AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

1791 Tullie Circle, N.E./Atlanta, GA 30329

404-636-8400

TC/TG/MTG/TRG MINUTES COVER SHEET

(Minutes of all Meetings are to be distributed to all persons listed below within 60 days following the meeting.)

TC/TG/MTG/TRG No.	2.6	DATE	June 24, 2013
TC/TG/MTG/TRG TITLE	Sound and Vibration		
DATE OF MEETING	June 24, 2013	LOCATION	Denver, CO

MEMBERS PRESENT	YEAR APPTD	MEMBERS ABSENT	YEAR APPTD	EX-OFFICIO MEMBERS AND ADDITIONAL ATTENDANCE
Voting Members:		**Voting Members:**		**Visitors:**
Francis Babineau		Eddie Lau		Victor Clemente
John Dunlap		Jerry Lilly		Sami Elkhazin
Curt Eichelberger		Richard Peppin		Scott Camphell
Dan LaForgia		Karl Peterman		Naira Campbell-Kyvreghyan
Dustin Meredith		Matthew Stead		Mark Smith
Erik Miller-Klein		Terence Tyson		John Frugard
Kim Osborn				Tim Orris
Raj Prime		**Corresponding Members:**		Tim Kuski
Douglas Reynolds		Rami Alkhalil		Greg Sanchez
Kenneth Roy		Jeffrey Babich		Tim Mathson
Michael Schwob		Mark Bastasch		Joe Brooks
Randal Zimmerman		Norm Broner		Nathan Redman
		Todd Busch		Kasey Worthington
Corresponding Members:		David Carroll		Joonhee Lee
Danny Abbate		Nicole Cuff		David Herin
Joseph Bridger		Erroll Eaton		David Bloom
Zvirimumwoyo Chinoda		Ronald Eligator		Scott Hobbs
Mark Fly		Michael Froehlich		John Murphy
Robert Hassler		Kevin Gaghan		Franco Cincotti
Michael Keating		Radha Ganesh		Jim Lundblad
Reginald Keith		Jason George		Matthew Hooti
Jim Kline		John Gierzak		Don Warick, Jr.
Patrick Marks		Lewis Goodfriend		John Iacobellis
Greg Meeuwsen		Brian Guenther		
Paul Meisel		Ali Kemal Guney		
Patrick Oliver		Art Hallstrom		
Brian Reynolds		Ali Herfat		

These draft minutes have not been approved and are not the official, approved record until approved by this committee.

ASHRAE TC 2.6 Sound and Vibration Control
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Denver, CO

MEMBERS PRESENT	YEAR APPTD	MEMBERS ABSENT	YEAR APPTD	EX-OFFICIO MEMBERS AND ADDITIONAL ATTENDANCE
Mark Schaffer		Joseph Horesco		
Robert Simmons		Manoj Khati		
John Sofra		Marvin Kloostra		
Jack Wang		Will Kowald		
Lily Wang		Kevin Lai		
Zhiping Wang		Brian Landsberger		
		Joshua Leasure		
		Geoff Leventhall		
		Robert Lilkendey		
		Charles Mattocks		
		Alexander Michaud		
		Andrew Mitchell		
		Ralph Muehleisen		
		Matthew Murello		
		Jose Nepomuceno		
		Chris Papadimos		
		John Pappas		
		James Pooler		
		Michael Resetar		
		William Rockwood		
		Lauren Ronsse		
		Erica Ryherd		
		Benjamin Sachwald		
		Ken Shook		
		Tim Simcoe		
		Michael Spencer		
		William Stewart		
		Jason Swan		
		Nicholas Sylvestre-Williams		
		Vijay Tripathi		
		Jonathan Weinstein		
		Steve Wise		
		Roman Wowk		

ASHRAE TC 2.6 Sound and Vibration Control
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DISTRIBUTION

All Members of TC/TG/MTG/TRG plus the following:	
TAC Section Head:	Thomas Sobieski
TAC Chair:	Walter Grondzik
All Committee Liaisons As Shown On TC/TG/MTG/TRG Rosters:	Sheila Hayter Hugh McMillan Cyrus Nasseri Harvey Sachs Michael Vaughn Chris Fudge
Manager Of Standards: Manager Of Research & Technical Services:	Stephanie Reiniche Mike Vaughn

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Table of Contents

Main Committee Meeting Attendance List

Voting Members:

Francis Babineau	Johns Manville	francis.babineau@jm.com
John Dunlap	Dunlap & Partners	jdunlap@dunlappartners.com
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Robert Simmons	Petra Seismic Design	res@seismic-source.com
John Sofra	Kinetics Noise Control	jsofra@kineticsnoise.com
Jack Wang	Trane	jjwang@trane.com
Lily Wang	University Of Nebraska	lwang4@unl.edu
Zhiping Wang	Morrison Products Inc	zpwang@morrisonproducts.com

Main Committee Meeting Attendance List Continued

Visitors:

Victor Clemente	IAC Acoustics	victor.clemente@iac-acoustics.com
Sami Elkhazin	Vibro-Acoustics	selkhazin@vibro-acoustics.com
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John Iacobellis	Vibration Eliminator Co.	johniac@veco-ny.com

ASHRAE TC 2.6 Main Committee Meeting Minutes

2:15-4:15pm Monday, January 28, 2013

1. Call to order (Oliver)
   - Call to order by Patrick Oliver 2:15.

   1.1. Read scope of TC 2.6
      - The scope is posted on the TC website.
      - Oliver read the scope. There was discussion about revising the scope to match the expanded scope of ASHRAE in our executive committee. We will address this later in the operation segment of the agenda.

   1.2. Additions and/or modifications to the agenda
      - Some additions were made by Oliver since posting on the website. Changes are recorded in these minutes.
2. Introduction of those present (All)
3. Confirmation of current voting members (Meredith)
   - 11 of 18 voting members present – constitutes a quorum
4. Review and approval of the minutes (Oliver)
   - Motion by Curt Eichelberger and seconded by Oliver: The 2013 Winter Meeting (Dallas) minutes were approved by unanimous vote.
5. Secretary's report (Schwob)
   - Please provide all subcommittee reports by Monday, July 8th.
6. TC Chair's meeting report (Oliver)
   - The TC/TG/TRG Manual of Procedures has been updates to include MTG's.
   - Hightower award nominations are due September 1, 2013.
   - A TAC presentation template is now available on the ASHRAE website.
   - Please update your bio on the ASHRAE website with your employment discipline.
   - The CEC is looking for volunteers to chair technical sessions or review session papers.
   - Upcoming conferences will be in New York and Seattle.
7. Chair's announcements and correspondence (Oliver)
   - Included above.
8. Subcommittee Reports (also see attached reports from subcommittee Chairs)

   8.1. Research Subcommittee (Eichelberger)

      8.1.1. Research Chair's meeting report
         - There are no projects on hold for funding. ASHRAE needs new projects.
         - The new research liaison Harvey Sachs.
         - The RAC liaison should review all RTAR's. Any communication should copy Curt. They will be our advocate.
         - The most current form for RTAR submission is on the website. The society is trying to streamline this process.

- ASHRAE does not have any RTAR's that are waiting for funding.
- RTAR's are due May 18, Aug 18 and Dec 18.

8.1.2. Ongoing research projects

8.1.2.1 RP-1408 The effect of lining length on the insertion loss of acoustical duct liner

- The objective of this research is to show how the sound attenuation of lined ducts depends on duct length. This project is operating under a no-cost extension which has been granted to June 2014. The UNLV Lab is making good progress.

8.1.2.2 RP-1529 Full frequency numerical modeling of sound transmission in and radiation from lined ducts

- This project will develop and validate full-frequency numerical modeling techniques for sound transmission through, and radiation from, HVAC ductwork. Dr. Herrin presented an overview of the project approach and work completed to date at the PMS meeting. So far the preliminary analysis models look very promising. Target completion date is mid 2014, but this may be delayed until completion of RP-1408 testing.

8.1.3. Work Statements/RTAR's/URP's

- Annoyance Thresholds of Tones in Noise as Related to Building Services Equipment. Lily Wang championed this RTAR, along with contributions from Mark Schaffer, Steve Wise and Patrick Oliver. The TC approved the RTAR by letter ballot and it was forwarded to RAC. TC 2.1 has voted to co-sponsor this research. RAC reviewed the RTAR last week and returned it with comments. The RTAR should be revised and comments address by August 15.

8.1.4. Topics for future research

- Refer to attached Research Subcommittee Report.

8.2. Programs Subcommittee (Miller-Klein)

8.2.1. Program Chair's meeting report

- Refer to attached Programs Subcommittee Report.

8.2.2. Programs this meeting

8.2.2.1. Basics of Noise Control

- Nothing discussed.

8.2.3. Potential programs next meeting – New York, Jan 2014

- We are looking for volunteers, especially international members.
- Abstracts for the New York meeting are due by August 13th.
- Programs to be submitted for New York Conference include Chillers (Jack Wang), New Standards for Chiller Sound Ratings (Pat Marks), Chilled Beam (Patrick Oliver), Roof or Building Mounted Wind Turbines (contacting someone in UK), Operable Windows – Energy compared to Noise, Thermal storage in floors & footfall noise.
- Please start thinking about papers for Seattle.

8.3. Publications Subcommittee (Wise/Schwob)

8.3.1. Handbook chapters

8.3.1.1. Handbook Applications 2015 (Chapter 48)

- Jack Wang briefly discussed some changes to the chiller section. He indicated that the amount of noise generated by a chiller is dependent upon the operating conditions of the chiller and that this is very complex.
- There was a general consensus that Table 47 requires updating regarding the treatment of air springs and the formatting of the table notes. There was a general consensus that this would be an improvement to this section, but that there would be much work required to complete prior to submission.

8.3.1.2. Handbook Fundamentals 2013

- There was nothing to discuss.

8.3.2. Other publications

- There was nothing to discuss.

8.3.3. Web page (Schwob)

- The meeting schedule and agenda for this conference have been posted.
- Publications and handbook pages have been reviewed by Steve Wise and updated.
- Standards page has been reviewed by Lauren Ronsse page and updated.
- Research page has been reviewed by Curt Eichelberger and will be updated.
- The subcommittee page has been reviewed by Mike Schwob and updated.
- Mike Schwob is currently in the process of updating the roster page for the next term.

8.4. Standards Subcommittee (Lily)

8.4.1. SPC 79 – Method of Test for Fan Coil Units (Oliver)

- Met Saturday morning. Discussed current draft. SPC 79 will be harmonized with AHRI standards (ducted and un-ducted). Drawing on AHRI 250 and 350. It will go out for public review prior to New York meeting.

8.4.2. SPC 130 – Method of Test for Rating Ducted Air Terminal Units (Zimmerman)

- Addressed comments in their recent meeting. Will issue for public review prior to the New York meeting.

8.4.3. SPC 189 – Design for High Performance Green Buildings

- This will be issued July 12 for review for comment to the TC.

8.4.4. SPC 197 – Method of Test for Passive Vibration Isolators (Simmons)

- Existing methods of test that are applicable have not been found.
- A test fixture has been developed.
- A literature search has be completed.
- The old RTAR will be revised based on current development.

8.4.5. SPC 200 – Method of Test for Chilled Beams (Zimmerman)

- Progress is good and will issue a draft for review.

8.4.6. GPC 10 – Interactions Affecting the Achievement of Acceptable Indoor Environments (Wang)

- They are currently word-smithing the document. They are hoping to raise the influence of this guideline.

8.4.7. Performance Measurement Protocol (PMP) Best Practices document (Eichelberger)
- This MTG voted itself to disband at this conference.

8.4.8. Updates from Other Standards Organizations

8.4.8.1. AHRI (Abbate)
- Working on revisions to standards 270, 300, 350.
- Working on proposed standard 1280 Sound Performance Rating of Water Cooled Refrigerating and Air-Conditioning Equipment.

8.4.8.2. AMCA (Brooks)
- The new AMCA Standard 270, Laboratory Methods of Testing Fan Arrays for Rating, was approved for development by the AMCA Board of Directors.
- Standard 300 is being revised.
- Standard 301 is going through the approval process.
- Standard 210 is being revised.

8.4.8.3. ANSI
- Nothing discussed.

8.4.8.4. ASTM (Oliver & Clemente)
- The revised standard E477 should be approved and issued this year.

8.4.8.5. ISO (Reynolds); ISO TC205 (Roy)
- Nothing to report.

8.5. Standing Subcomittees

8.5.1. Sound Criteria (Wang)
- We are currently working on work statement for annoyance thresholds of tones in noise produced by HVAC equipment. Considering both lab and field studies. Will discuss further at NY meeting.

8.5.2. Vibration Isolation (Simmons)
- The RTAR for “Method of Test for Passive Vibration Isolators” will be revised and resubmitted.

8.5.3. BIM (Mitchell)
- Nothing discussed.

8.6. Operations Subcommittee (Meredith)

8.6.1. Bylaws
- The bylaws are posted on the website.

8.6.2. Honors and awards (Wang)
- Encouraged members to submit for distinguished service award. Will provide help if required.

8.6.3. Long range planning
- Nothing discussed.

8.6.4. Membership (Meredith)
- We have 70 corresponding members, 18 voting members with 1 non-quorum member and 1 provisional corresponding member.

8.6.5. Liaisons (Meredith)

8.6.5.1. International Green Construction Code update (Roy)
- Nothing discussed.

8.6.5.2. ASHRAE TC 2.1 Physiology and Human Environment (Wang)
- TC 2.1 is cosponsoring the RTAR for Annoyance Thresholds of Tones in Noise as Related to Building Services Equipment.

8.6.5.3. ASHRAE TC 2.7 Seismic and Wind Restraint Design (Simmons)
- TC 2.7 is working on revised test standard SPC 171 static method of test in conformance with ICC requirements.
- Pursuing testing or study on the effect of shielding for wind applications and criteria.

8.6.5.4. ASHRAE TC 5.1 Fan Design and Application (Osborne)
- The research project on system effects under way.

8.6.5.5. ASHRAE TC 5.2 Duct Design (Oliver)
- TC 5.2 is looking for volunteers to review the duct design guide.

8.6.5.6. ASHRAE TC 5.3 Room Air Distribution (Zimmerman)
- SPC 200 and 130 are the only thing they are working on regarding acoustics.

8.6.5.7. ASHRAE TC 6.10 Fuels and Combustion (Herrin)
- TC 6.10 meets tomorrow. They have a couple of papers ready to be presented at the Denver or New York conferences.

8.6.5.8. ASA (Wang)
- The next ASA meeting is in San Francisco. Abstracts are due July 8.

8.6.5.9. VISCMA
- The VISCMA website has been redesigned.

8.6.5.10. Others: CTI, INCE, NCAC, CIBSE etc.
- Joe Bridger: NCAC is interested in getting more engaged with ASHRAE Standard 189 and IgCC.

9. New business/Old business
- Patrick presented new proposed scope from executive committee for review by the TC. The revised scope read: “To develop, promote and disseminate scientific and engineering information to address /enhance for the control of noise and vibration associated with HVAC systems, acoustics and vibration in the built environment. The work of this committee will be coordinated with other ASHRAE committees and other organizations having mutual interest.”
- There were many disagreements with this statement. Eichelberger recommended the formation of an ad-hock committee to develop a scope. Oliver asked for volunteers. Curt Eichelberger, Joe Bridger, Dustin Meredith, Mark Schaffer, Kenneth Roy, Mark Fly and Michael Schwob volunteered. Meredith will chair and will schedule a meeting prior to the meeting in New York.

10. Next meeting date and location
    - The next conference will be held January 18-22, 2014 in New York.
11. Adjournment
    - Motion by Doug Reynolds and seconded by Dustin Meridith.

ASHRAE TC 2.6 Research Subcommittee Report

Submitted by: Curt Eichelberger (curtis.eichelberger@jci.com)

Highlights of the Research Chair's meeting:

- Harvey Sachs (RL2@ashrae.net) is our new liaison. Reminder that our Research Liaison, should review all RTARs and WS. Please copy Curt Eichelberger (curtis.eichelberger@jci.com) on all correspondence with the Research Liaison.
- A new RTAR form will be posted on the web site soon. All new RTARS should use this form.
- There are no projects on hold for funding. ASHRAE needs new projects.
- RTARs due May 15, August 15 and December 15.

Ongoing Research Projects:

RP-1408 The effect of lining length on the insertion loss of acoustical duct liner. Jerry Lilly PMS chair. Doug Reynolds, UNLV, principle investigator. The objective of this research is to show how the sound attenuation of lined ducts depends on duct length. This project is operating under a no-cost extension which has been granted to June 2014. The UNLV Lab is making good progress in testing the round ducts and Dr. Reynolds provided an overview of the test results to date at the PMS meeting. Testing of rectangular ducts is expected to start in September, 2013.

RP-1408 Extension. An extension to the 1408 Work Statement was approved January 2010. The purpose is to collect vibration and sound intensity test data on a small subset of duct configurations. This test data will then be used to validate the analytical models of breakout noise that will be developed in RP-1529. This testing will start soon.

RP-1529 Full frequency numerical modeling of sound transmission in and radiation from lined ducts. Pat Marks, PMS Chair. Dr. David Herrin, University of Kentucky, principle investigator. This project will develop and validate full-frequency numerical modeling techniques for sound transmission through, and radiation from, HVAC ductwork. Dr. Herrin presented an overview of the project approach and work completed to date at the PMS meeting. So far the preliminary analysis models look very promising. Target completion date is mid 2014, but this may be delayed until completion of RP-1408 testing.

RTARs:

Annoyance Thresholds of Tones in Noise as Related to Building Services Equipment. Lily Wang championed this RTAR, along with contributions from Mark Schaffer, Steve Wise and Patrick Oliver. The TC approved the RTAR by letter ballot and it was forwarded to RAC before May 15. Since then TC 2.1 has voted to co-sponsor this research. RAC reviewed the RTAR last week and returned it with comments. The RTAR should be revised and comments address by August 15.

Topics discussed and prioritized for future research:

The top topics discussed during the research subcommittee meetings are listed below in order of

priority.

1. **Room effect** (include effect of single pass ceiling systems) – Joseph Bridger agreed to champion this topic and prepare and RTAR, along with help from Ken Roy and Erik Miller-Klein.
2. **Silencer system effects** – Patrick Oliver and Victor Clemente will work on an RTAR. TC 5.2.
3. **Fluctuation criteria** – Objective would be to develop a metric for Criteria section of Handbook. Criteria subcommittee decided to work on tone criteria first.
4. **Effect of HVAC noise in hospitals** – Ken Roy and J. R. Babineau soliciting support from other TCs, in particular TC 2.1 and 9.6. The thought is to break this into three topics … speech privacy, intelligibility and healing effects.
5. **BIM** – TC2.6 efforts are focused on ASHRAE Multidisciplinary Task Group and SPC 205.
6. **Flow noise generation in ducts** – No champion for this topic at this time.

Added topics that were discussed, but not prioritized, include:

- **"Green" duct liners** -- May be a good discussion for a "Hot-Topic".
- **Flex duct –** Where does the sound go? Where should the duct end correction be applied?
- **IL in terminal units –** Why isn't this accounted for and is it important?
- **With ASHRAE rebranding itself and promoting a boarder scope to include the built environment, we may want to consider added topics such as:**
  - Speech privacy and, the opposite, speech communication.
  - Noise intrusion from outside or adjacent interior spaces.
  - Background noise consideration that extend beyond HVAC system noise, such as sound masking.

ASHRAE TC 2.6 Programs Subcommittee Report

Submitted by: Erik Miller-Klein

Program Topics – Future & For Consideration

Status	Subject	Type	Champion
Denver 2013 Wednesday @ 8:00 AM in Plaza Ballroom A	**Basics of HVAC Noise Control** ***(New Sub-Topics)*** • Sound Power vs. Pressure (Miller-Klein) • Propagation of Sound (Terry Tyson) • Vibration Isolation – The Basics (Reginald Keith)	Seminar	Miller-Klein
New York 2014	**Advanced Topic: Green Buildings & Their Noise Issues (TRACK 5: International Design)** • Roof or Building Mounted Wind Turbines (contacting someone in UK) • Operable Windows – Energy compared to Noise • Thermal storage in floors & footfall noise **New York - Track 5: International Design** **Track Chair: Samir Traboulsi** samir.traboulsi@mail.ashrae.org	Seminar	Jason Swan & Patrick Oliver (European & Canadian Panelists)
New York 2014	**On-going Equipment Series (TRACK 7: Hydronic System Design)** • Chillers (Jack Wang) • New Standards for Chiller Sound Ratings (Pat Marks) • Chilled Beam (Patrick Oliver) New York **Track 1: Systems and Equipment** **Track Chair: Yunho Hwang** yhhwang@umd.edu **Track 7: Hydronic System Design for Efficiency and Large Buildings** **Track Chair: Douglas C. Cochrane** doug.cochrane@carrierenterprise.com	Seminar	Pat Marks
New York 2014 (Tentative)	**Basics of HVAC Noise Control (New Sub-Topics) (New York – Track 2: Fundamentals & Applications; Seattle - Track 6: Standards, Guidelines, Codes)** • Environmental Noise Codes: Current and Future	Seminar	Miller-Klein

Status	Subject	Type	Champion
	(Miller-Klein) • Objectionable: Tones & Fluctuations (Lily Wang's Student) • Outdoor Equipment Noise Control (Dan Laforgia/Sami Elkhazin) **NYC - Track 2: Fundamentals and Applications** **Track Chair: Dan Fisher** dfisher@okstate.edu **Seattle - Track 6: Standards, Guidelines and Codes** **Track Chair: Samir Traboulsi** samir.traboulsi@mail.ashrae.org		
Resubmit Denver for Seattle 2014 (Tentative)	**Green Building Acoustic Performance – LEED, IGCC, PMP Best Practices** **(New York - TRACK 3: IEQ, or Seattle - Track 6: Standards, Guidelines, Codes)** • Kenneth Roy/Ralph Meuhleisen • Lily Wang • Curt Eichelberger **NYC - Track 2: Fundamentals and Applications** **Track Chair: Dan Fisher** dfisher@okstate.edu **NYC - Track 3: Indoor Environmental Health/Indoor Environmental Quality** **Track Chair: Thomas H. Kuehn** kuehn001@umn.edu **Seattle - Track 6: Standards, Guidelines and Codes** **Track Chair: Samir Traboulsi** samir.traboulsi@mail.ashrae.org	Seminar	Lily Wang
Seattle 2014	**On-going Equipment Series** • VRF the Advantages and Challenges (Schaffer) • Need Volunteer • Need Volunteer	Seminar	Mark Schaffer
Seattle 2014	**Advanced Topics, Conference Papers…** • Need Volunteer: Idea - Speech Privacy and Interior Noise with Low Noise Open Offices • Need Volunteer: Idea - Exterior to Interior Sound	Seminar	Need Volunteer

Status	Subject	Type	Champion
	Reduction • Need Volunteer		
Chicago 2015	**Basics of HVAC Noise Control** ***(New Sub-Topics)*** • Duct Liner, Breakout & Flanking (Doug Reynolds) •	Seminar	Champion?
Chicago 2015	CTEC - Back to Basics for Refrigeration (brought up by Mark Fly, Aaon) • Refrigeration Rooftop • Transportation Refrigeration		

New York City 2014 (Winter Conference)

Upcoming Deadline:
August 13, 2013 – Seminar and Forum Program Proposals Due

TC2.6 Program Meeting Attendance	
Name	E-mail
Mark Schaffer	mark@schaffer-acoustics.com
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David Bloom	dbloom@mason-ind.com

ASHRAE TC 2.6 Publications Subcommittee Report

Meeting Minutes

June 24, 2013

Submitted by: Michael Schwob

Handbook Applications 2015 (Chapter 48)

Jack Wang briefly discussed some changes to the chiller section. He indicated that the amount of noise generated by a chiller is dependent upon the operating conditions of the chiller and that this is very complex. Mike Schwob asked if the current paragraph is adequate and he indicated that it should be improved in future editions of the handbook with more description and images.

Don Warick requested a copy of the current version of this chapter for review. He indicated that he is on the list of people who are reviewing this chapter, but has not received the current version. Jack indicated that those who submitted changes received the current version. Don indicated that he had not yet submitted changes.

Regarding Table 47

Mark: Air springs are identified in the table notes as isolator type 6 but not used in the table. Reference is made to Note 25 in the Notes for Table 47. The following statement should be reworded: "Air springs can be designed for any frequency, but are economical only in applications with natural frequencies of 1.33 Hz or less (6 in. [150 mm] or greater deflection)."

Curt Eichelberger: Notes for Table 47 should be moved to main text prior to Table 47. The information in the notes is important and should be moved to a more prominent location. The notes are rarely read. There was a general discussion regarding this topic that included Reggie, Mark, Curt, Patrick and Robert Simmons. The suggested format is similar to vibration isolation specifications. Rewording of text may be required. There was a general consensus that this would be an improvement to this section, but that there would be much work required to complete prior to submission. Reggie indicated that he would contact Steve directly regarding this. Patrick volunteered to help.

Mark Schaffer: Transformers should be added to the table. Mike Schwob added that unit substations should also be added.

Sami Elkhazin: Should there be a different requirement for new high RPM centrifugal chillers with magnetic bearings. There was some discussion. The consensus was that the vibration isolation of these chillers is less stringent than typical centrifugal chillers and that the current table entry is adequate.

ASHRAE TC 2.6 Webmaster Report

Submitted by: Michael Schwob

- The meeting schedule and agenda for this conference have been posted.
- Publications and handbook pages have been reviewed by Steve Wise and updated.
- Standards page has been reviewed by Lauren Ronsse page and updated.
- Research page has been reviewed by Curt Eichelberger and will be updated.
- The subcommittee page has been reviewed and updated.
- The roster page for the next term is currently being updated and will be posted in July.

ASHRAE TC 2.6 Criteria Subcommittee Report - Special Working Session

Minutes of Joint Meeting between Research & Criteria Subcommittees

June 24, 2013

Submitted by: Lily Wang

Attendees: V. Clemente, E. Eaton, C. Eichelberger, S. Elkhasin M. Fly, R. Hassler, M. Hooti, L. Hopkins, D. Laforgia, S. Lau, P. Marks, D. Meredith, E. Miller-Klein, A. Mitchell, P. Oliver, R. Peppin, D. Reynolds, K. Roy, M. Schaffer, M. Smith, J. Swan, J. Wang, L. Wang, S. Wise

I. Scope/purpose of the criteria committee: "To define and promote measurement protocols and benchmarks/guidelines/criteria to evaluate building acoustics, as related to building mechanical systems"

II. Development of an RTAR on Tones: *Today's goal is to decide on some specific guidelines that can be written up in an RTAR, but committee should ultimately remain open to alternative approaches proposed by bidders that still answer the research question*

A. Definition of the problem… what is the research question?

1. It would be helpful if ASHRAE had criteria for acceptable levels of tones in noise (acceptable meaning less annoying, or reduced number of complaints)
2. Less interested in effects of tones on performance (because that effect is not as clearly measurable or simple to detect, based on RP-1322 results)
3. When do 50% say that it's OK? (Or 90%?)
    a. Noise sensitivity may be a significant variable to consider; can acquire noise sensitivity data from test participants

Patrick Oliver referred to ASHRAE Standard 55 on Thermal Comfort which lists levels at which 80% will be satisfied, and those at which 90% will be satisfied. Swan mentioned that similar has been done for environmental noise levels. Consensus of the group is that this should be the goal for our research as well. So the research question may be phrased as: "At what point is a tone in noise rated as 'annoying' by 80% (and 90%) of the general population?"

Previous work by Hellweg-Nobile used 7 point subjective scale on 'prominence', not 'annoyance'.

We may need to specify both absolute and relative levels (K. Roy). Wise pulled up equal loudness contours of tones versus narrow bands of noise, to indicate that the same *relative* levels of tone to different *absolute* levels of BNL may be perceived differently.

Schaffer asked for clarification on the eventual purpose of the research: is it to inform design criterion or to help validate a person's complaint (i.e. diagnostics)? Consensus is to start on the diganostic side … when do 80% or 90% of population claim

that this degree of tones in noise is annoying? Then this feeds back to what appropriate design would be.

What is considered the general population for this research? Suggestions are to limit test subjects to be: normal hearing; adults (age 19 to 65?); normal distribution of noise sensitivities?

Other factors that we should continue to keep in mind:

- Multiple tones
- Time variance… because if more than one tone, there will be some time-varying fluctuations. Variations in noise also often due to operating conditions. That variation may be frequency modulation, amplitude modulation, or combinations of both. Consensus of the group is that these should perhaps be areas of future research.
- Does the individual have control over it? This has been shown to affect annoyance in other areas (thermal comfort, etc.) Consensus is to limit our study to 'worst case' where individual has no control over it.
- Subject's ability to adapt to the noise… or notice the noise when it's particularly pointed out.

B. How should the tones be quantified or measured? Current methods include:

1. Prominence Ratio (PR) and Tone to Noise Ratio (TNR), both in ANSI S1.13-2005 a. RP-1322 only tested tones with PR = 5 or 9 … but tones with PR from 9 to 18 are now listed as limits of acceptability in the current ANSI S1.13-2005 standard, based on Hellweg-Nobile work (2002).
2. Aures Tonalness Metric
3. Annex D of ISO Standard 1996-2 (2007): 1/3 octave band method
4. Appendix D of ANSI/AHRI Standard 1140 (2006) provides sound power level penalties in dB for tones in assorted 1/3 octave bands (source of data still unclear?)
    a. But one-third octave band data do not always show the tonal problem; should we move towards narrowband FFT procedure, providing signals that could be used to 'calibrate' FFT?
5. Check new ISO loudness standard (based on work by Moore and Glasberg) ... and review how this metric changes with tonal components. Muehleisen reports that there is a way to include a temporal component as well.
6. Consideration of Sound Quality Indicator (SQI), resulting from AHRI sponsored research at Penn State (PI: Hodgdon) (because tones does factor into SQI)… someday this information will become mandatory from manufacturers.

For this research, consensus is that it's best to use narrow band data and apply the psychoacoustically developed metrics of PR and TNR (already used in standard ANSI S1.13).

Researcher will be asked to use high quality equipment and specify what FFT procedures

will be applied (window, number of lines, etc), and also perhaps to determine what the variability of metrics would be based on FFT settings.

Part of research scope may also be to compare reliability of different metrics (PR, TRN, 1/3, 1/12, 1/24 octave band data) in assessing annoyance of tones … can a new technique be proposed, using one-third octave band data?

C. Signal/measurement details

1. Number of signals to test?
    a. Hellweg-Nobile study (2002) only looked at 250 Hz and 1000 Hz b. Vary frequency of tones
        i. Should include 29.5 Hz fundamental … because that's motor rpm; plus sixth harmonic (177 Hz) which is the one that particularly sticks out (Hopkins shared a typical spectrum)
        ii. Low frequency tones (60 Hz fundamental)
        iii. Mid frequency tones (250 or 300 Hz fundamental)
        iv. Higher frequency tones (750 or 800 Hz fundamental)
        v. As high as 1000 Hz (screw chillers moving in this direction…)
        vi. One proposal: include 7 fundamental tones alone (29.5, 60, 125, 250, 500, 750, 1000 Hz) and also all of the above with harmonics (e.g. 29.5 Hz + 177 Hz, etc.)
    c. Vary number of levels?
        i. Rather than using set levels, Oliver (after reviewing ASHRAE Std 55) suggests a similar test procedure of magnitude adjustment … allow subjects to adjust levels until the point at which the tone is considered acceptable (not annoying).
        ii. Approach 'annoyance threshold' from both above (with PR too high) and below (PR too low)?
        iii. Test effect of the base absolute level of the background noise … so is 18 dB PR above a 50 dBA noise more annoying than 18 dB PR above 30 dBA noise? (Steve Wise's hypothesis is that a smaller PR is required at higher levels, and a larger PR at low levels.) Maybe this would be a Phase I of research?

2. Questions that remain…
    a. Should we have test signals mimic spectra produced by actual equipment? Or completely digitally synthesize (tone on top of pink noise spectrum)?
    b. No need to add other subjective tests, or questionnaire … or should we consider?
        i. Paired comparison tests between signals where subjects rate annoyance
        ii. Attention
        iii. Working memory, cognitive load

iv. Similar questions to those used by Berkeley's Center for Built Environment : two fundamental questions
- "Are you dissatisfied with the acoustics?"
- "Does it interfere with your work (or with what you're trying to do)?"

D. Ongoing Tasks
1. Volunteers to take this information to draft RTAR: Lily Wang, Mark Schaffer, Patrick Oliver, Steve Wise
2. RTAR to be discussed in Dallas, 1.5 hours requested for criteria meeting

III. Standard 189.1 "Standard for the performance of high performance buildings, except for low-rise residential buildings"
A. Schaffer mentioned that the new revision seems to include table of acceptable BNL due to HVAC equipment, listing NC/RC/NCB for design
B. Will move forward by attending meeting on Tuesday, and suggesting that they only include NC and dBA, in line with our Handbook Applications Chapter
C. There is a TC 2.6 Standards Subcommittee, currently being led by Joe Bridger

ASHRAE TC 2.6 Criteria Subcommittee Report

Meeting Minutes

23 June, 2013
Submitted by: Lily Wang

Attendees: J. Bridger, V. Clemente, J. Dunlap, R. Hassler,R. Keith, D. LaForgia, P. Marks, D. Meredith, E. Miller-Klein, P. Oliver, K. Roy, M. Schaffer, M. Schwob, L. Vargas, J.Wang, L. Wang

I. Scope/purpose of the criteria committee: "To define and promote measurement protocols and benchmarks/guidelines/criteria to evaluate building acoustics, as related to building mechanical systems"

II. Update on RTAR on Tones
   A. Comments from TC 2.1 review were presented.
      1. Annoying 80%? Shouldn't we aim for lower numbers (20%)?
      2. "Performing experiments in the field, in a series of well-defined and very different contexts at work and at home, will produce findings that are more then be relevant and useful."
      3. "Focus on audibility in context, defined perhaps as the proportion of occupants in each context who spontaneously mention noticing the presence of equipment noise against the normal noise background from other sources, including noise from traffic and occupants' activities and conversations."
      4. Perhaps focus on acceptability rather than annoyance (increase acceptability, decrease annoyance)
   B. Some other final minor revisions made by subcommittee (see attached).
   C. Draft RTAR submitted for vote to TC 2.6 (14 for – 0 against – 1 abstain – 2 absent) and TC 2.1 (7 for – 0 against – 2 abstain – 3 absent) in early May.
   D. RTAR subsequently submitted to RAC by May 15 deadline, and expected to be voted upon at the Denver conference.
   E. [Update: RAC returned with comments; subcommittee will review and resubmit.]

III. Development of Work Statement on Tones:

   A. Summary of Dallas (+prior) Discussion

      1. Definition of the research question: "At what point is a tone in noise rated as 'annoying' by certain percentages (10%, 20%, 50%, etc) of the general population?"
      2. WHO: Definition of 'general population'… Normal hearing adults, ages 19 to 65?; investigators should consider subjects' noise sensitivities and compare against any published normal distributions
      3. WHAT (Signals):
         a. Tones: 7 fundamental (29.5, 60, 120, 240, 500, 750, 1000 Hz), alone and also all of the above with harmonics (e.g. 29.5 Hz + 177 Hz, etc.) =

14 tonal signals … two of these fundamental frequencies (marked in red) were modified away from 125 and 250 Hz, per M. Schaffer's suggestion.

b. Level of the tones: varying levels

c. Background level and/or spectrum:

i. Include testing to determine if the base absolute level of the background noise impacts the perceived annoyance of a tone
…so is 18 dB PR above a 50 dBA noise more annoying than 18 dB PR above 30 dBA noise?

d. Multiple (non-harmonic) tones and fluctuating tones will not be covered in this RTAR, but may be a topic for future research

4. HOW (Methodology):

a. Test a 'worst case' scenario where participants do not have control over the tone

b. For this research, consensus is that it's best to use narrow band data and apply the psychoacoustically developed metrics of PR and TNR (already used in standard ANSI S1.13)

c. Researcher will be asked to use high quality equipment and specify what FFT procedures will be applied (window, number of lines, etc), and also perhaps to determine what the variability of metrics would be based on FFT settings.

B. Questions that remain …

1. WHAT (Signals)

a. Generation: Should test signals mimic spectra produced by actual equipment? Or be completely digitally synthesized (tone on top of pink noise spectrum)?

i. J. Wang commented that we can filter live spectra as needed. ii. Consensus was to digitally synthesize, tones on top of a common spectra produced by equipment. b. Bandwidth: what bandwidth of the tones?

i. Mechanical/electrical tones tend to be narrow in bandwidth,

while aerodynamic tones tend to be wider in bandwidth. Perhaps in Work Statement state: "Bandwidth of tones should match typical building systems equipment."

c. Levels: ranging from below detectability to above annoyance

levels d. Background noise spectrum: RC contour?

i. Consensus was to start with recording of HVAC noise (i.e. measured at inlet of large 30" FC fan) and then shape to match an RC contour

e. Signals with harmonics: investigator should consider probable harmonic structure of building services equipment

2. HOW (Subjective testing methodology)

a. Field studies: "Performing experiments in the field, in a series of well-defined and very different contexts at work and at home, will produce findings that are more then be relevant and useful." (feedback from TC 2.1)

i. Much discussion centered on how this test method could get to the heart of what we want to know.

ii. Perhaps investigator would coordinate with some large firms (with open offices and masking systems; maybe military spaces), to irradiate floors of workers with different acoustic stimuli. Then every hour the workers could buzz in on whether
or not the work environment has been acceptable over the past hour? And what was it about the environment that caused unacceptability?

iii. Consider using Berkeley's CBE survey? Software program already exists… but would they allow us to use it?

iv. Does this method give loss of control of the experiment? Or does it price the research project out of range? We need to be able to separate crap from gold (no good to polish a turd, so to speak). Subcommittee will try to do some preliminary calculations on time/cost.

v. Perhaps some combination of lab tests, validated with field test results? Could seek to mimic field environment in the lab… have subjects work for 4 or 8 hour day, interrupt every hour with survey on acceptability of environment.

vi. Another alternative… Management says to staff: we are participating in an environmental study next week; whenever you find the environment unacceptable, shoot an email to this address. Others felt that staff would be more likely to ignore such a mandate!

b. Direct assessment (lab study): expose test subject to a tonal signal (for how long?) … ask subject to rate if that acoustic environment is annoying (maybe on an annoyance scale? Maybe after they have been working on some task?)

i. Pros: analysis to answer the research question can be straightforward

ii. Cons:

- to do this expediently, may have to test signals back to back … which could cause subjects to judge comparatively (e.g. 14 tones x 5? discrete PR levels x 2 base BNL levels x 10 minutes = ~24 hours per subject) x 100 subjects = $?
- If subjects aren't doing any task, then the annoyance responses may be superficially inflated (or deflated)

asked to compare them (rate which is more annoying, or move slider bars for both signals)

i. Pros: Possible reduction in number of tests??

ii. Cons: harder to answer the research question, easier to obtain relative annoyances (but we already know what we expect those to be)

d. Magnitude estimation (lab study): the subject can change the level of the tone in the noise until they decide that it is just annoying

i. Pros: analysis to answer the research question is straightforward; used to determine thermal comfort in ASHRAE Std. 55

ii. Pros: no worries about defining an exposure time … subject makes decision at their own pace

iii. Cons: Subjects won't be doing any tasks then, so annoyance responses may be superficially inflated (or deflated)

iv. Cons: Would there be a difference in approaching the

annoyance threshold from below or from above? Maybe would have to pilot test.

e. Cognitive load through completing two competing tasks (lab study): involves determination of task load under each acoustic condition (e.g. answer listening comprehension tasks while conducting an adaptive rotor pursuit task), followed by subjective questionnaire

i. Pros: getting more data than just the subject's own opinion of whether they are annoyed. Can find out what speed the rotor pursuit task is to maintain 70% on-task ("80% of subjects resulted in at least 20% decrease in rotor pursuit task speed when PR = *")

PR	Comprehension Tests	Rotor pursuit task speed to maintain 70% on task	Annoyance (scale of 1-100)
9	90%	14 cm/sec	33
12	90%	4 cm/sec	48

ii. Cons: not answering our research question directly… unless you decide that the point where they mark 50 on the annoyance scale counts as a threshold

iii. Cons: maybe there won't be an effect on the APR task (even though people are annoyed)

f. Working memory – ability to retain target information

what type of subjective test is used)

a. RP-1322 suggests that each exposure should be separately scheduled, rather than back-to-back which allows more relative comparison by the test subjects.

4. Subjective questionnaires

a. UC Berkeley's Center for Built Environment model with 2 fundamental questions

i. "Are you dissatisfied with the acoustics?"

ii. "Does it interfere with your work (or with what you're trying to do)?"

b. NASA Task-Load Index: http://humansystems.arc.nasa.gov/groups/TLX/index.html

IV. Ongoing Tasks
   A. RTAR subcommittee to review RAC comments and modify further (L. Wang, P. Oliver, M. Schaffer, S. Wise)
   B. Submit to RAC Liaison for review
   C. Aim to complete TC 2.6 and TC 2.1 email ballot vote so that we can submit prior to RAC's next RTAR deadline of 8/15
   D. L. Wang and C. Eichelberger will endeavor to be on the next RAC conference call discussion
   E. Continue to work on details for eventual Work Statement at next meeting in New York City (request 1.5 hours)

ASHRAE TC 2.6 Criteria Subcommittee RTAR

Annoyance Thresholds of Tones in Noise as Related to Building Services Equipment

Unique Tracking Number Assigned by MORTS

RESEARCH TOPIC ACCEPTANCE REQUEST (RTAR) FORM

(Generally 2 to 6 pages, with 10 pt Times New Roman font)

Sponsoring TC/TG/MTG/SSPC/EHC/REF:_____ TC 2.6 Sound and Vibration Control_____

Title:
Annoyance Thresholds of Tones in Noise as Related to Building Services Equipment

Applicability to ASHRAE Research Strategic Plan:
This project is directly applicable to Goal 4 of the ASHRAE Research Strategic Plan 2010-2015 (Navigation for a Sustainable Future) "*Significantly advance our understanding of the impact of indoor environmental quality (IEQ) on work performance, health symptoms and perceived environmental quality in offices, providing a basis for improvements in ASHRAE standards, guidelines, HVAC&R designs and operation practices.*" Tones in noise associated with building services equipment are a source of complaints presented by building occupants and neighbors. Additionally newer more efficient designs of equipment are producing louder tones. This research project seeks to quantify the threshold at which the degree of tonalness in noise cause assorted percentages (i.e. 10%, 25%, 50%) of the general public to consider it annoying, similar to the thermal comfort and ventilation studies that have been applied in ASHRAE Standards 55 and 62. Such knowledge will advance understanding of how acoustic conditions impact the perceived environmental quality, upon which new guideline criteria can be established. This will eventually assist ASHRAE members with finding cost-effective means to limit the impact of tonal noise.

Research Classification:
Basic/Applied Research

TC/TG/MTG/SSPC Vote:
(For –Against-Abstentions-Absent-Total)
14 For-0 Against-1 Abstaining-2 Absent-17 Total

Reasons for Negative Votes and Abstentions:
(Negative Votes): 0
(Abstentions): 1 … ambivalence towards topic

Estimated Cost:
$180,000

Estimated Duration:
24 months

RTAR Lead Author
Lily Wang, LWang4@UNL.edu
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Expected Work Statement Lead Author
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Co-sponsoring TC/TG/MTG/SSPCs and votes:
TC 2.1 (7 For – 0 Against – 2 Abstaining – 3 Absent – 12 Total)

Possible Co-funding Organizations:
NA

Application of Results:
Results will be included in the chapters on sound and vibration in future editions of the ASHRAE Handbooks on HVAC Fundamentals (currently Ch. 8) or HVAC Applications (currently Ch. 48).

State-of-the-Art (Background):

There is a recent thrust for manufacturers of building services equipment to develop and produce more energy efficient equipment. However, the improved efficiency often comes at the price of poor sound quality because the tonal components of the equipment noise become stronger (for example, screw chillers, or heat pumps which are often located very near occupied spaces).

Currently, designers of building mechanical systems can use the table of noise criteria guidelines in Chapter 48 of the ASHRAE HVAC Applications Handbook (2011) to help them design HVAC systems that will meet acceptable noise conditions for assorted types of spaces. However, these criteria do not apply well if the noise contains perceptible tones, as commonly produced by building services equipment with tone-producing components such as compressors, fans, motors, transformers, etc. (The tables in the current Handbook actually note that in using the listed guidelines, it is assumed that there are no tones present in the background noise.) TC 2.6 does not find that sufficient data exist to be able to provide guidelines for noise with tones at this time; the annoyance thresholds experienced by the general population with regards to the degree of tones in noise is a significant piece of knowledge that is currently unknown.

The topic of noise with tones has generated much interest over the years, as many other types of equipment (aircraft, industrial machinery, and other office equipment) generate such spectra as well (Kryter and Pearsons 1965, Hellman 1982, 1984). A number of methods have been developed for quantifying the prominence of the tone in the noise or its 'tonalness', including Tone-to-Noise Ratio (ANSI S1.13-2005), Prominence Ratio (ANSI S1.13-2005), and Aures' Tonalness metric (1985). A round robin test was conducted to compare the two metrics discussed in ANSI S1.13, Tone-to-Noise Ratio and Prominence Ratio (Balant et al. 1999, Hellweg and Nobile 2002). They found that for broadband noise with a single prominent tone, the two metrics correlate well with each other and also with the degree of tonalness perception, but further issues need to be clarified regarding more complex tones (e.g. multiple tones in the same critical band, harmonic series of tones, or time-varying tones). Some work has been directed towards dealing with these more complex cases (Hellman 1985; Hastings et al. 2003, Lee et al. 2004, 2005). Many of these previous investigations have focused on how the tonal additions affect the perceived loudness of the acoustic signal, but none has directly sought to determine the human thresholds of annoyance for tones in noise.

The recent revision of ANSI S1.13 in 2005 includes the work of Hellweg and Nobile (2002), updating the prominence ratios at frequencies less than 1000 Hz from the previously listed value of 7 dB to range between 9 dB (at 1000 Hz) and 19 dB (at 100 Hz). Hellweg and Nobile's study, though, was limited in that they extrapolated their findings based on testing only two tonal frequencies (250 Hz and 1000 Hz). Furthermore, their subjective questionnaires focused on the perception of 'prominence' rather than annoyance.

ASHRAE TC 2.6 committee has determined that there is consequently a significant gap in knowledge that must be filled with regards to tones in noise. At what point is a tone in noise rated as 'annoying' (not just prominent) by the some percentage (i.e. 10%, 25% or 50%) of the general population? If one knows that the HVAC equipment is producing a certain tonalness, does one have to design acoustic attenuation into the system? We are currently unable to base such decisions on solid experimental evidence, but rather the issue is left unaddressed (which can result in complaints) or is over-designed to compensate for the lack of knowledge.

Ventilation-like noise spectra that specifically include tones have been utilized in a few investigations involving perception or performance, but all of these studies have been limited to testing across six or less signals each. The results sometimes show that the presence of tones can impact perception or performance (Landström et al. 1991, 1993, 1994; Holmberg et al. 1993; Ryherd and Wang 2010), but again no one has been able to comprehensively provide guidelines for what the threshold of annoyance for tones in noise should be across a wide range of tonal frequencies. In particular, the study by Ryherd and Wang (2010), sponsored by ASHRAE, tested three frequencies (120 Hz, 235 Hz, or 595 Hz) at two prominence ratios (5 and 9). These two prominence ratios were selected based on the previous version of ANSI S1.13-2005 which listed the prominence ratio as 7 across all frequencies; but the gathered results support Hellweg and Nobile's finding that such prominence ratios do not cause significant annoyance across all test participants at the frequencies tested.

Further work is required to link tonalness levels to human annoyance thresholds, and to determine an industry-accepted metric for quantifying the tonal nature of building services equipment.

Advancement to the State-of-the-Art:
This research will provide quantitative data on the levels of tones in noise that cause certain percentages (such as 10%, 25%, or 50%, etc.) of the human population to be annoyed, which is not currently available. This informative data will lead to better designs with regards to the amount of acoustic attenuation to apply to tonal equipment installations so that the tone level is acceptable, reducing the number of complaints, and conversely improving occupant comfort and performance in the built environment.

Justification and Value to ASHRAE:
As noise can impact all ASHRAE members, this research has great value to the entire society. We estimate that 100% of the society in total will be affected within 10 years, as the data gathered in this project are embedded into the ASHRAE Handbooks and eventually into design criteria, regarding noise from building services equipment. A further benefit is that manufacturers of building services equipment will have quantitative guidelines with which to benchmark their equipment. Eventually the data can lead to or inform the development of an industry-accepted metric to quantify the tonal nature of equipment noise. We do not foresee any intellectual property rights resulting from this project.

Objectives:
The project goals are to:

- ☐ Determine what the human annoyance thresholds are of tones in noise, across the most common tonal frequencies found in building services equipment
- ☐ Determine if those thresholds vary, depending on whether there is a single fundamental tone (e.g. only 60 Hz) or multiple harmonics (e.g. 60 Hz + 120 Hz)
- ☐ Determine if those thresholds vary, depending on the absolute level of the ambient background noise; that is, does a certain tonalness above a low background noise level demonstrate the same annoyance as that same tonalness above a higher background noise level?

Subjective studies will be conducted by exposing test subjects to assorted tonal noise signals. Further details on the proposed testing procedures (lab versus field studies; direct assessment, magnitude adjustment, or comparison methods; etc.) will be developed when working on the Work Statement, if this RTAR is approved. Statistical analyses of the gathered data will result in an anticipated table of the annoyance thresholds across tonal frequencies.

Key References:
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