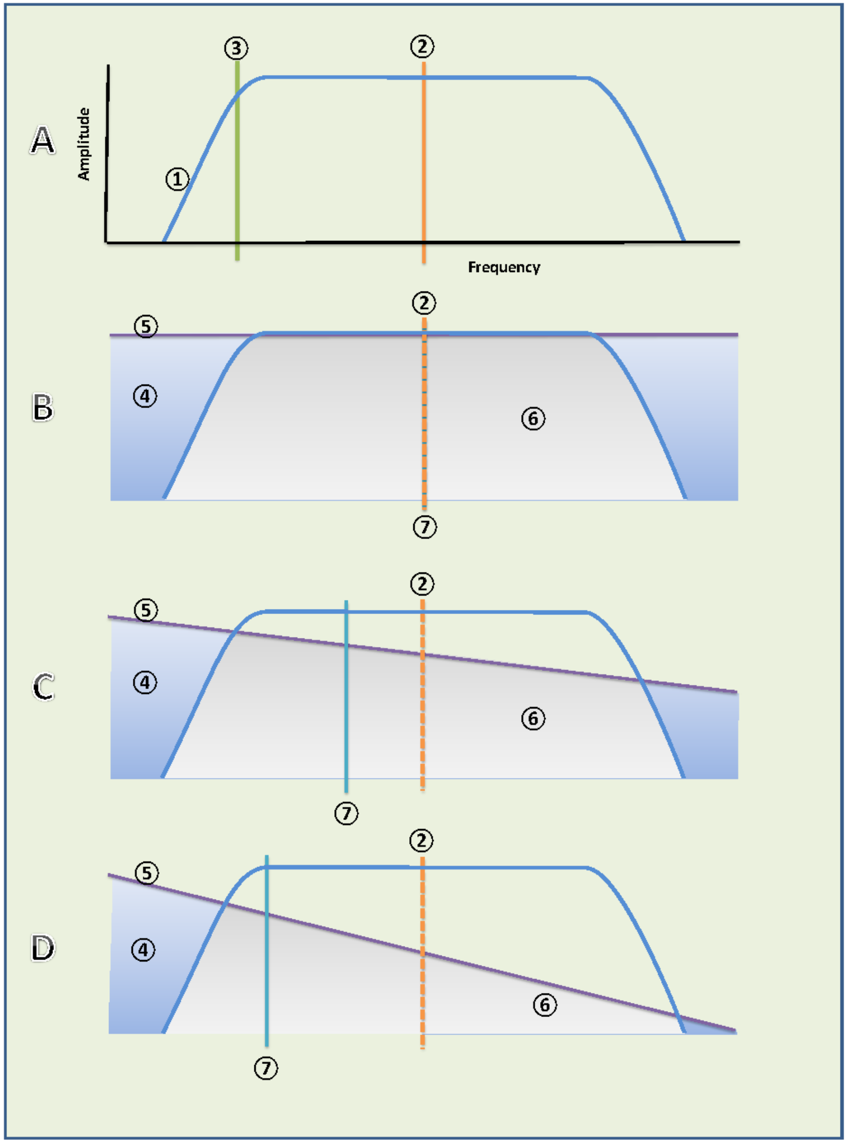
4) (blue area) noise to be passed though filter
5) Slope of the noise (zero in this case)
6) (grey area) noise passed through filter
7) Critical frequency best representing noise (same as midband frequency)

C. Filter effect on negative-sloping noise

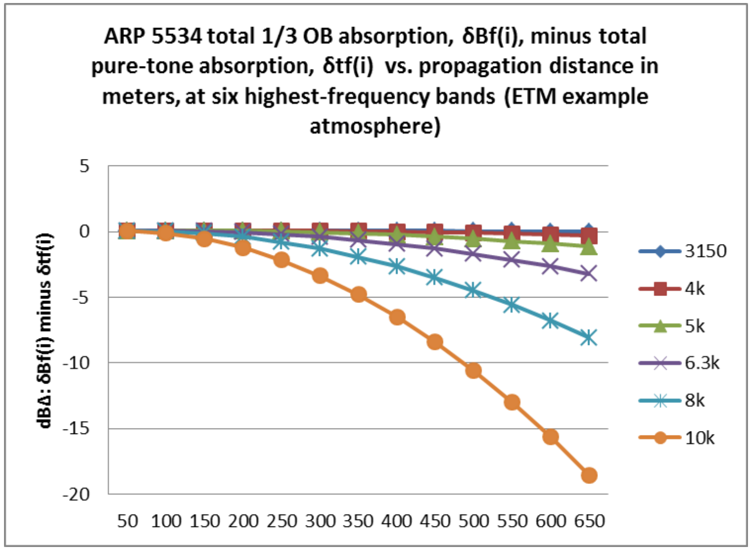
7) Critical frequency has shifted downward to represent sloped energy content within band

D. Noise with increased negative slope

7) Critical frequency has shifted farther downward



Implementation of ARP 5534 into EPNL software



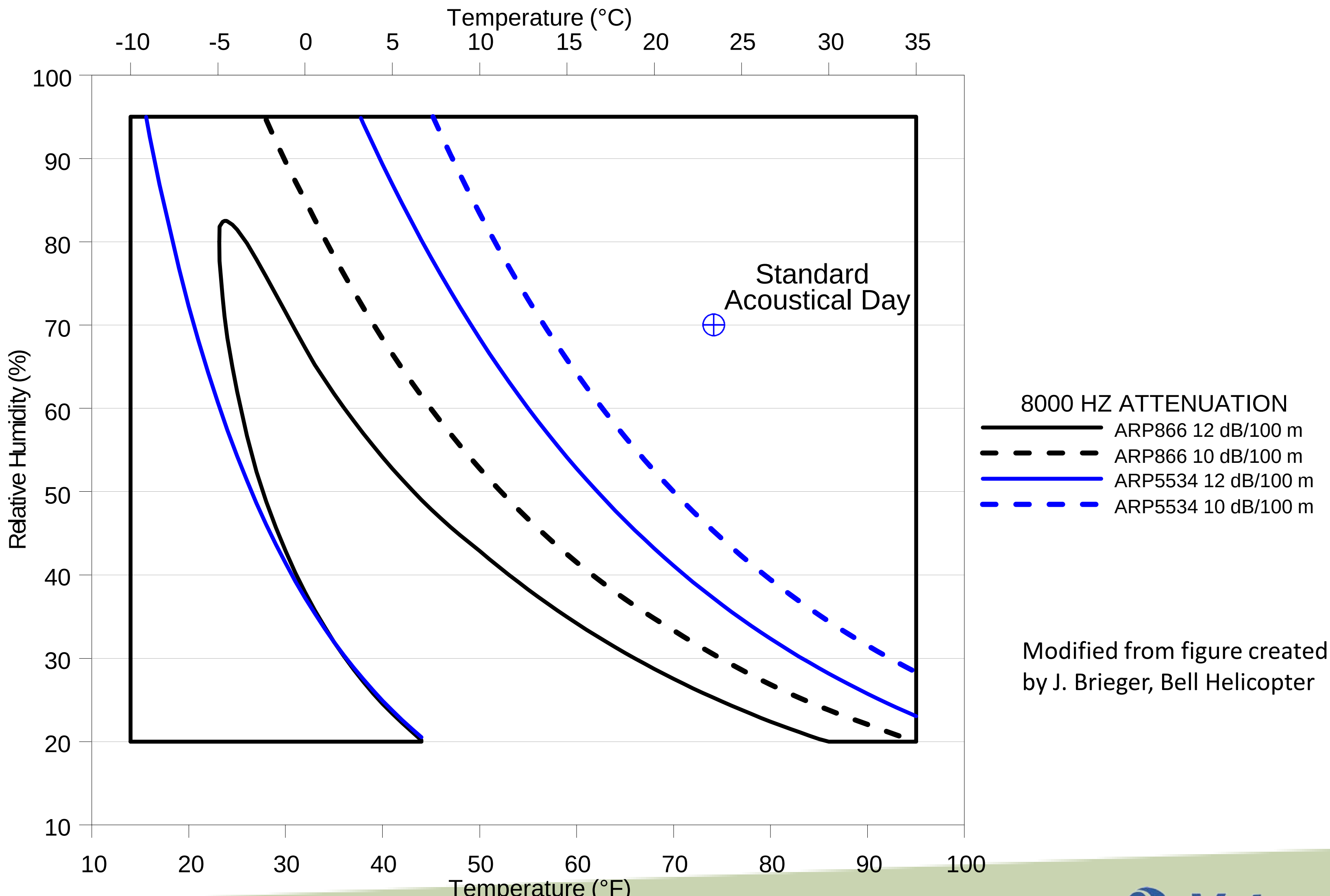
- Distance-dependent nature of ARP 5534 absorption effects prevents direct replacement in EPNL calculation software:
  - Where ARP 866A method calculates absorption coefficients (or “alphas”) in dB/100 m or dB/ 1000 ft, α(i), that are distance-independent, ARP 5534 method additionally requires calculation of total pure-tone absorption ,$\delta_t f(i)$, and total one-third octave band absorption, $\delta_B f(i)$, over sound propagation distance;
  - These additional values require different logic and sequencing in EPNL software, and affect frequency and time extrapolation of masked data as well as adjustment of test-day noise data to reference conditions – layered atmospheres require special attention;
  - The Annex includes limits or decision-points based on values of alphas in the 3150 Hz and 8 kHz bands – incorporation of ARP 5534 methodology into the Annex will require development of new criteria for these decision-points;
  - All applicants will likely be required to undergo complete re-validation of software and methodology to ensure that ARP 5534 method is being properly implemented;

Implementation of ARP 5534 Methodology into Aircraft Noise Certification via Annex 16

- Deltas between EPNLs calculated using old and new methods need to be addressed in several areas:
  - Issue of perceived validity of EPNL values calculated using ARP 866A method
    - do not want to invalidate existing base of noise certification levels, which have been proven to relate to public annoyance;
  - Comparison of EPNL values – for 40 years, an aircraft with a higher EPNL value was louder than one with a lower EPNL:
    - adoption of new methodology will create a step-change in EPNL values
    - there is a strong desire to maintain a level playing field
    - WG1 is aware that it needs to find a solution to this issue
  - Re-Certification to a new Chapter (or Stage), Family Plans, Static-to-flight equivalencies and other procedures involving the potential mix of old and new methods will create unique problems that need to be addressed prior to adoption

- New criteria need to be developed for decision-points such as the current 3150 Hz trigger for layering and the 12 dB/100 m @ 8 kHz go/no-go criterion
  - The first step in both of these will be determining the original technical bases for the criteria, which will be no small exercise on its own

Comparison of allowable weather windows



Modified from figure created by J. Brieger, Bell Helicopter

Work to be done prior to adoption of ARP 5534 method into aircraft noise certification specifications

- Obtain additional EPNL comparison data for differences between methods, including additional configurations, categories, and designs of aircraft, and covering more areas of the allowable measurement window for meteorological conditions;
- Evaluate trends of various parameters to determine EPNL dependencies, if any;
- Develop new specifications and guidance materials for the Annex and ETM to address such elements as:
  - Equations for computation of one-third octave band absorption;
  - Instrumentation performance & accuracy specifications, and scheduling & location requirements for the measurement of barometric pressure;
  - Guidance on implementation of methodology into EPNL software, including reconstruction of masked SPLs via frequency and time extrapolation, adjustment to reference conditions, and atmospheric layering;

Conclusion

Volpe encourages questions and comments from the aircraft noise certification community

Volpe Acoustics Website

[Under Construction]

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