

**Room Acoustics and Background Noise at  
The Curtis R. Priem Experimental Media and Performing Arts Center**

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Supported by EMPAC  
Rensselaer Polytechnic Institute  
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## Overview

The Curtis R. Priem Experimental Media and Performing Arts Center (EMPAC) is among the highest calibre performing arts facilities in the world. All stages of its design and construction were executed with the intent of high performance in room acoustics, background noise, and sound isolation. Each of the four primary venues at EMPAC - the Concert Hall, Theater, Goodman Studio 1, and Studio 2 - were designed with layout, volume, distribution of surfaces, and variable acoustic systems that allow them to comprise a large continuum of acoustic possibility.

This report contains room acoustic and background noise measurements performed in 2011. Its purpose is to inform artists and researchers who will use EMPAC for their work. For room acoustics the usual frequency range of testing was extended to higher and lower frequencies using a supplemental high-frequency omni source and low-frequency subwoofer, respectively. For background noise a special low-noise microphone was used. An equipment list is available at the end of this report.

Reverberation time (RT) is currently the most widely used room acoustic parameter and is reported here. The impulse responses used to calculate RT are available in EMPAC's archives for further analysis and creative use. For background noise Room Criteria (RC) is reported, which is a single number rating that is in common use. RC requires full octave band data, which means much of the nuances of spectrum can get lost, so one-third octave band data is also provided in the form of additional background noise plots. These additional plots yield more information on the spectral qualities the listener might discern while in the spaces.

RT was calculated carefully while monitoring the best fit line and sometimes choosing it manually. This was done for accuracy since automatic fitting can skew results, sometimes into meaningless territory.

Note that the main venues at EMPAC are so quiet that RC values often fall far below the reference curves. When this happens distinctions such as "neutral" and "tonal" do not carry their intended meaning. When this occurs these distinctions were disregarded.

## Measurement Equipment - Room Acoustics (Impulse Response Acquisition)

All RT measurements were conducted in unoccupied conditions with mics at 4'-6" above finished floor.

- Dodecahedral loudspeaker [School of Architecture]
- High-frequency dodecahedral loudspeaker [School of Architecture]
- Custom crossover for low, mid, and high signal distribution [School of Architecture]
- Custom amplifier for dodecahedral loudspeakers [School of Architecture]
- d&b audiotechnik Q-Sub [EMPAC]
- d&b audiotechnik D6 amplifier [EMPAC]
- Earthworks M30 [2x Architecture, 5x EMPAC]
- DPA 4006 [2x EMPAC]
- Neuman KM 183 [2x EMPAC]
- Laptop running EASERA
- M-Audio ProFire 2626 audio interface [EMPAC]
- FuzzMeasure Pro 3.2.3
- Archivox Room Impulse Response Software 1.0

## Measurement Equipment - Background Noise

- Brüel & Kjær 2270 sound level meter
- Brüel & Kjær 4955 ½" low-noise microphone Ser. No. 2694938

## Venue Descriptions

### *Concert Hall*

The geometry of the Concert Hall at EMPAC is a modified shoebox that is a strong step toward a new typology. The form was developed to accommodate the requirement that sound sources could be placed anywhere in the room, and not just on the stage. This led to convex walls and ceiling - a macro-scale "diffusion" - that works in tandem with meso-scale diffusive treatment covering the upper side walls, gallery walls, and upstage walls. The large scale shaping allowed the diffusive treatment to be acoustically mild, which is an important step away from the aggressive treatment often seen in concert halls. The ceiling is made of a medium-weight fabric of flame resistant Nomex fibers - the product of a substantial development effort - that selectively transmits lower frequency sound while reflecting higher frequencies for reverberation and communication. The front half of the room is a two-ply fabric and the rear is a single ply. The side galleries are inset and the lower walls are flat and massive, an approach which provides strong lateral reflections for a sense of envelopment. The Concert Hall as a whole is incredibly massive, with a thick concrete enclosure and heavy, fully backed interior surfaces to retain bass energy. Adjustable absorptive banners can be deployed on all wall surfaces, including the galleries, to reduce reverberation time. Heating and cooling are supplied via a perforated floor slab from a near-silent underfloor plenum. The seats were designed for EMPAC<sup>1</sup>. The Concert Hall rests on its own structure, isolated from the rest of the building. It seats 1273.

### *Goodman Studio 1*

Studio 1 is a black box space which could be described as acoustically inert, neither live nor dead. Its heavy concrete enclosure retains energy at all frequencies including lows, but its sound is highly controlled. Studio 1's form is rectangular with walls clad in a mixture of diffusive and absorptive panels, both specifically designed for EMPAC. The diffusive panels are cast from glass-fiber reinforced gypsum in an integral black color, and are backed with a layer of damping material<sup>2</sup> to control resonance. The design of the panel was driven by continuity across scales of audible sound, beginning with the finely machined surface texture, overlaid with surface holes of increasing scale, carrying through to the cylindrical form of the panel itself, and finally to the spacing and positioning of the arrays of panels as a whole. The absorptive panels are finished in black anodized aluminum and also cylindrical in shape. They are not traditional porous absorbers, but instead rely on the air permeability of fabric sandwiched between layers of perforated metal. They absorb about sixty percent of incident sound in broad band fashion. The diffusive and absorptive panels are arranged in a weighted pseudo-random pattern, with the frequency of absorptive panels increasing high in the room, and the erratic nature of tilt increasing at the corners. Absorptive banners can be deployed from the ceiling to cover the walls in whole or in part. Custom bass absorbers - panel and cavity resonators - line all wall surfaces behind the panels, and more traditional absorptive banners can be deployed to result in a very dead acoustic. Studio 1 is true box-in-box, with the interior box floated on large isolations springs to prevent transfer of sound and vibration. Studio 1 has 3400 square feet (315 square meters) of floor area, and a distance of 32'-3" (9.75 m) from floor to walkable grid.

### *Studio 2*

Studio 2 is of similar shape and layout to Studio 1, but is smaller. Its walls are lined entirely with white diffusive panels - the same as those for Studio 1 - with no absorptive panels or bass absorbers present. Absorptive banners can be deployed from the ceiling to cover the diffusive walls. The room's most reflective condition - when banners are retracted - is almost entirely diffusive. This results in high speech intelligibility and a reverberation time that is lower than predicted by reverberation time equations. Studio 2 is not floated on springs as Studio 1 is, but does rest on its own foundation to prevent structure-borne vibration transmission. Studio 2 has 2475 square feet (230 square meters) of floor area, and distance of 18'-5" (5.6 m) from floor to walkable grid.

### *Theater*

The Theater is perhaps the most traditional acoustic space, though it shares many features with the other venues, such as the same seating and underfloor air supply as the Concert Hall. The surfaces are simple and the side walls offer horizontally-retractable absorptive curtains for acoustic variability. The Theater is the only space with a strong acoustic "directionality", meaning that sources work best when on stage with the audience in the designated seating area, whereas the three other venues function very well with sources and audience in any location. When performers are placed in the balconies at the rear of the space, flutter echo can occur between the rear portions of the side walls if the absorption is retracted. The Theater seats 397 and has a large stage of about 3200 square feet (297 square meters).

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<sup>1</sup> The author believes the split wood design of seat and back absorb less bass energy than typical seat designs and therefore are an important part of the bass response of the room, but this is speculation.

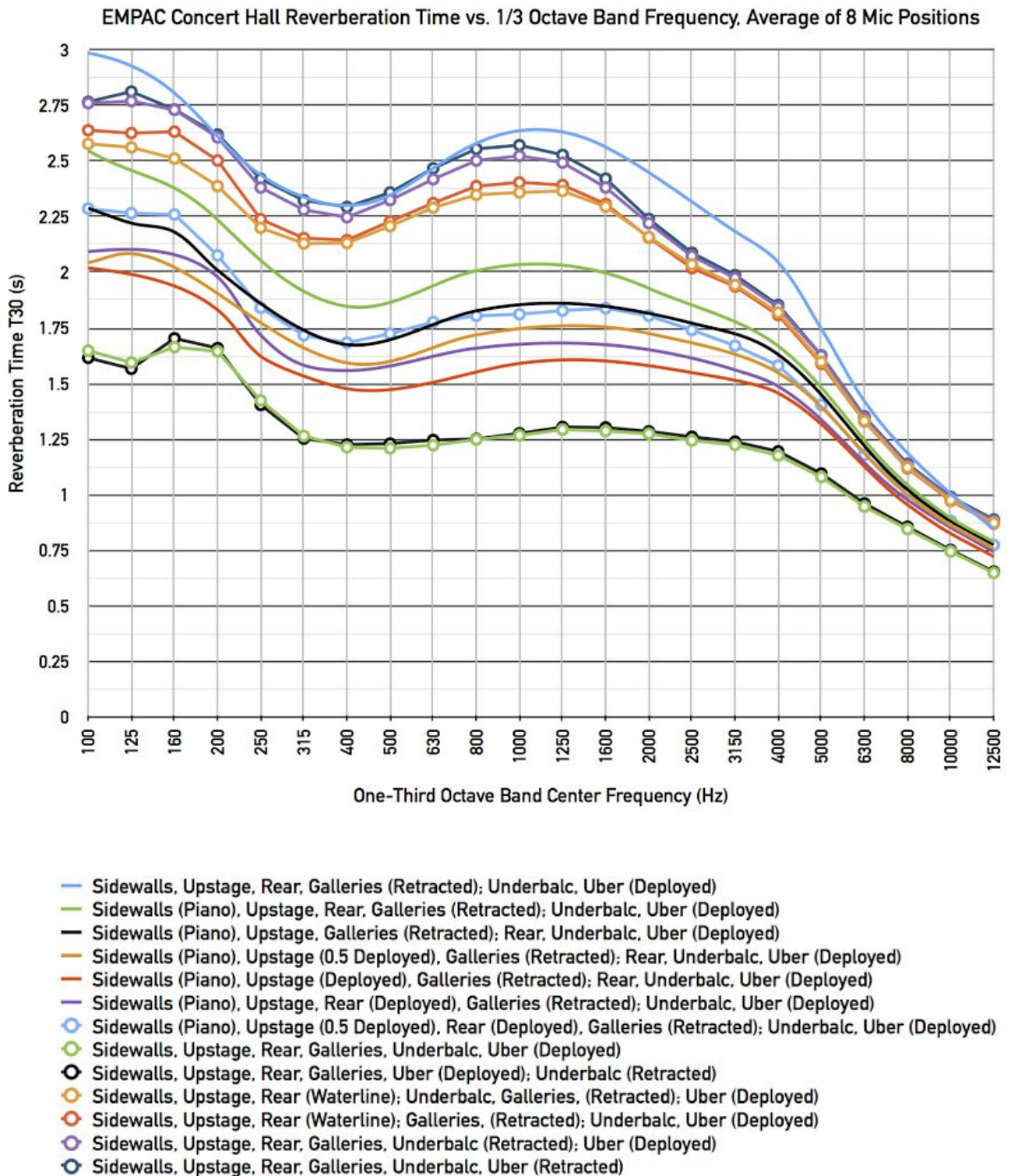
<sup>2</sup> The damping layer was added after the opening of EMPAC when it became apparent that the resonance of the panels was distracting in the near-silent room.

### *Additional Spaces*

A variety of other spaces are important for the acoustic function of EMPAC, including Audio Production, Studio Beta, and the Conductors Suite, among others. These spaces were measured for background noise but not room acoustics.

Room Acoustics - Reverberation Time Plots and Notes

Concert Hall Room Acoustics (19 March, 2011)



"Waterline" means the banners cover the opening of the technical galleries, just above the fabric ceiling.

"Uber" means the absorptive panels that hang in the rear of the room, above the fabric ceiling

"Underbalc" means the banners on the rear (east) wall below the balcony, on either side of the doors

"Piano" means deployment of banners on side walls in four levels: in stage area all the way down; along parterre seating 3/4 down, then 1/2 down and 1/4 down

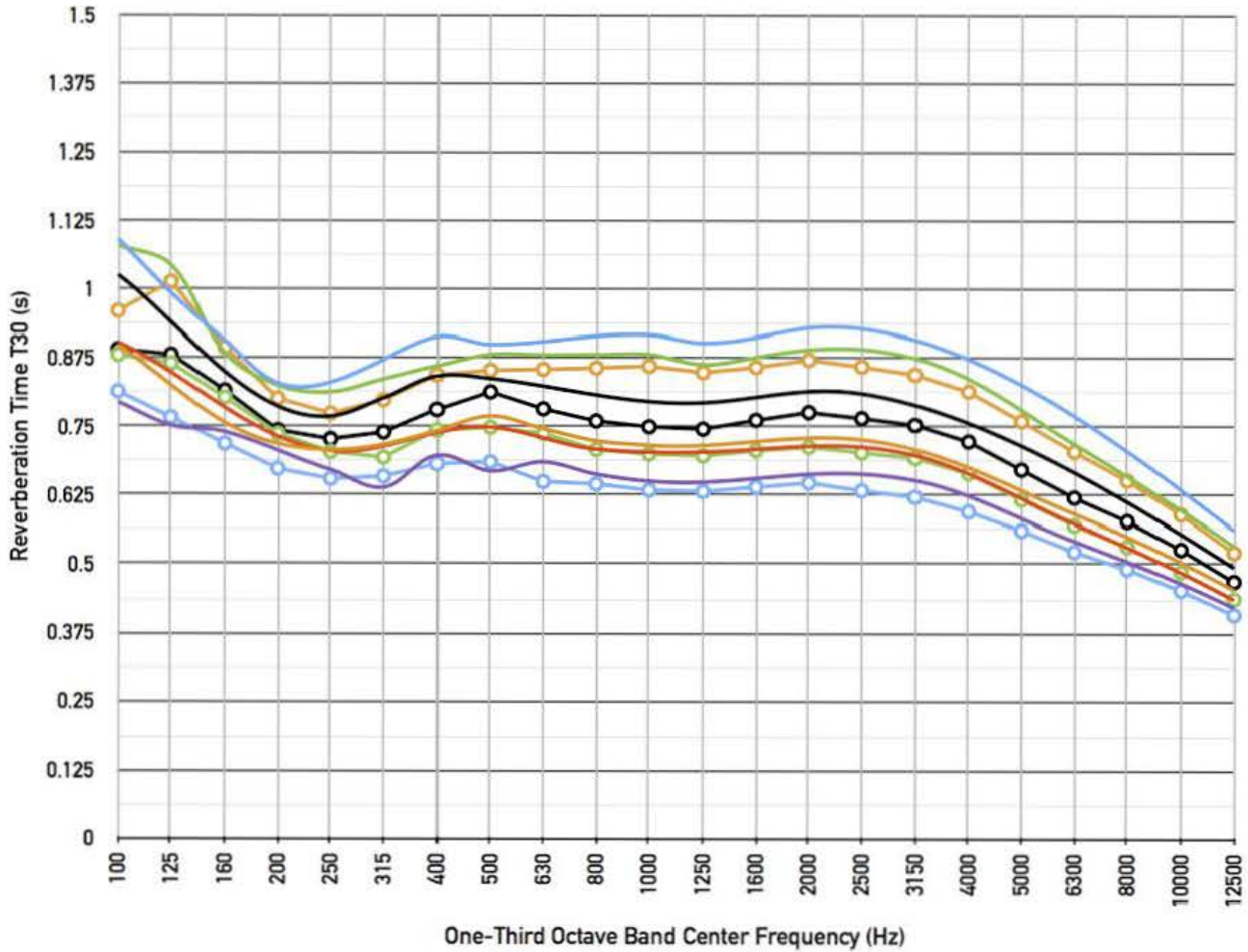
Banner Conditions

<i>Meas. #</i>	<i>Sidewalls</i>	<i>Upstage</i>	<i>Rear</i>	<i>Underbalcony</i>	<i>Galleries</i>	<i>Uber</i>
1	Retracted	Retracted	Retracted	Deployed	Retracted	Deployed
2	Piano	Retracted	Retracted	Deployed	Retracted	Deployed
3	Piano	Retracted	Deployed	Deployed	Retracted	Deployed
4	Piano	0.5 Deployed	Deployed	Deployed	Retracted	Deployed
5	Piano	Deployed	Deployed	Deployed	Retracted	Deployed
6	Piano	Deployed	Retracted	Deployed	Retracted	Deployed
7	Piano	0.5 Deployed	Retracted	Deployed	Retracted	Deployed
8	Deployed	Deployed	Deployed	Deployed	Deployed	Deployed
9	Deployed	Deployed	Deployed	Retracted	Deployed	Deployed
10	Waterline	Waterline	Waterline	Retracted	Retracted	Deployed
11	Waterline	Waterline	Waterline	Deployed	Retracted	Deployed
12	Retracted	Retracted	Retracted	Retracted	Retracted	Deployed
13	Retracted	Retracted	Retracted	Retracted	Retracted	Retracted

For all measurements the source was located at the Concertmaster position and the microphones were located as follows:

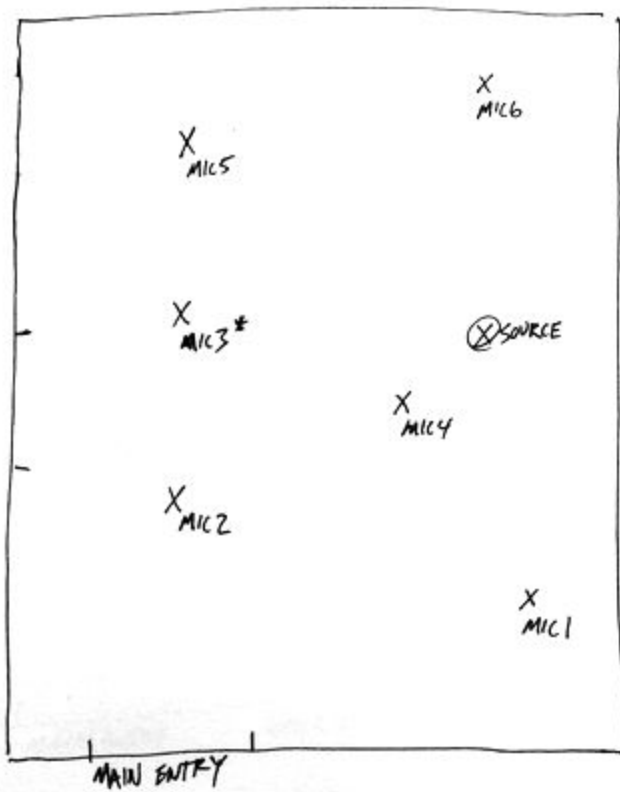
<i>Mic #</i>	<i>Location</i>
1	Stage
2	Parterre Row L1 Seat 6
3	Orchestra Row I Seat 17
4	Orchestra Row J Seat 27
5	Balcony Row A2 Seat 18
6	Balcony Row H2 Seat 6
7	Choral Balc Row A Seat 14
8	Gallery, house left, 3rd bay from stage, first row, middle seat

EMPAC Studio 1 Reverberation Time vs. 1/3 Octave Band Frequency, Average of 6 Mic Positions



- All absorption retracted
- Bottom 7 Rows Exposed
- Bottom 4 Rows Exposed
- No Rows Exposed Except Doors and Corner Banner Pairs. Bottom 4 Rows Exposed
- Absorption Retracted on N and E Wall.
- Bottom 9 Rows Exposed
- Bottom 5 Rows Exposed
- Bottom 2 Rows Exposed
- Absorption Retracted on N Wall.
- Absorption Retracted on N, E, and W Wa

Meas. #	Condition
1	All absorption retracted
2	Bottom 9 rows of diffusive/absorptive panels exposed
3	Bottom 7 rows of diffusive/absorptive panels exposed
4	Bottom 5 rows of diffusive/absorptive panels exposed
5	Bottom 4 rows of diffusive/absorptive panels exposed
6	Bottom 2 rows of diffusive/absorptive panels exposed, except at doors and corner banner pairs, where bottom 4 rows are exposed.
7	No rows exposed, except at doors and corner banner pairs, where bottom 4 rows are exposed.
8	Absorption completely retracted on north wall. East, west, and south walls as in 007.
9	Absorption completely retracted on north and east walls. West and south walls as in 007.
10	Absorption completely retracted on north, east, and west walls. South wall as in 007.

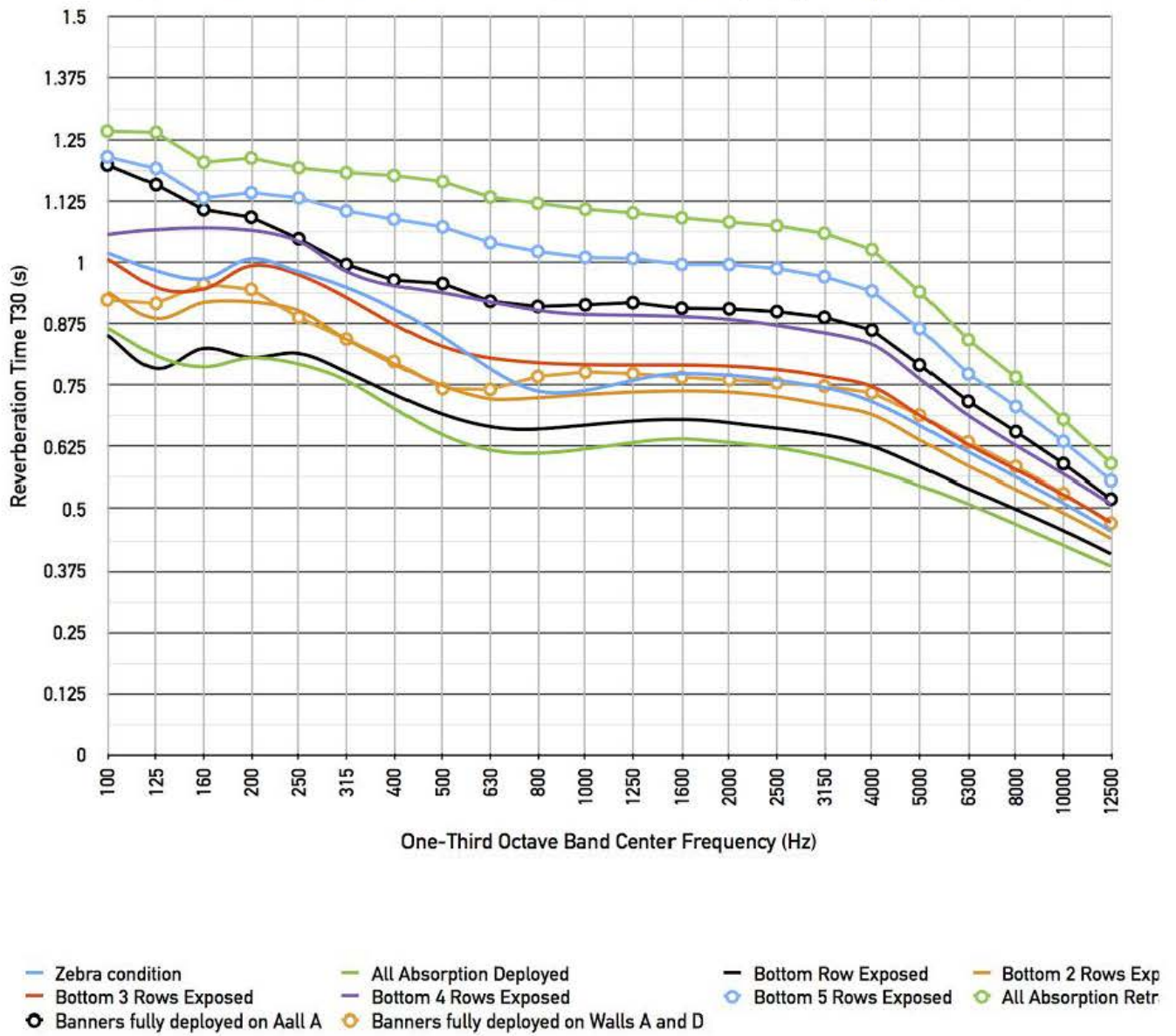


STUDIO 1 SOURCE  
AND MIC LOCATIONS

ALL MICS AT 4'-6" A.F.F.  
\* INDICATES 15'-0" A.F.F.



EMPAC Studio 2 Reverberation Time vs. 1/3 Octave Band Frequency, Average of 5 Mic Positions



Conditions tested (five microphone locations for each):

001 - Zebra condition

002 - All absorption deployed

003 - Bottom row of diffusive panels exposed

004 - Bottom 2 rows of panels exposed

005 - Bottom 3 rows of panels exposed

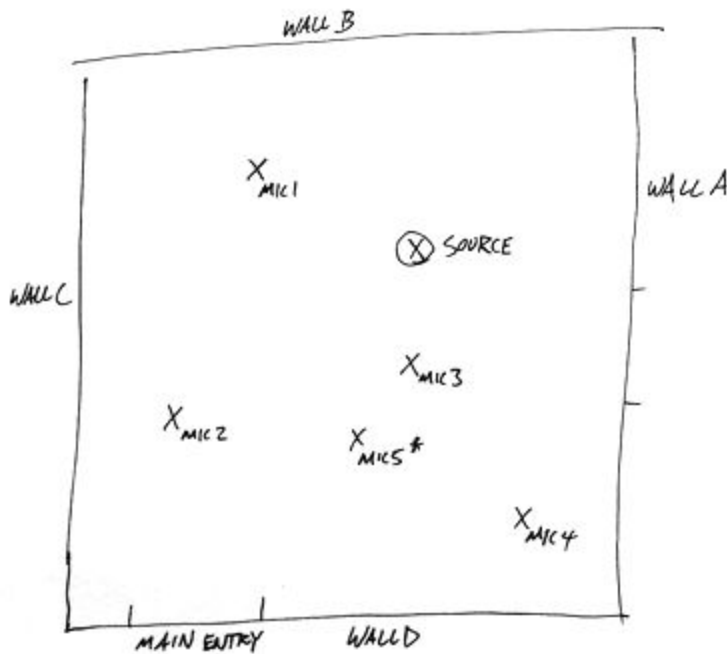
006 - Bottom 4 rows of panels exposed

007 - Bottom 5 rows of panels exposed

008 - All rows of panels exposed (all absorption retracted)

009 - Banners fully deployed on Wall A

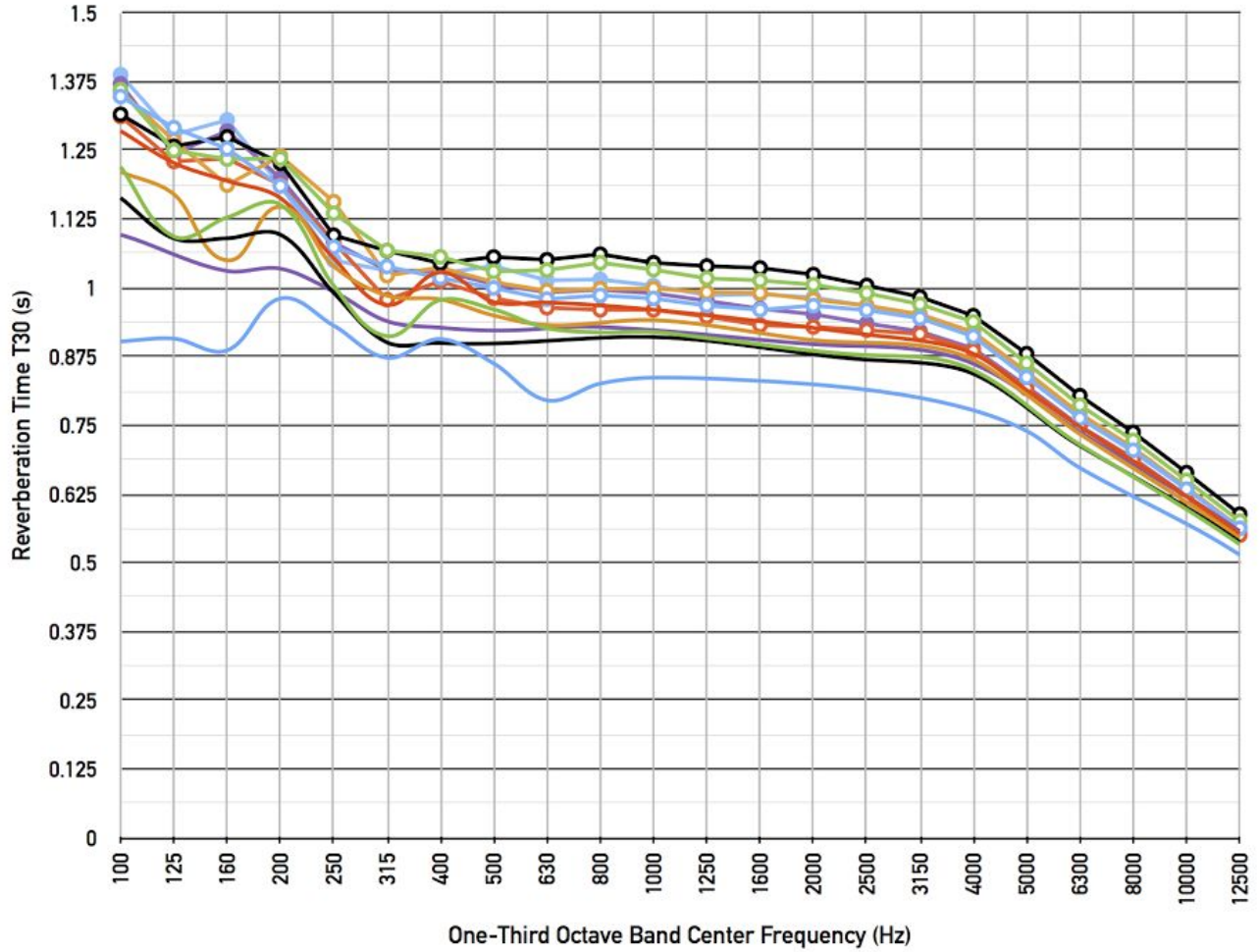
010 - Banners fully deployed on Walls A and D



STUDIO 2 SOURCE  
AND MIC LOCATIONS

ALL MICS AT 4'-6" A.F.F.  
\* INDICATES HEIGHT HALFWAY  
TO GRID

EMPAC Theater Reverberation Time vs. 1/3 Octave Band Frequency, Average of 6 Mic Positions

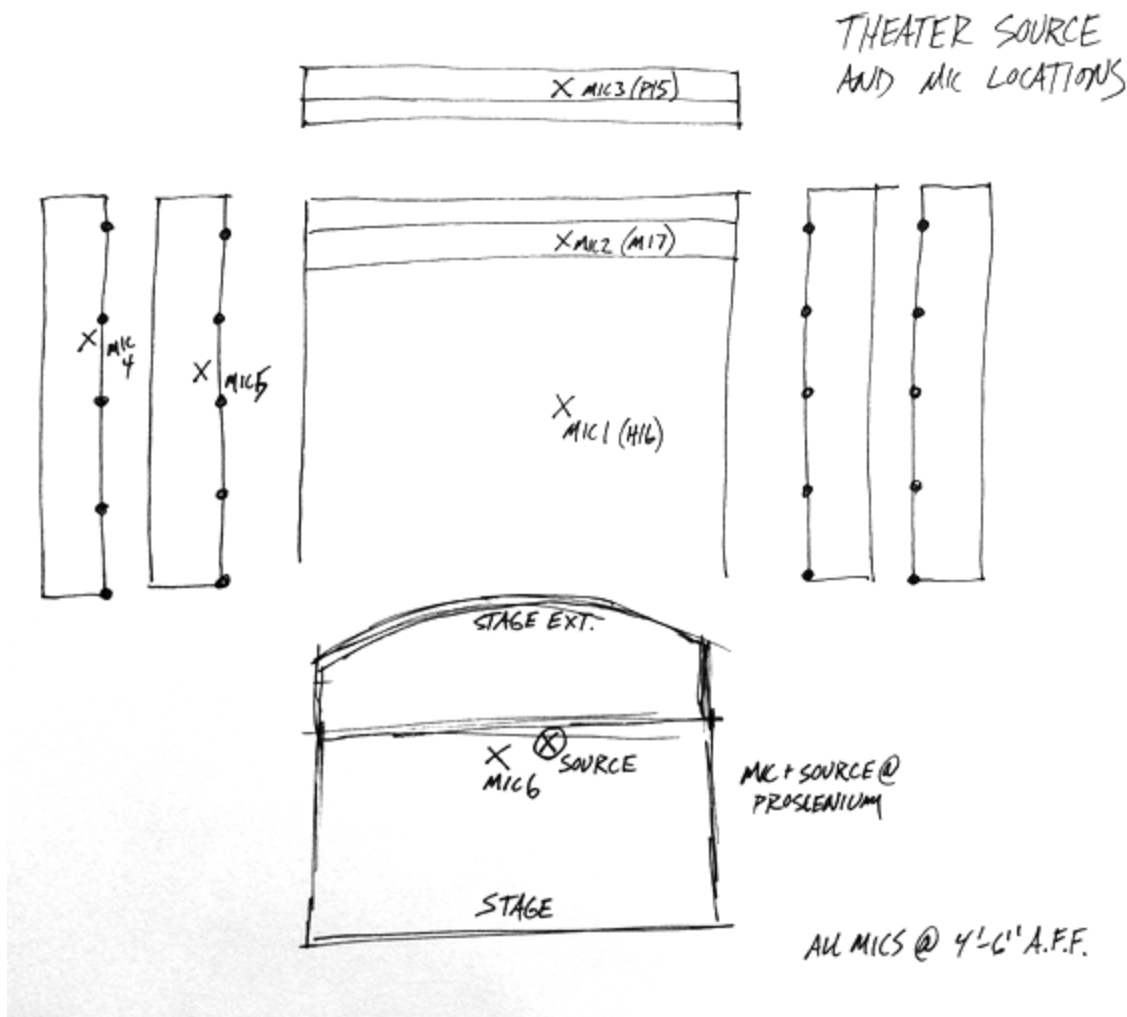


- All absorption deployed
- Rear red panel exposed
- Two rear red panels exposed
- Three rear red panels exposed
- Four rear red panels exposed
- Five rear red panels exposed
- Six rear red panels exposed
- Upper and lower gallery absorption retracted, Orchestra-level curtains deployed
- All absorption retracted
- Upper gallery fully deployed, lower gallery and orchestra-level curtains retracted
- Upper gallery and orchestra-level curtains fully deployed. Lower gallery retracted.
- Lower gallery and orchestra-level curtains fully deployed. Upper gallery retracted.
- Lower gallery deployed. Upper gallery and orchestra-level curtains retracted.

Source located at line of proscenium, just off center. The orchestra lift was at stage level.

Mic locations: Mic 1: Main floor H16; Mic 2: Under balcony drip line M17; Mic 3: Balcony P15; Mic 4: Upper side gallery; Mic 5: Lower side gallery; Mic 6: Stage near source

Meas. #	Condition
11	All absorption deployed
12	One red panel exposed (from rear)
13	Two red panels exposed
14	Three red panels exposed
15	Four red panels exposed
16	Five red panels exposed
17	Six red panels exposed (upper gallery house left panel could not be completely exposed)
18	Upper and lower gallery absorption retracted (red panels as exposed as possible, absorption stored toward stage). Orchestra-level curtains deployed.
19	All absorption retracted (most reflective room condition for any given stage condition).
20	Upper gallery fully deployed, lower gallery and orchestra-level curtains retracted.
21	Upper gallery and orchestra-level curtains fully deployed. Lower gallery retracted.
22	Lower gallery and orchestra-level curtains fully deployed. Upper gallery retracted.
23	Lower gallery deployed. Upper gallery and orchestra-level curtains retracted.



## Background Noise

Background noise measurements were conducted over multiple days. The raw notes are presented here first, followed by room criteria (RC) plots, and then by one-third octave band plots. Measurement numbers listed in the notes refer to file numbers which can be found in the archived data.

### Concert Hall (07 August 2011)

All banners retracted, uber fuzz deployed, House lights at 50%, Work lights on, Underbalcony and Gallery lights off, AHU at 0%, Projector off. For mic locations 1 - 6, see diagram. Work lights turned off, Small stage line arrays turned off

002 - Location 1

003 - Location 2

004 - Location 3

005 - Location 5

006 - Location 4

Work lights turned off

007 - Location 1 (30 s)

008 - Location 2 (30 s)

009 - Location 3 (30 s)

010 - Location 4 (30 s)

011 - Location 5 (30 s)

012 - Location 5 (5 s)

013 - Location 5 (5 s)

014 - Location 4 (5 s)

015 - Location 4 (5 s)

016 - Location 3 (5 s)

017 - Location 3 (5 s)

018 - Location 2 (5 s)

019 - Location 2 (5 s)

020 - Location 1 (5 s)

021 - Location 2 (5 s)

Small stage line arrays turned off

022 - Location 1 (30 s)

023 - Seat C24

024 - Trash

034 - Sound and Light Lock (outside door just below to the wall of the parterre seating)

### Studio 2 (07 August 2011)

Banners retracted, Lights on night setting

025 - AHU off, center of space

026 - AHU low, center of space

027 - AHU medium, center of space

028 - AHU full, center of space

029 - AHU full, SE corner of space

030 - AHU med, SE corner of space

031 - AHU low, SE corner of space

032 - AHU off, SE corner of space

033 - Trash

Note: Balance is off. The room gets much quieter with door to Control Room stair open.

### Concert Hall 08 August 2011

All banners retracted, uber fuzz deployed, House lights at 50%, Underbalcony and Gallery lights off, AHU at 0%, Projector off. For locations 1 - 6, see diagram, Work lights turned off, Emergency lights on when transformers are off, Small stage line arrays turned off, All 3 transformers off, Dimmers on

035 - Location 1

036 - Location 6

037 - Location 2

038 - Sound and Light Lock (outside door just below to the wall of the parterre seating)

039 - Location 4

All 3 transformers off, Dimmers off

040 - Location 1

041 - Location 6

042 - Location 2

043 - Sound and Light Lock (outside door just below to the wall of the parterre seating)

044 - Location 4

All 3 transformers on, Dimmers off

045 - Location 1

046 - Location 6

047 - Location 2

048 - Sound and Light Lock (outside door just below to the wall of the parterre seating)

049 - Location 4

### Theater (14 August 2011)

Fire control panel buzzing, AHU (both) set to low, House lights off, Work lights off

001 - Trash

002 - Seat D11 (front row center)

003 - On stage, center of flytower

004 - Approx 1 meter from fire control panel

005 - Seat D11 (house lights full)

Note: measurements stopped here. Noise from fire control panel dominates.

### Studio 2 (17 August 2011)

All lights off; All measurements taken in center of room

006 - AHU at low setting

007 - AHU at medium setting

008 - AHU at high setting

009 - AHU at full flow setting

Note: Background noise level very high at high and full flow settings. Seems unbalanced. When door to control room stairwell is opened pressure is balanced and noise decreases.

### Studio 1 (17 August 2011)

All lights off; All measurements taken in center of room

010 - AHU at low setting

011 - AHU at medium setting

012 - AHU at high setting

013 - AHU at full flow setting

Note: Background noise level very high at high and full flow settings. Seems unbalanced. When door to control room stairwell is opened pressure is balanced and noise decreases.

Additional Spaces (22 August 2011)

All measurements taken under normal daytime use conditions

Note in brackets [] indicates most significant noise source to the ear. When not listed there was no primary noise source noticeable.

014 - Founder's Rm [traffic]

015 - APR Rm 7510

016 - Director's Office Rm 7418 [traffic]

017 - Head of Research Rm 7414 [traffic]

018 - Curator's Office Rm 7408 [traffic]

019 - Conference Rm 7403 [HVAC]

020 - Studio 2 Control Rm 6105 [control rack]

021 - Studio 1 Control Rm 6330 [HVAC]

022 - Concert Hall Control Rm 6032 [control rack]

023 - Green Rm [traffic]

024 - Soloist Suite 2 Rm 6713

025 - Trash

026 - Conductor's Suite [traffic]

027 - Senior Research Engineer Office Rm 6607 [traffic]

028 - Vos/Desposito/Svatek Office Rm 5615 [traffic]

029 - Abbas Office Rm 5609 [traffic]

030 - Tribu-Cromme/McLaughlin/Jenkins Office Rm 5608 [transformer hum]

031 - Theater Green Rm 3607

032 - Fritz Office Rm 3615

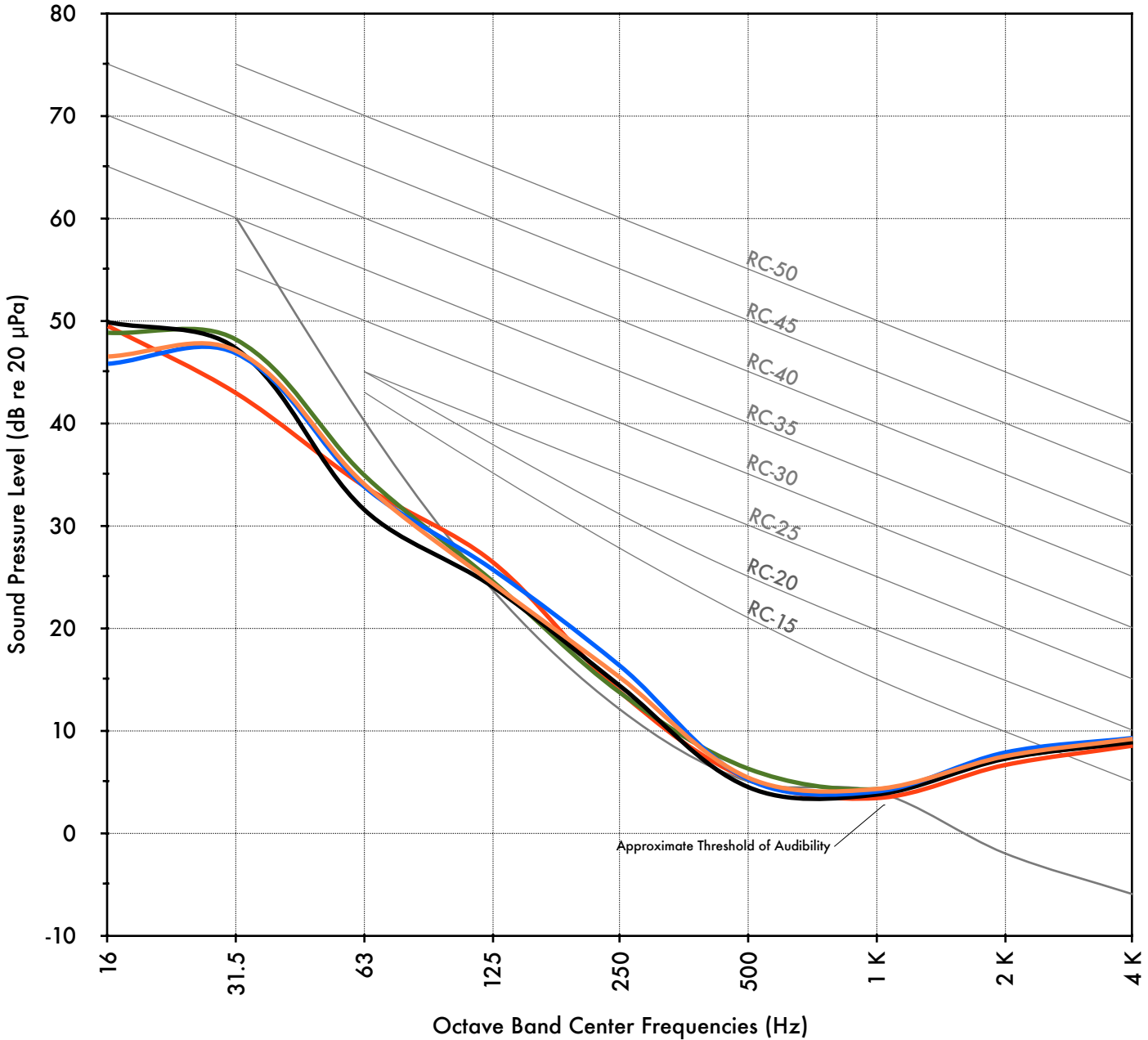
033 - Studio Beta

034 - Residence Studio 4 Rm 6609 [HVAC]

035 - Residence Studio 3 Rm 6613

Note: Video Production Rm 7504 - work underway for compressor room and machine room noise reduction. No measurements taken.

Stage	RC	5.7
Main Floor	RC	5.7
Under Balcony	RC	5.1
House Left Gallery	RC	5.9
Balcony	RC	5.1



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands  
 RC Spectrum letters appended to RC Number, when applicable, are determined as:  
 (N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.  
 (R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.  
 (H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.  
 (T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands  
 (RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.



EMPAC Background Noise

Venue: Studio 1

Date of Measurement: 17 Aug 2011

Measurement of noise from HVAC settings [Measurements R2-010, 011, 012, 013]

Center of Studio 1, HVAC at Low

RC 7.1

Center of Studio 1, HVAC at Medium

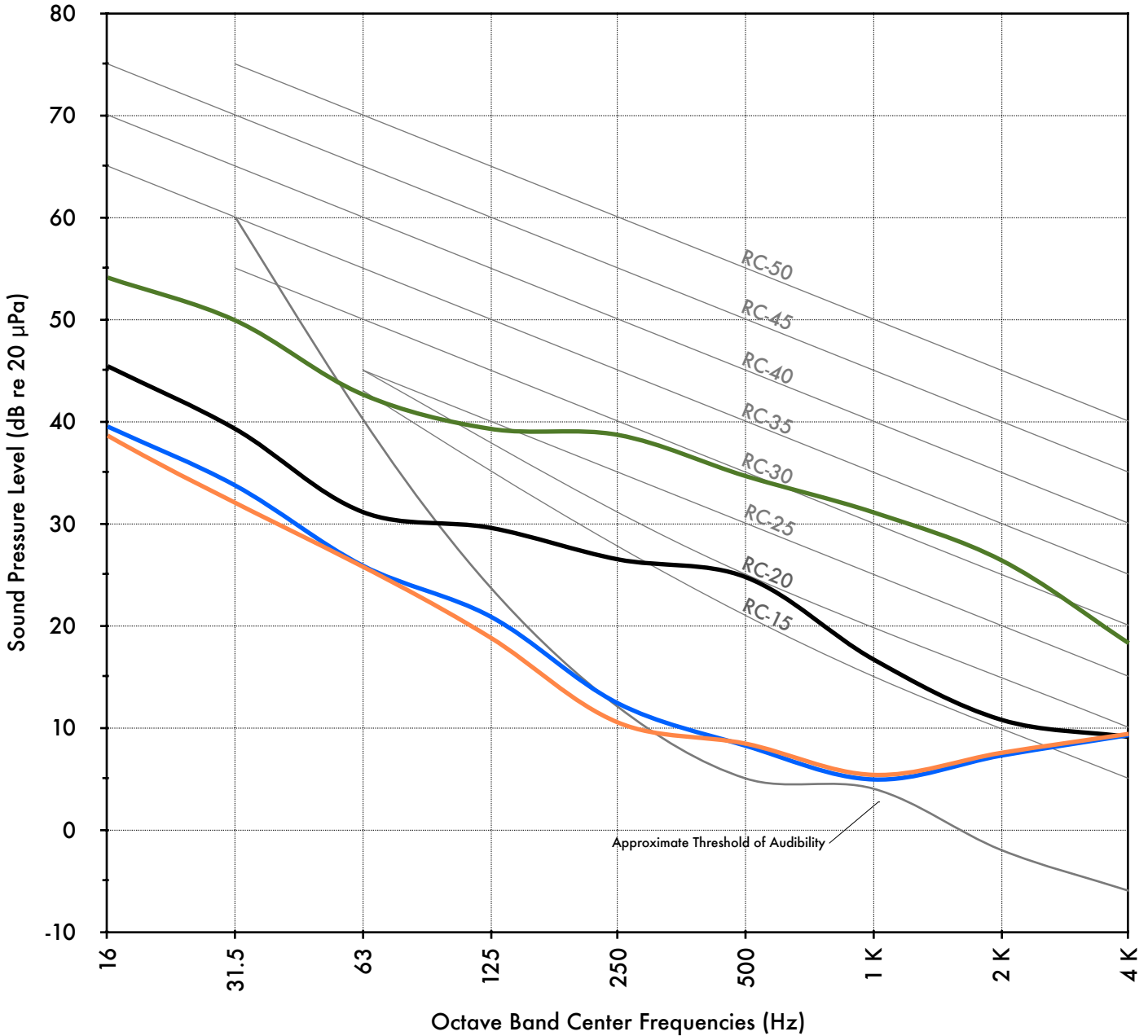
RC 6.8

Center of Studio 1, HVAC at High

RC 17.4 N

Center of Studio 1, HVAC at Full Flow

RC 30.7 N



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EMPAC Background Noise

Venue: Studio 2

Date of Measurement: 17 Aug 2011

Measurement of noise from HVAC settings [Measurements R2-006, 007, 008, 009]

Center of Studio 2, HVAC at Low

RC 5.7

Center of Studio 2, HVAC at Medium

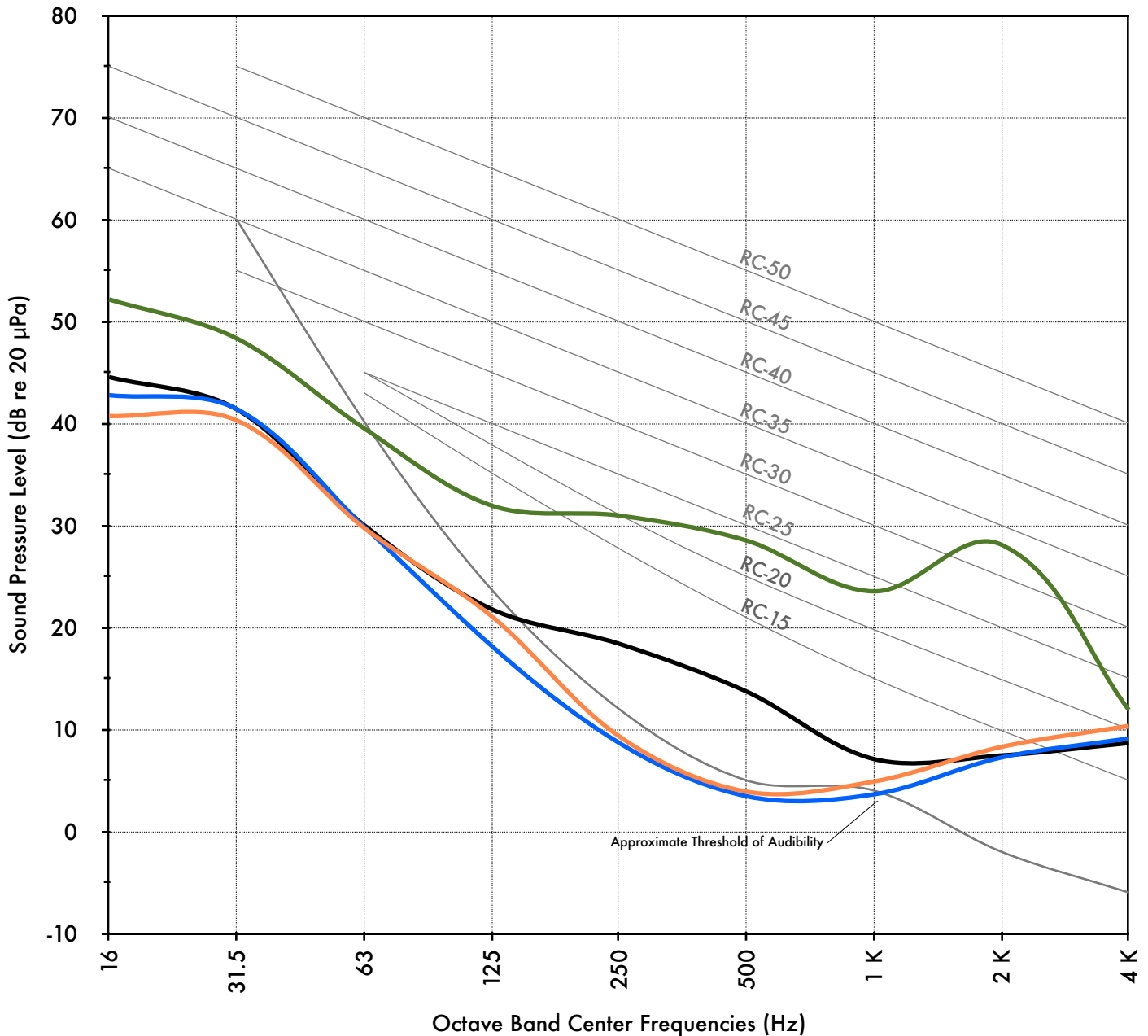
RC 4.8

Center of Studio 2, HVAC at High

RC 9.4

Center of Studio 2, HVAC at Full Flow

RC 26.7 H T



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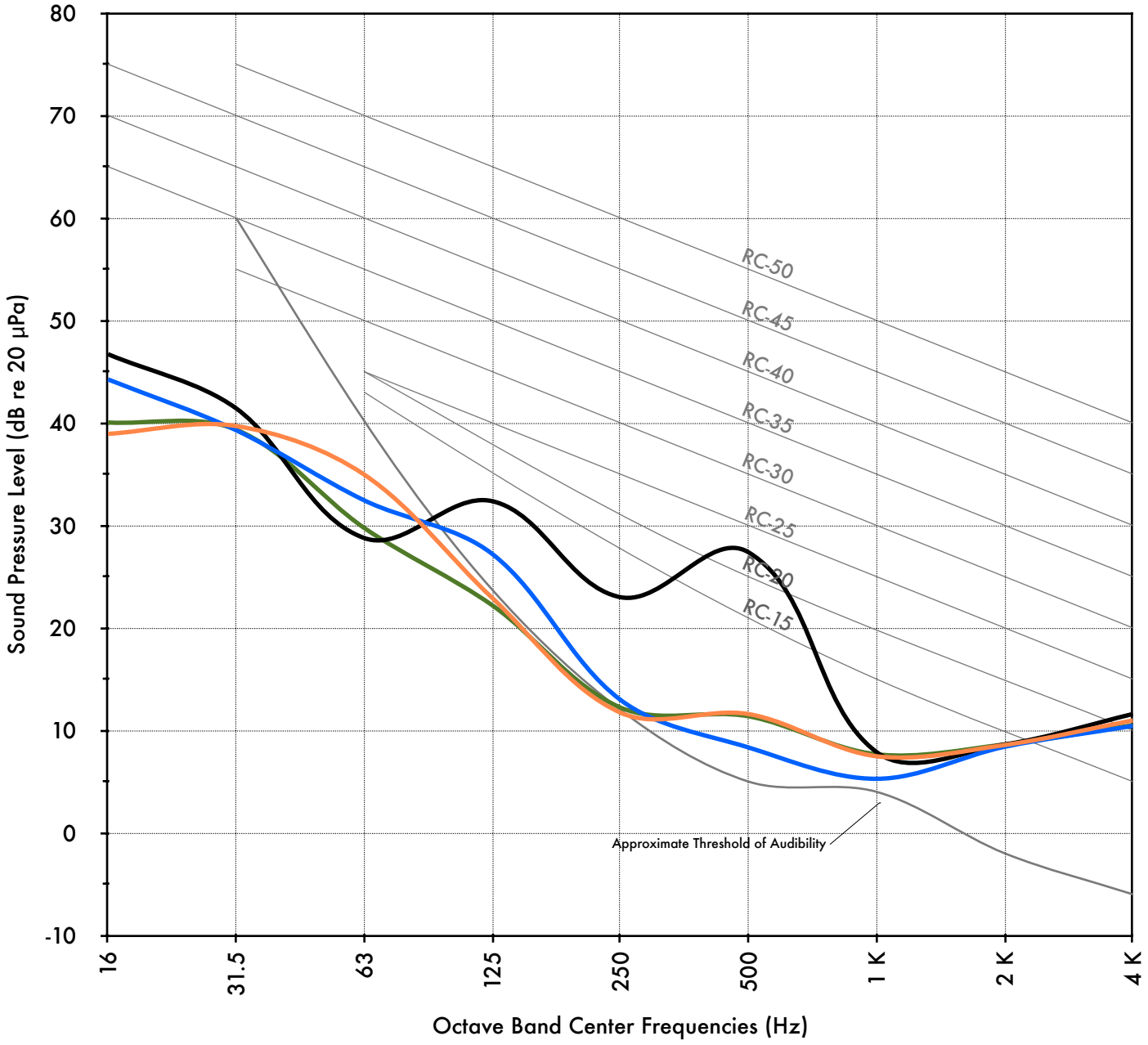
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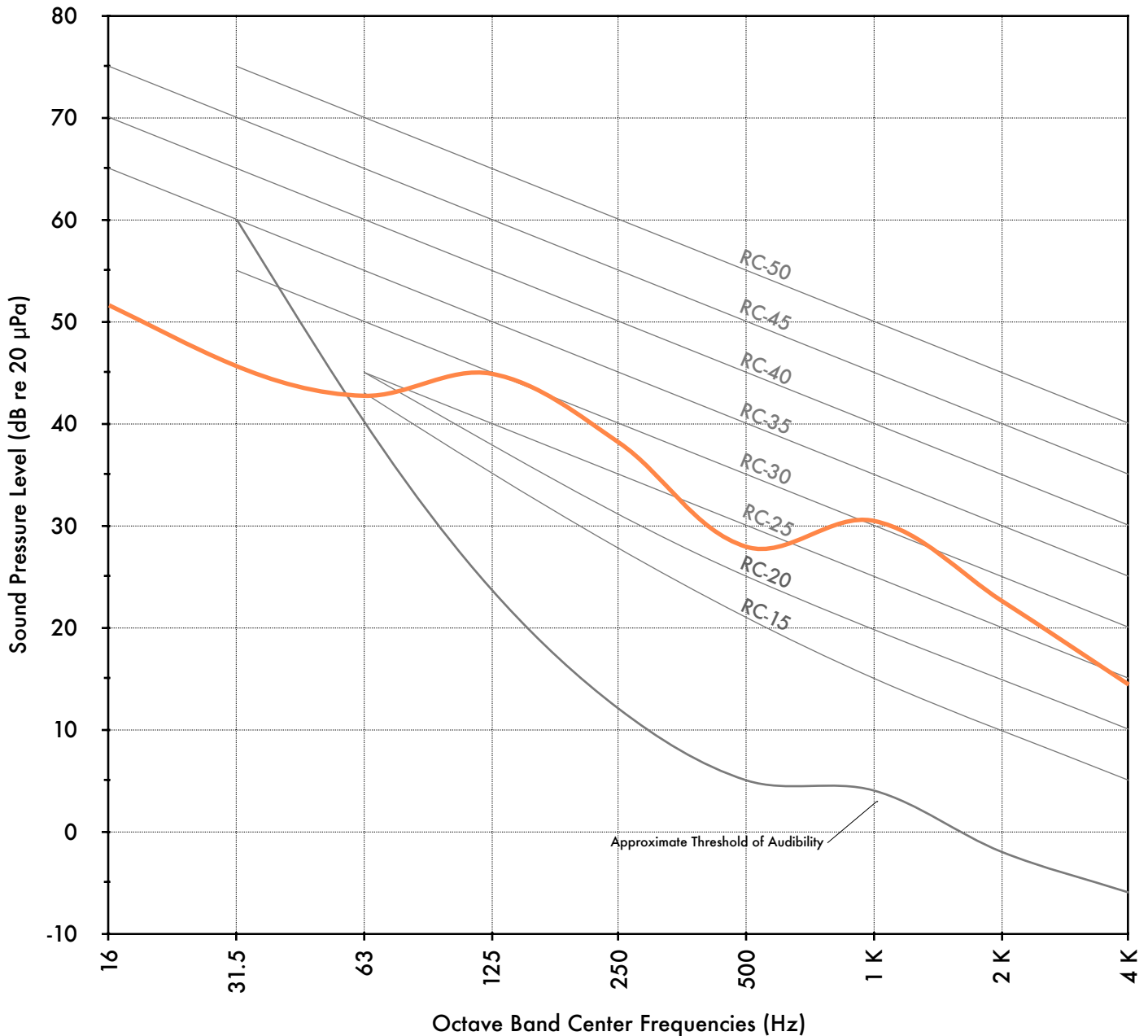
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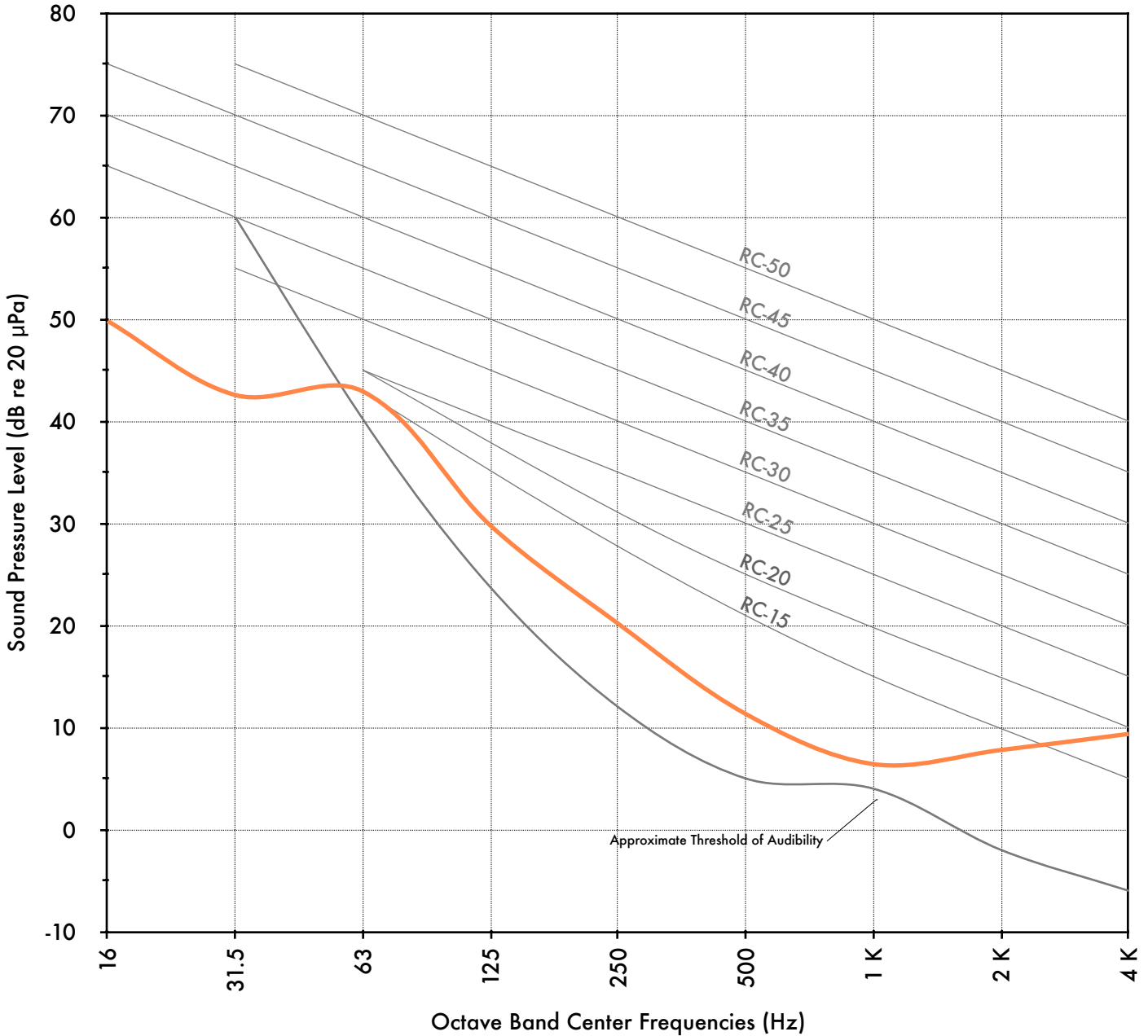
EMPAC Background Noise                      Venue: Theater                      Date of Measurement: 17 Aug 2011  
 Measurement Noisy Fire Control Panel [Measurements R2-002, 003, 004, 005]  
 Seat D11 (Front Row, Center)                      RC 9.2 |  
 Stage, Center of Flytower                      RC 7.3  
 Approximately 1 m from Control Panel                      RC 14.6 T



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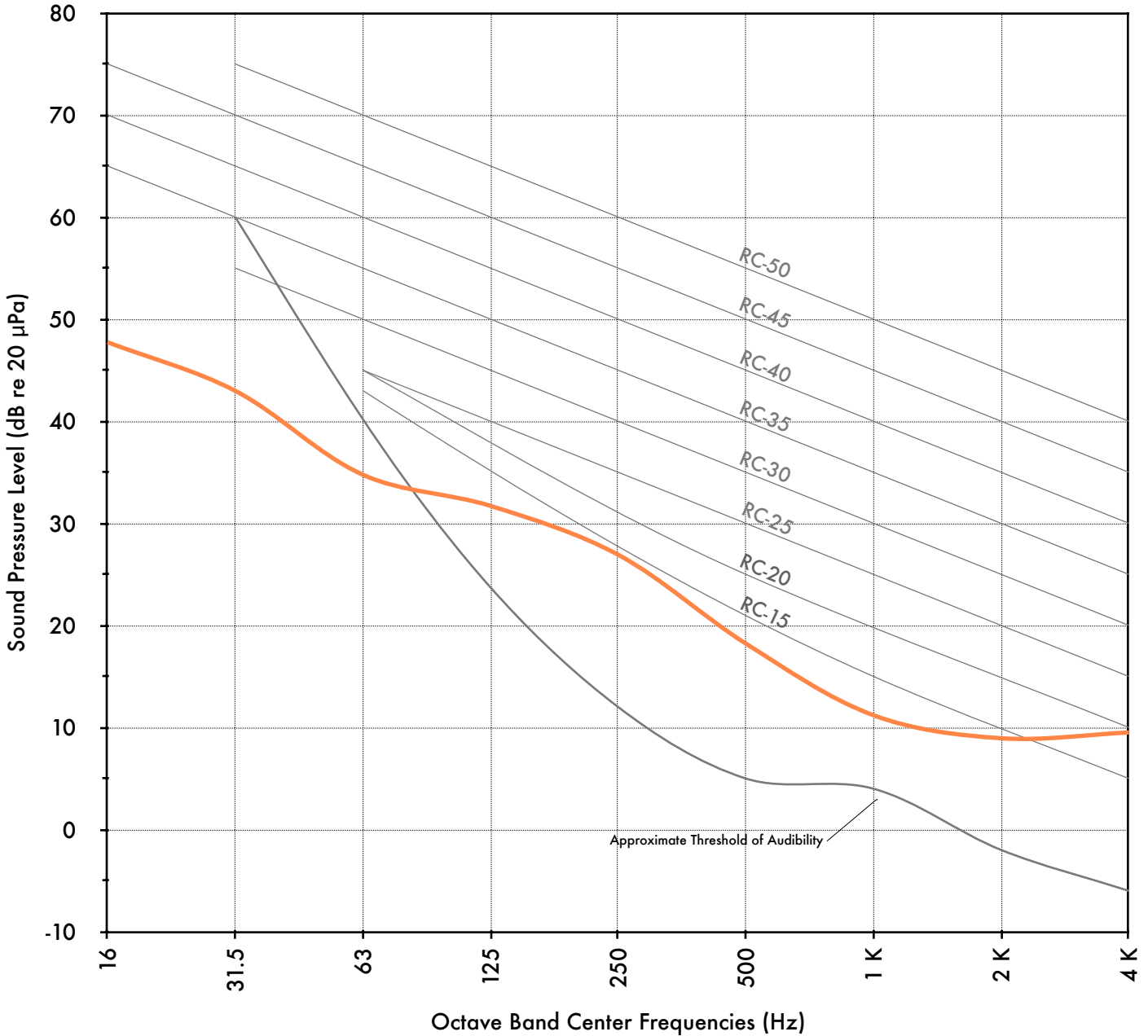
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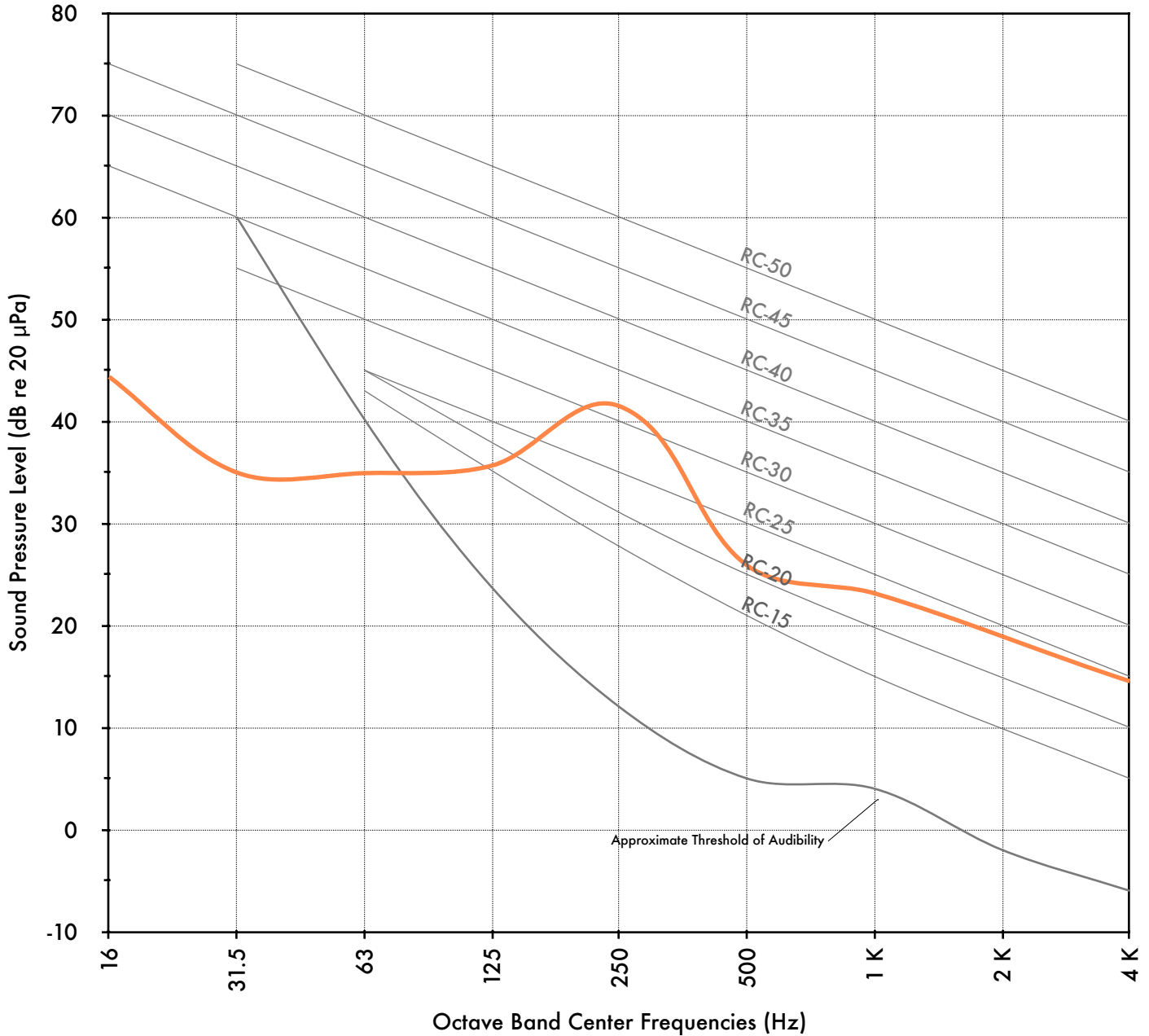
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(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.  
(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.  
(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands  
(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands

RC Spectrum letters appended to RC Number, when applicable, are determined as:

(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.

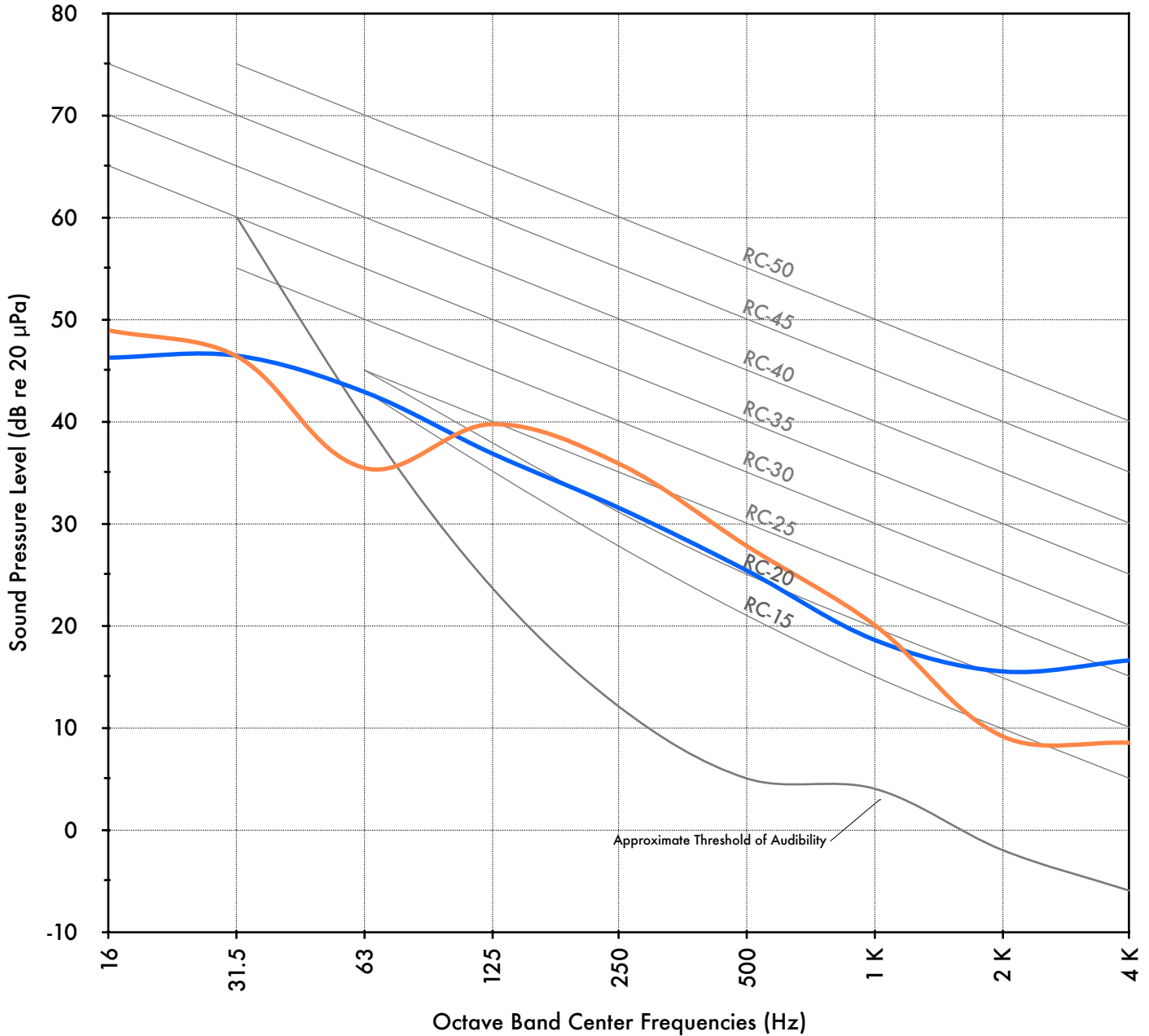
(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.

(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.

(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands

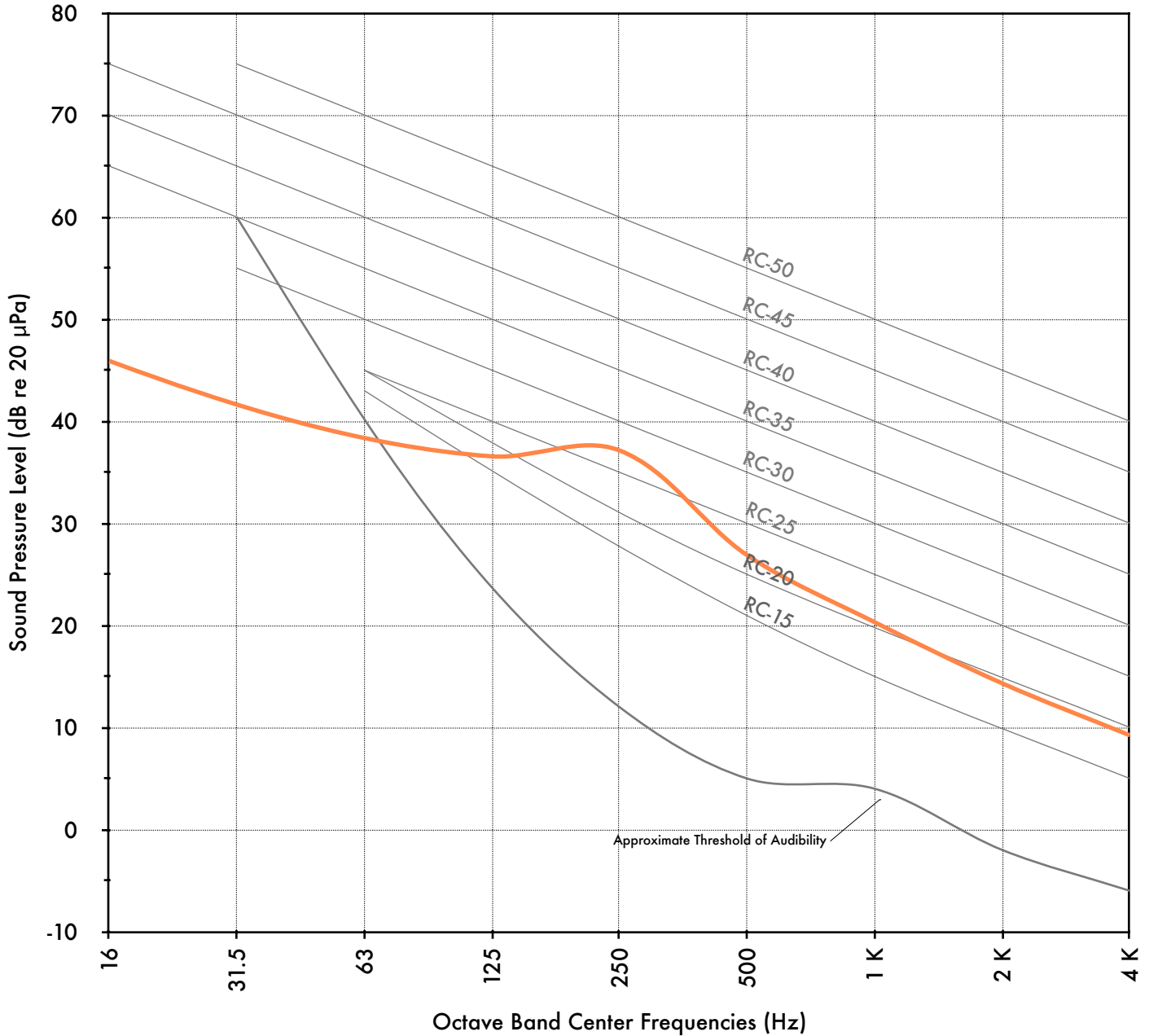
(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

RC 19.0 | N  
 RC 19.8 N



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands  
 RC Spectrum letters appended to RC Number, when applicable, are determined as:  
 (N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.  
 (R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.  
 (H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.  
 (T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands  
 (RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.





RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands

RC Spectrum letters appended to RC Number, when applicable, are determined as:

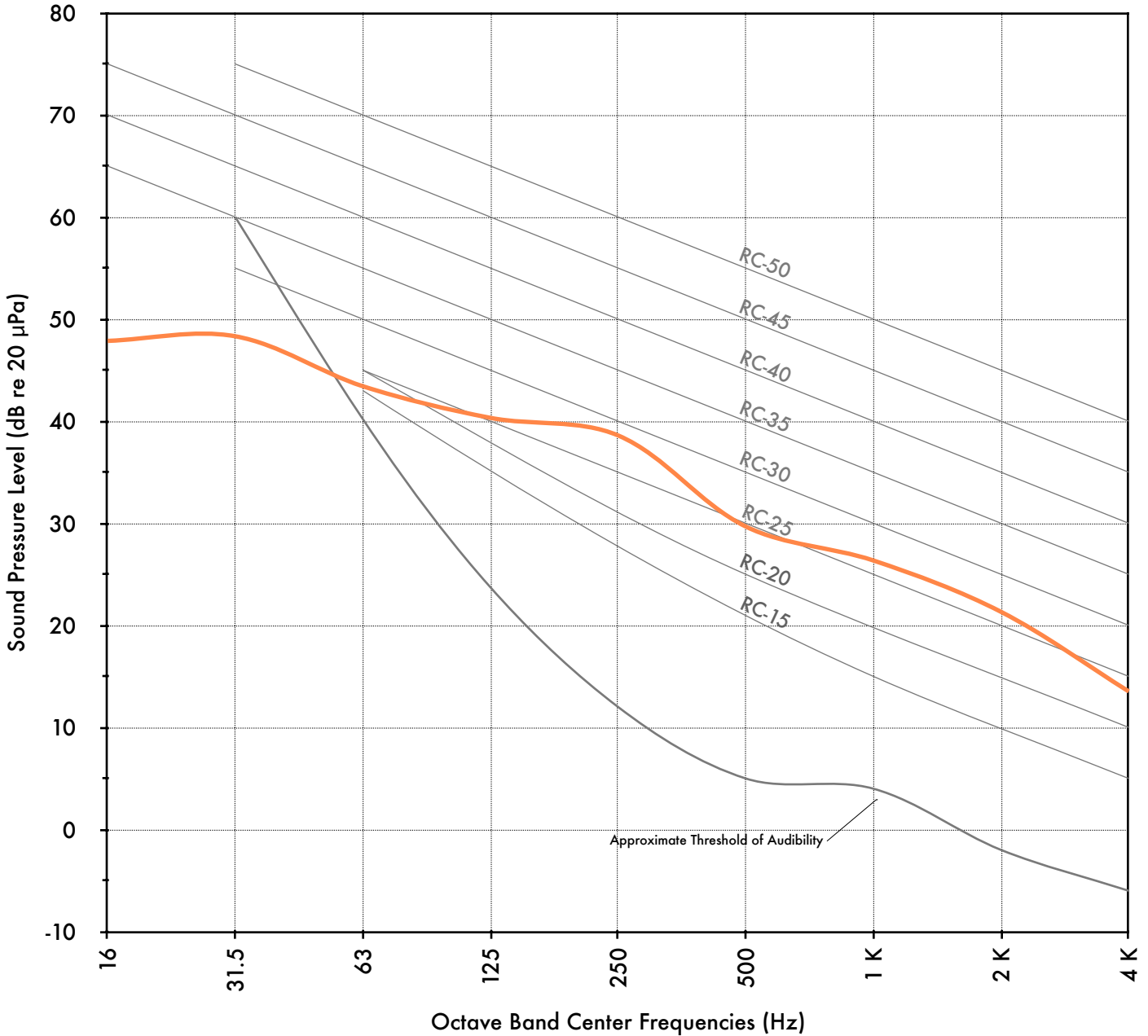
(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.

(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.

(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.

(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands

(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

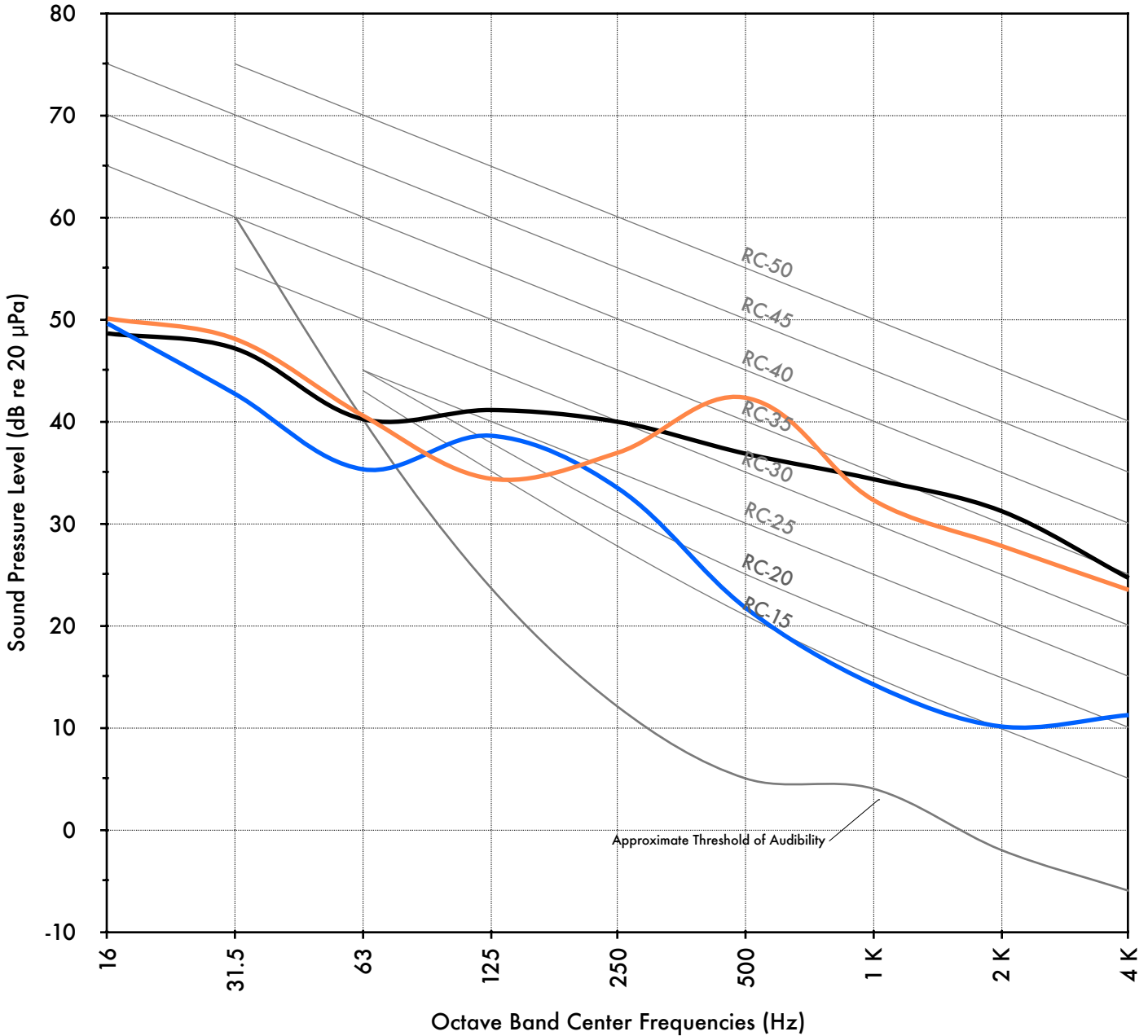


RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands  
RC Spectrum letters appended to RC Number, when applicable, are determined as:  
(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.  
(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.  
(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.  
(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands  
(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

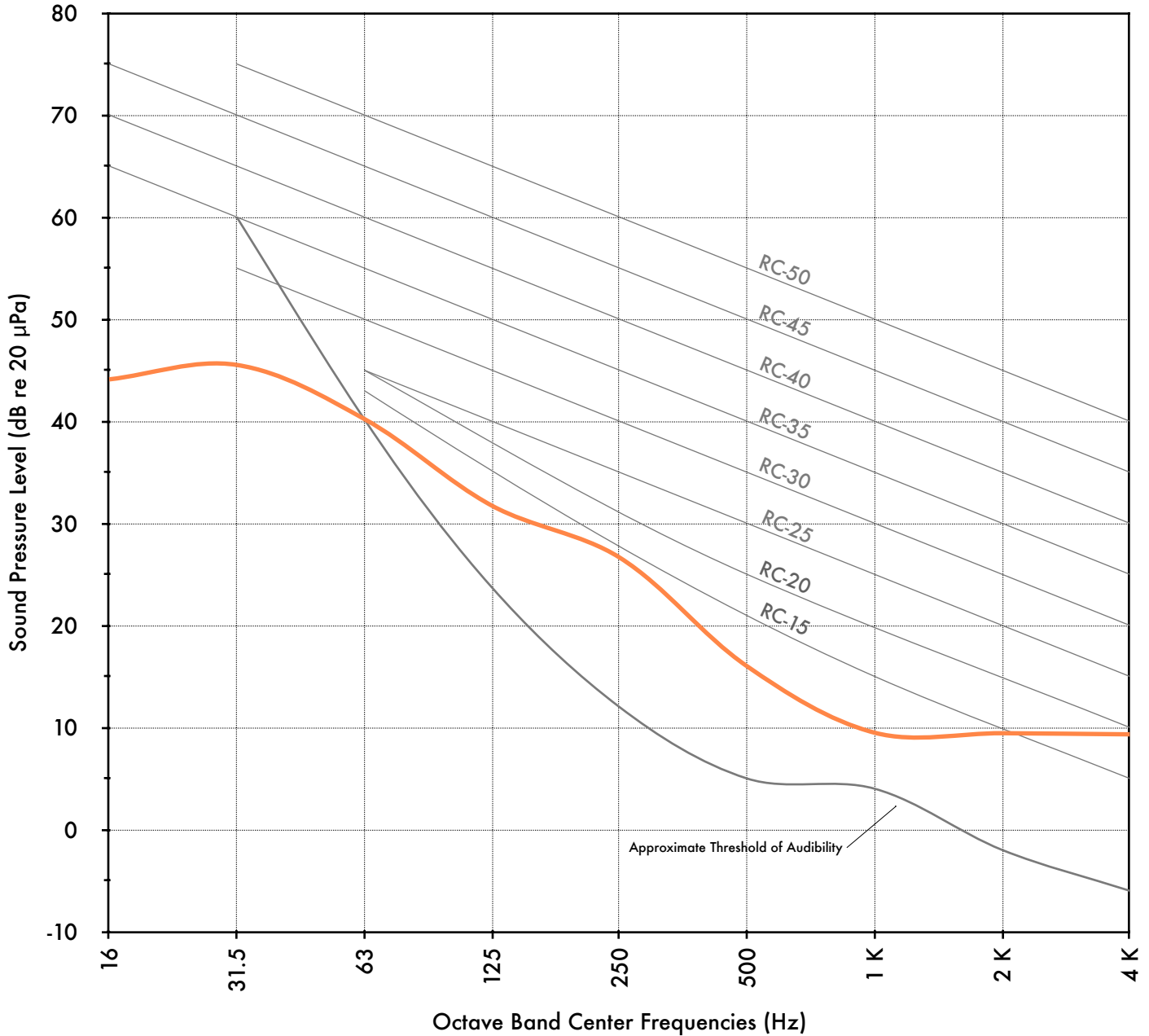
EMPAC Background Noise  
 Control Rooms [Measurements R2-020, 021, 022]  
 Studio 2 Control Room  
 Studio 1 Control Room  
 Concert Hall Control Room

Date of Measurement: 22 Aug 2011

RC 34.1 | R T  
 RC 15.3 N  
 RC 34.1 N



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands  
 RC Spectrum letters appended to RC Number, when applicable, are determined as:  
 (N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.  
 (R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.  
 (H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.  
 (T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands  
 (RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands

RC Spectrum letters appended to RC Number, when applicable, are determined as:

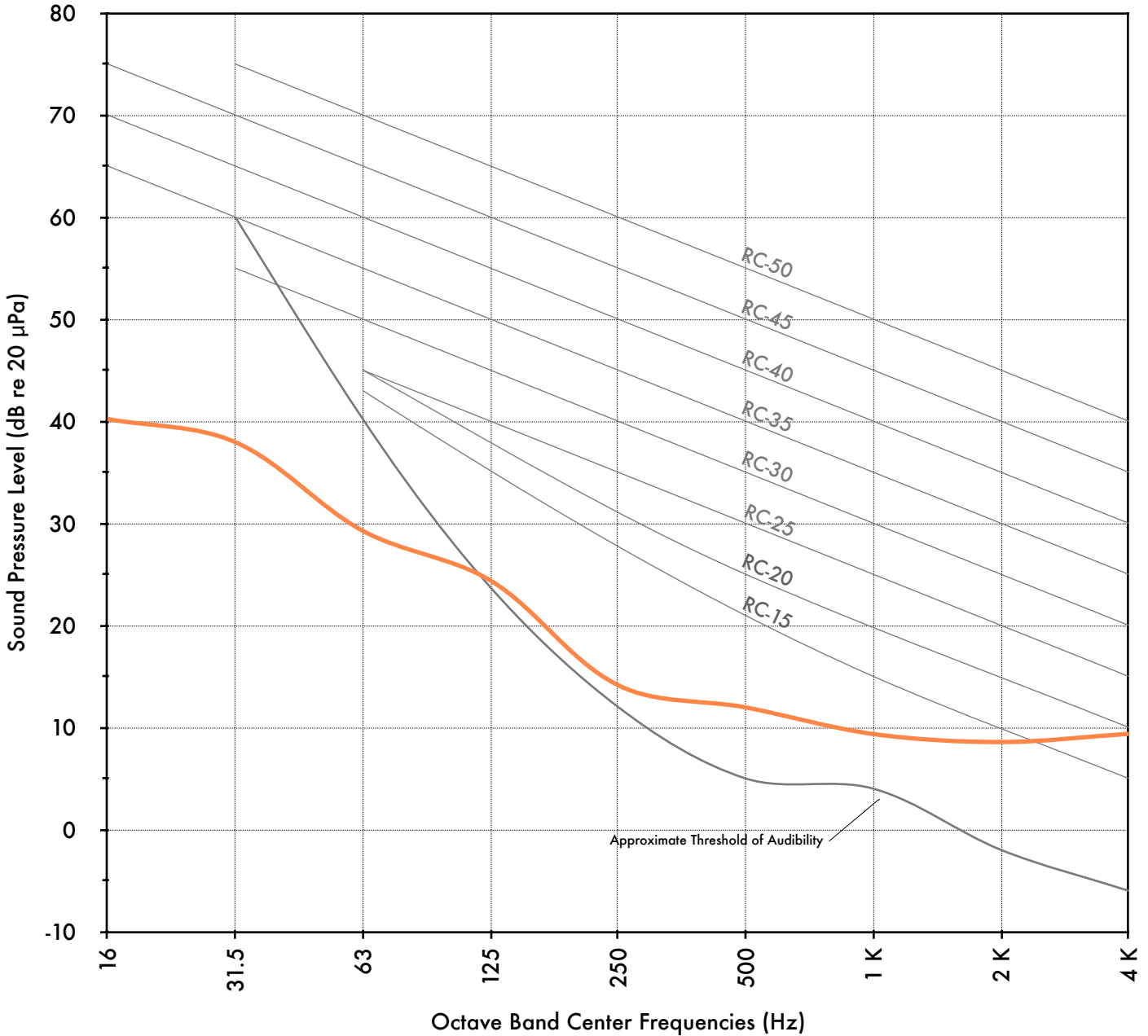
(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.

(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.

(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.

(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands

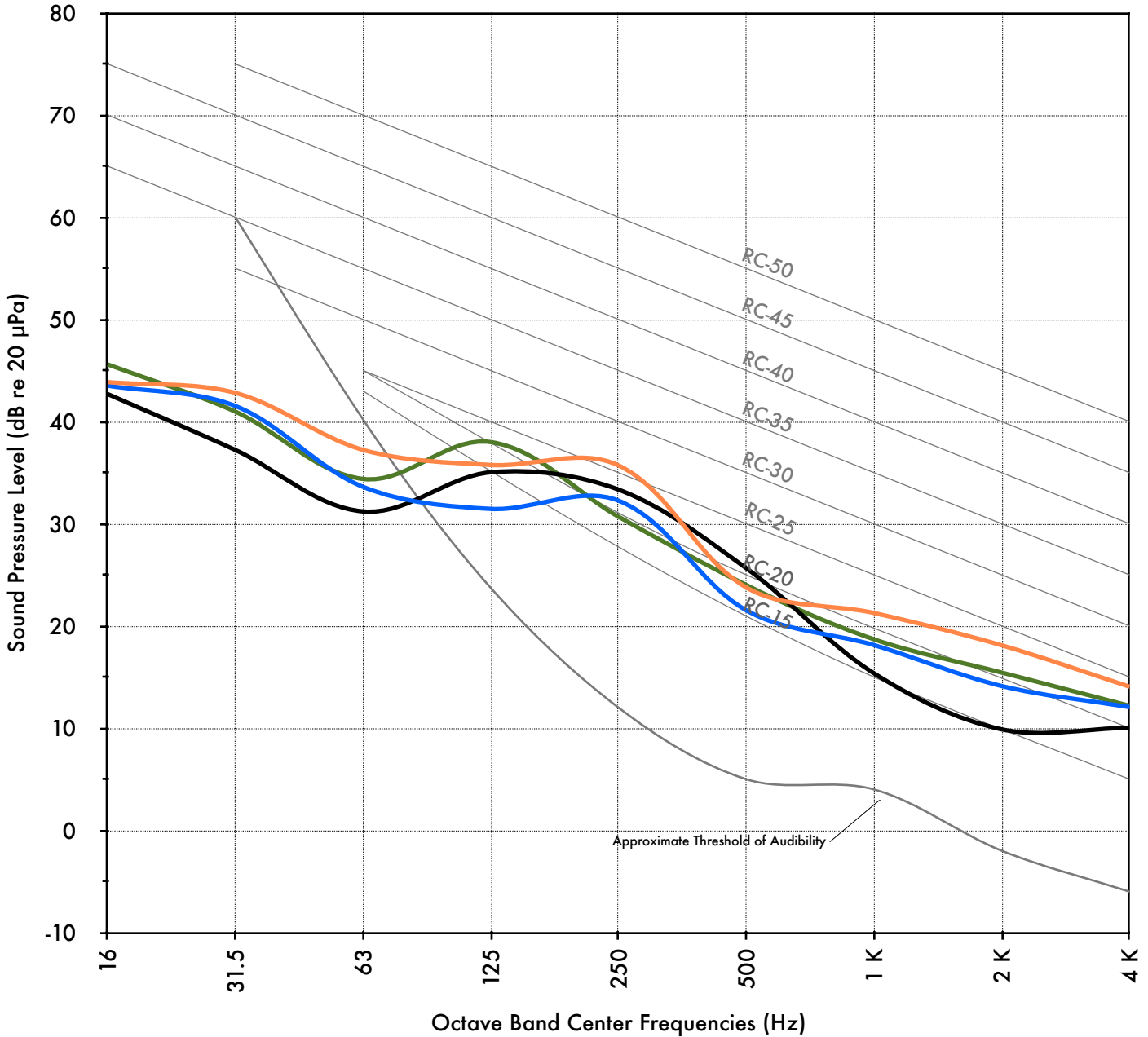
(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands  
RC Spectrum letters appended to RC Number, when applicable, are determined as:  
(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.  
(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.  
(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.  
(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands  
(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

Director's Office Rm 7418  
 Head of Research Rm 7414  
 Curator's Office Rm 7408  
 Conference Rm 7403

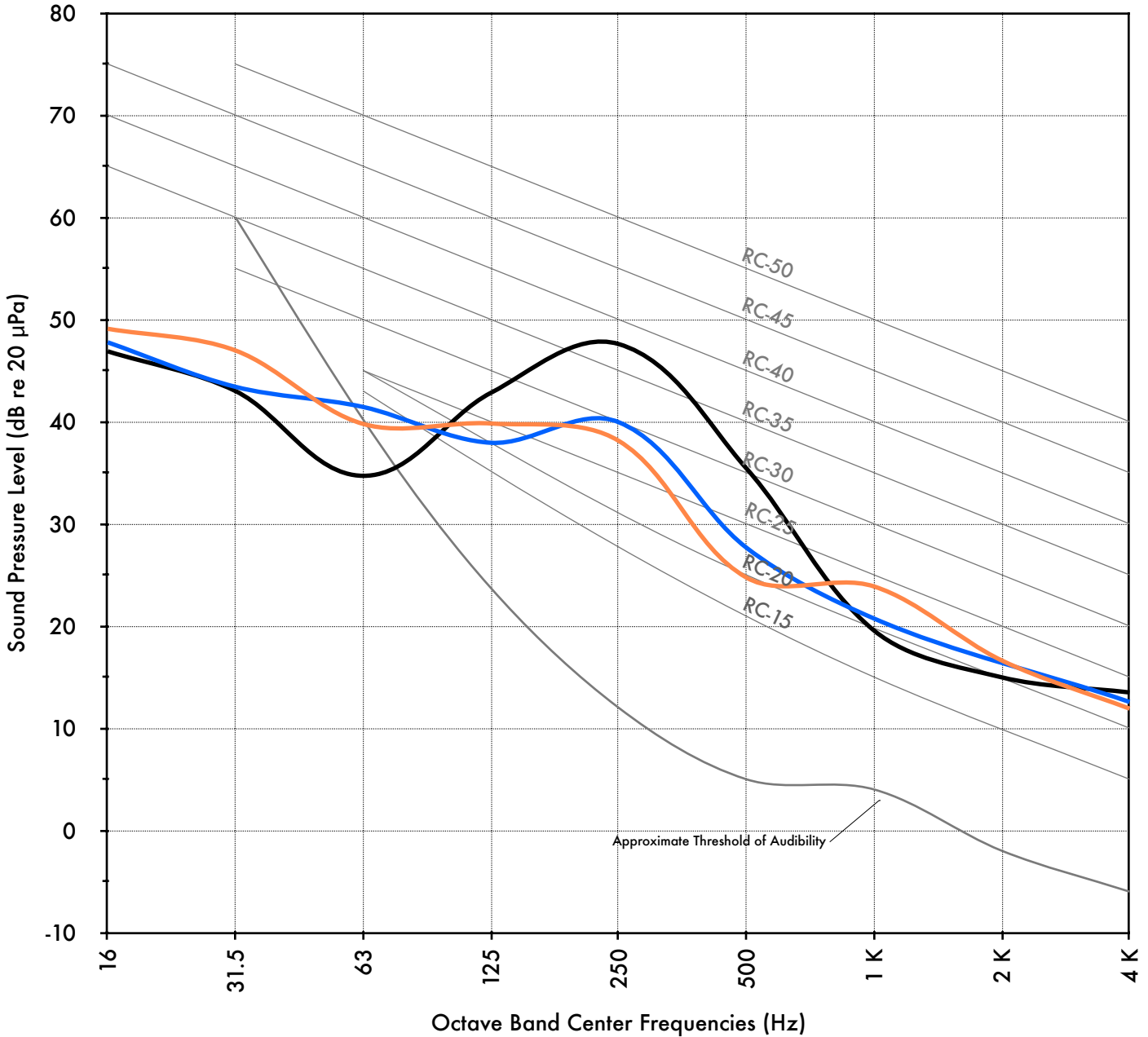
RC 21.0 | R T  
 RC 17.9 N  
 RC 17.0 N  
 RC 19.4 N



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands  
 RC Spectrum letters appended to RC Number, when applicable, are determined as:  
 (N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.  
 (R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.  
 (H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.  
 (T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands  
 (RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

Room 5615  
 Room 5609  
 Room 5608

RC 21.7 | R T  
 RC 21.7 R T  
 RC 23.3 R T



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands  
 RC Spectrum letters appended to RC Number, when applicable, are determined as:  
 (N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.  
 (R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.  
 (H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.  
 (T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands  
 (RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

Stage Measurement of Dimmer and Transformer Noise [Measurements R1-035, 040, 045]

Stage, Transformers Off, Dimmers On

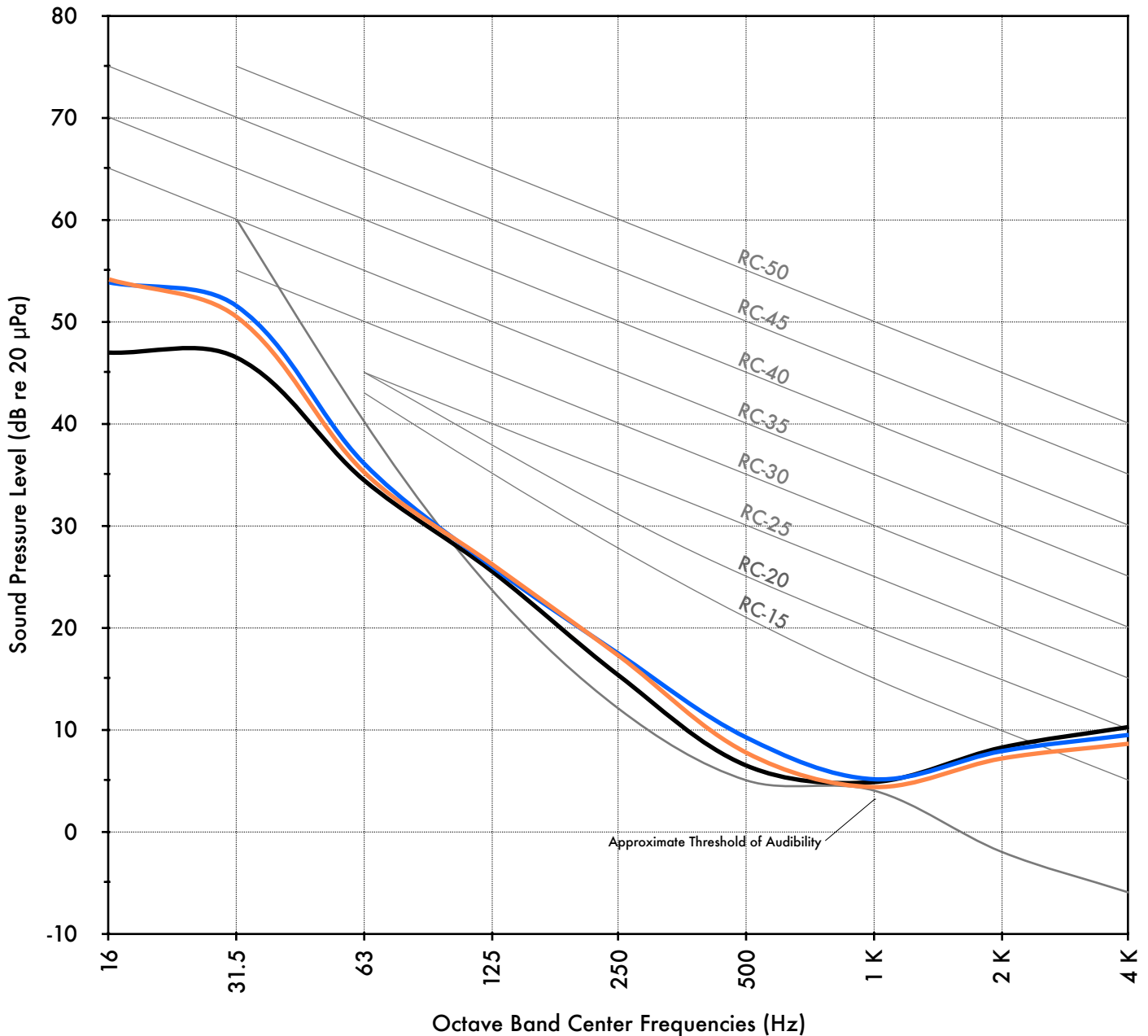
RC 6.4

Stage, Transformers Off, Dimmers Off

RC 7.4

Stage, Transformers On, Dimmers Off

RC 6.5



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands

RC Spectrum letters appended to RC Number, when applicable, are determined as:

(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.

(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.

(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.

(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands

(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.



EMPAC Background Noise

Venue: Concert Hall

Date of Measurement: 08 Aug 2011

Sound and Light Lock Measurement of Dimmer and Transformer Noise [Measurements R1-038, 043, 048]

Sound and Light Lock, Transformers Off, Dimmers On

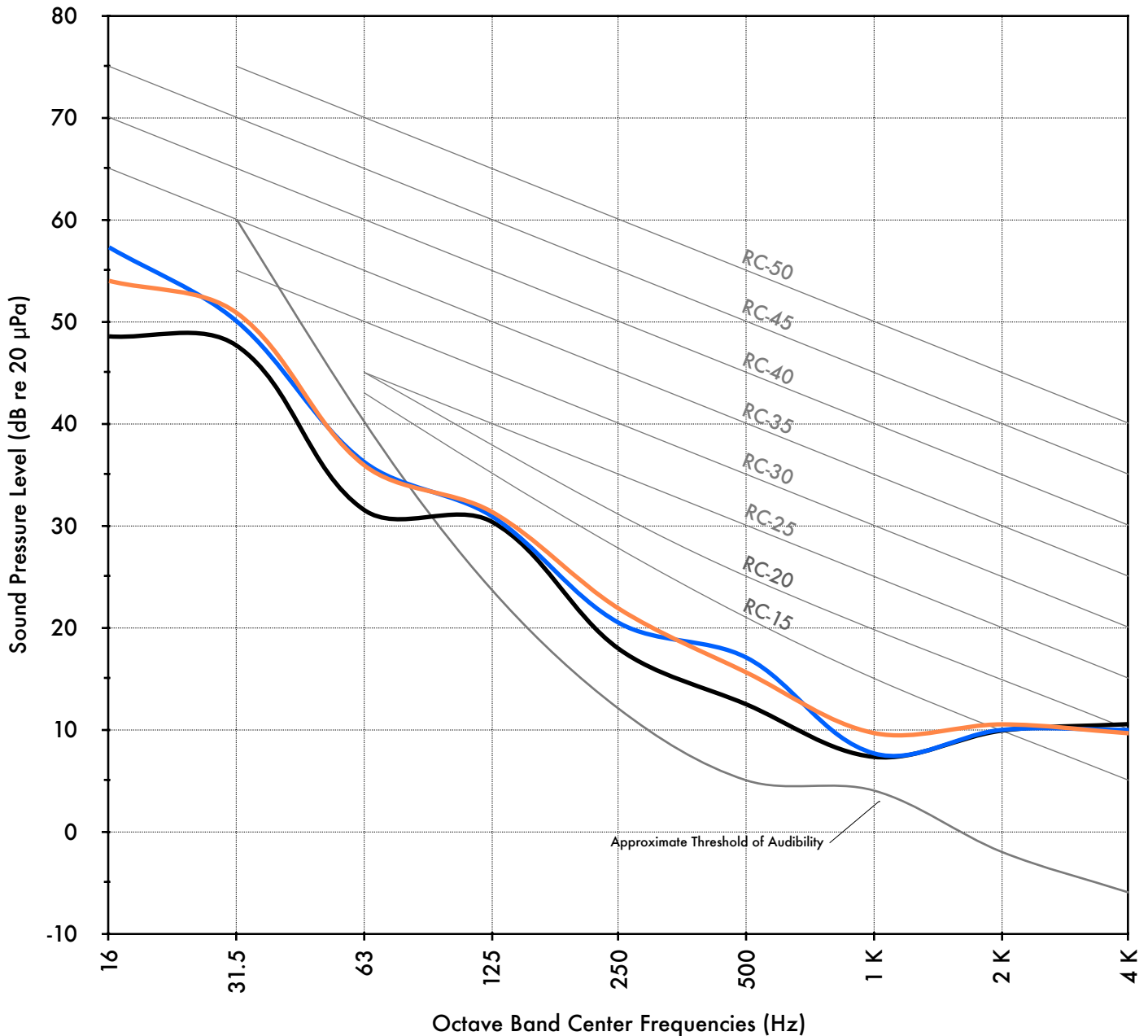
RC 11.9

Sound and Light Lock, Transformers Off, Dimmers Off

RC 11.5

Sound and Light Lock, Transformers On, Dimmers Off

RC 9.9



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands

RC Spectrum letters appended to RC Number, when applicable, are determined as:

(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.

(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.

(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.

(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands

(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

Seat C24, Transformers Off, Dimmers On

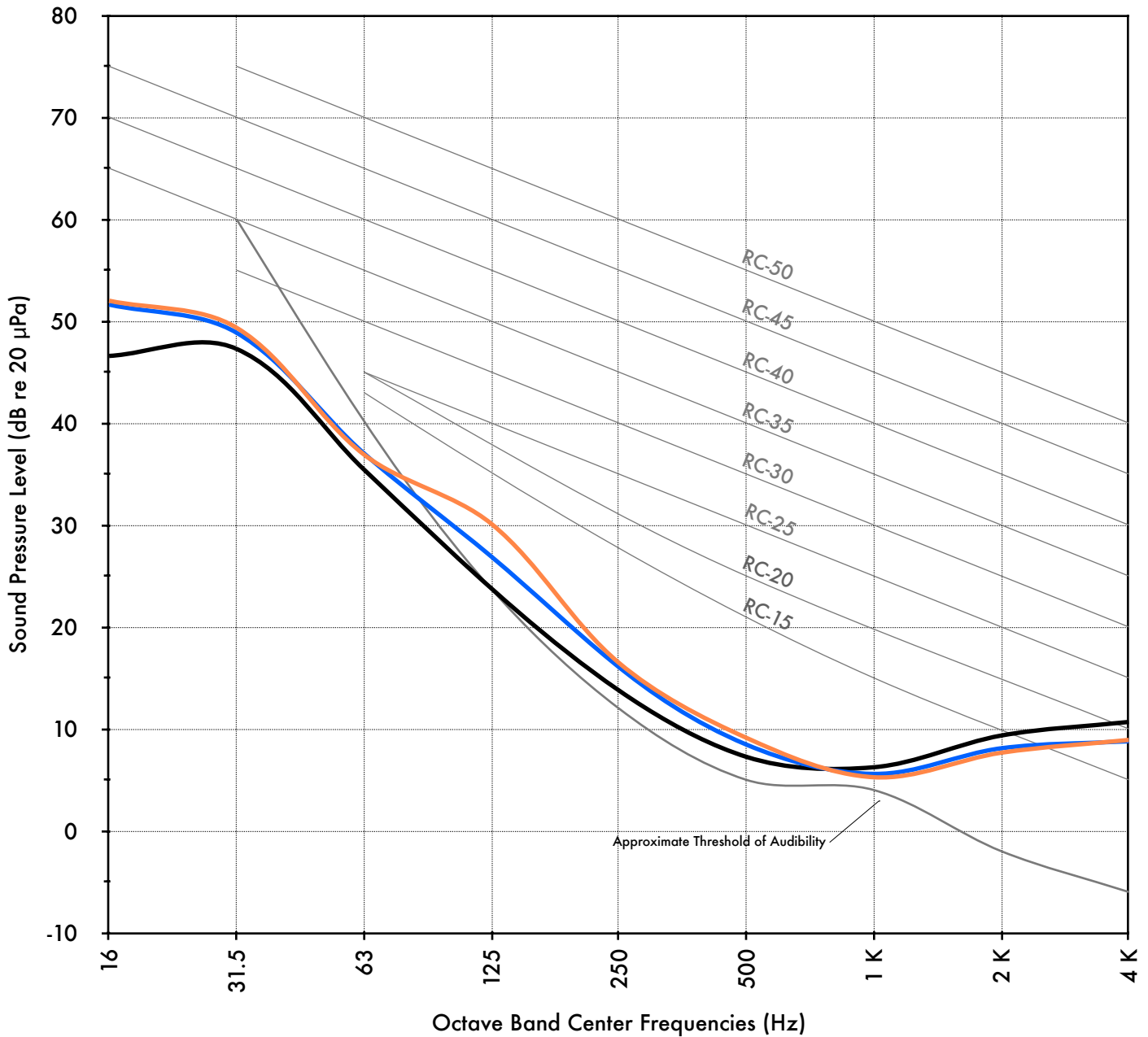
RC 7.3

Seat C24, Transformers Off, Dimmers Off

RC 7.4

Seat C24, Transformers On, Dimmers Off

RC 7.6



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands

RC Spectrum letters appended to RC Number, when applicable, are determined as:

(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.

(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.

(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.

(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands

(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

Main Floor, Transformers Off, Dimmers On

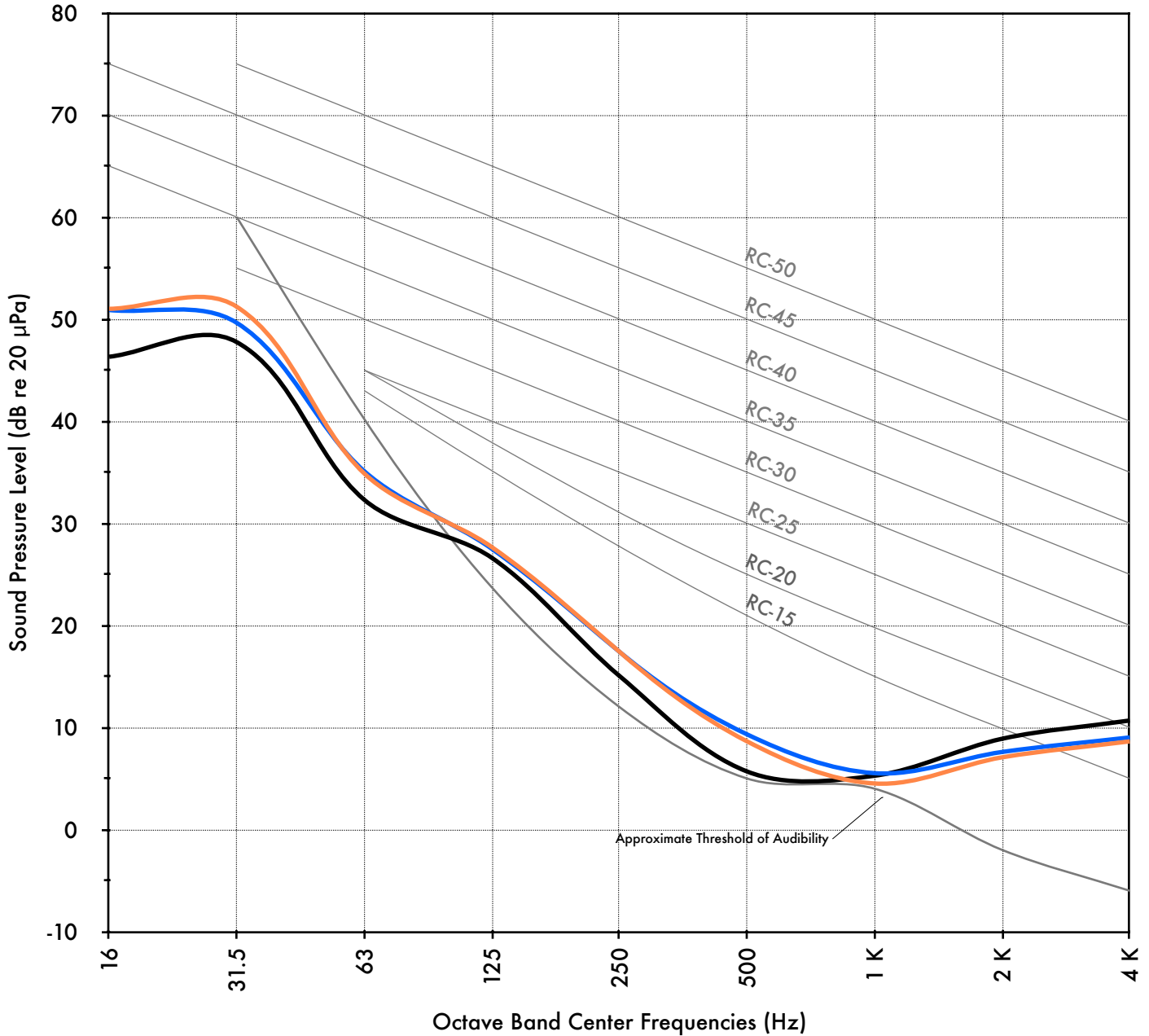
RC 6.7

Main Floor, Transformers Off, Dimmers Off

RC 7.5

Main Floor, Transformers On, Dimmers Off

RC 6.6



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands

RC Spectrum letters appended to RC Number, when applicable, are determined as:

(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.

(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.

(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.

(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands

(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

EMPAC Background Noise

Venue: Concert Hall

Date of Measurement: 08 Aug 2011

House Left Gallery Measurement of Dimmer and Transformer Noise [Measurements R1-039, 044, 049]

House Left Gallery, Transformers Off, Dimmers On

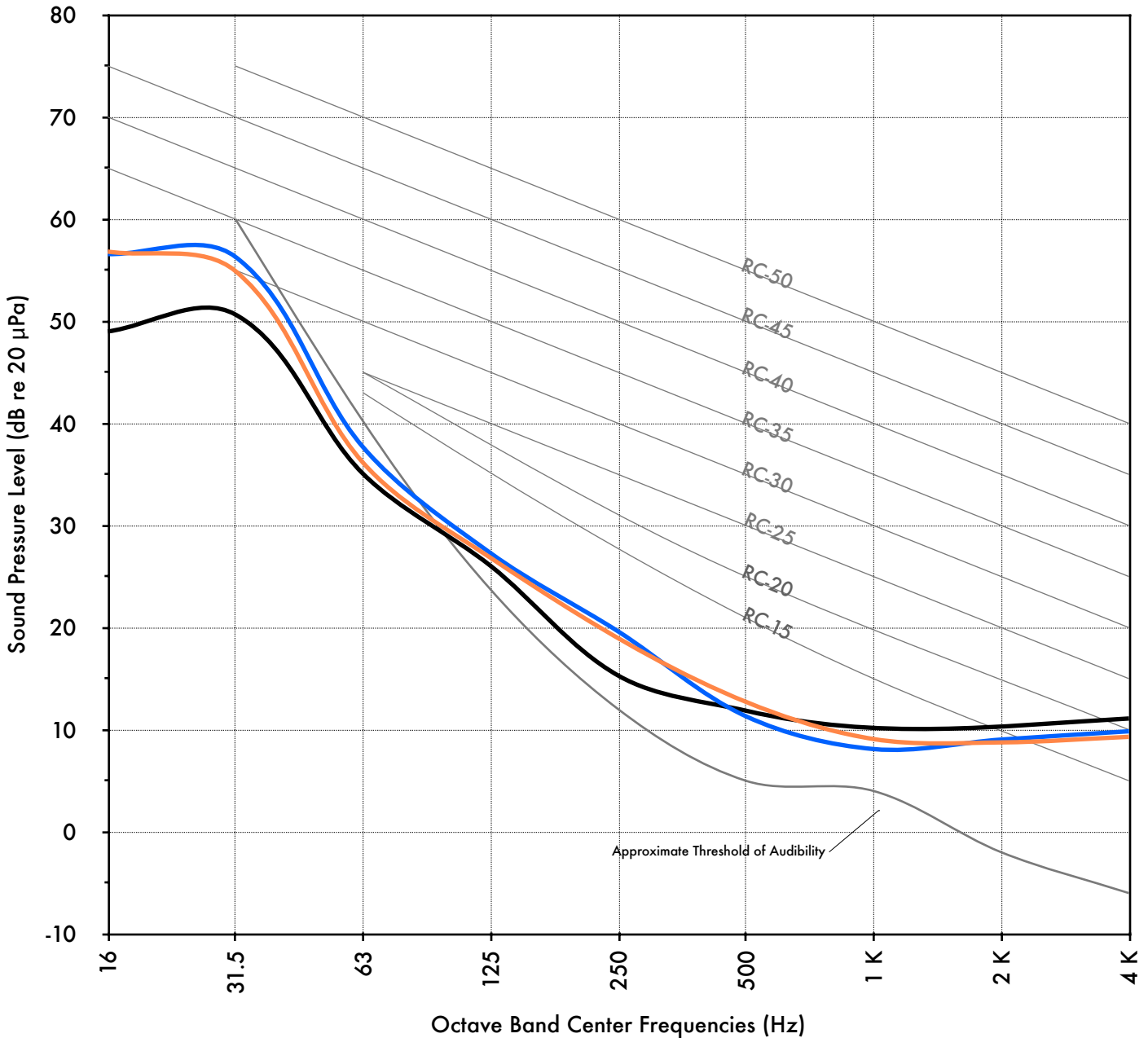
RC 10.2

House Left Gallery, Transformers Off, Dimmers Off

RC 9.5

House Left Gallery, Transformers On, Dimmers Off

RC 10.6



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands

RC Spectrum letters appended to RC Number, when applicable, are determined as:

(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.

(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.

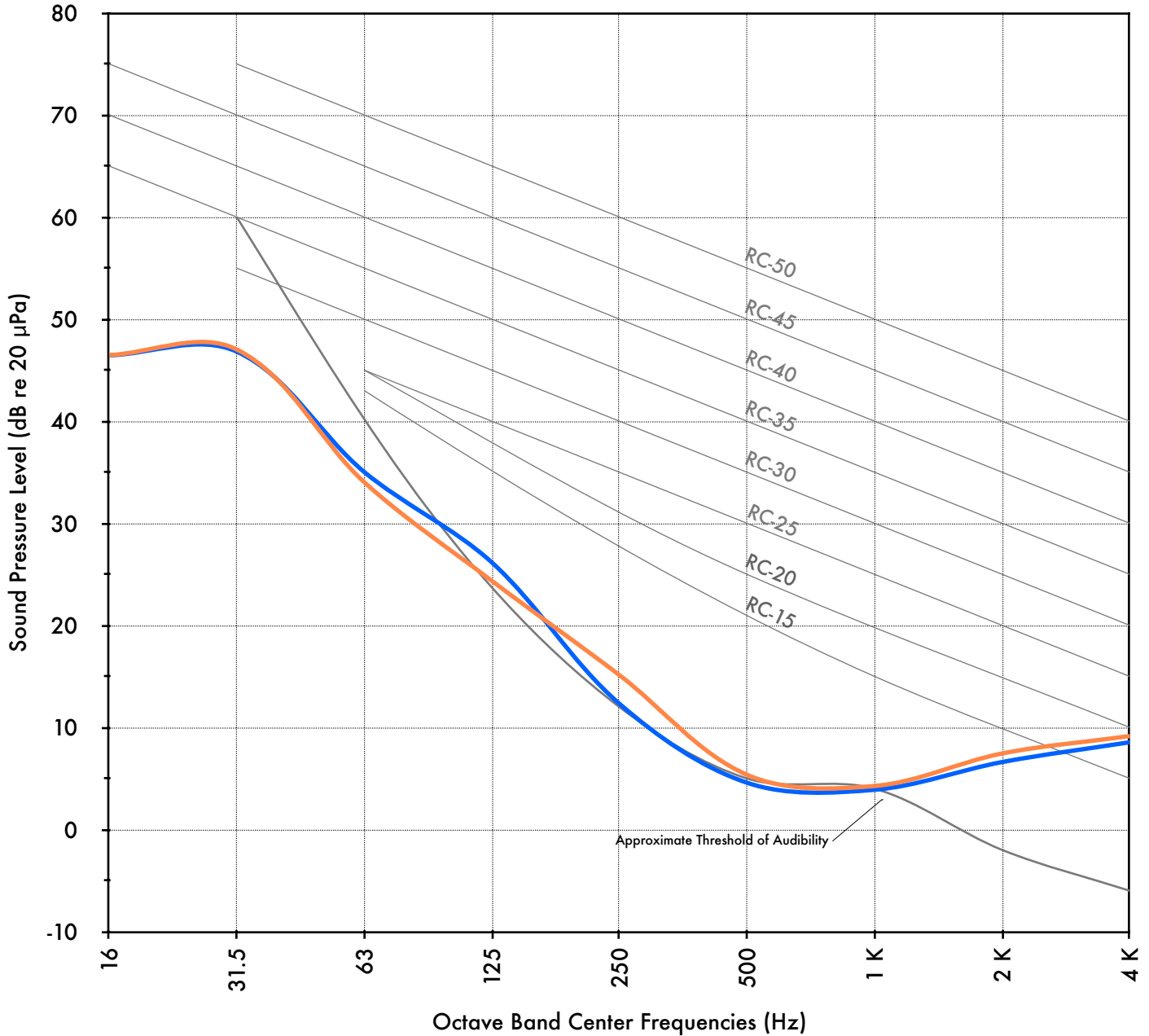
(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.

(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands

(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

Stage, Line Arrays On  
 Stage, Line Arrays Off

RC 5.7  
 RC 5.0



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands

RC Spectrum letters appended to RC Number, when applicable, are determined as:

(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.

(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.

(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.

(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands

(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

Main Floor, 30 s

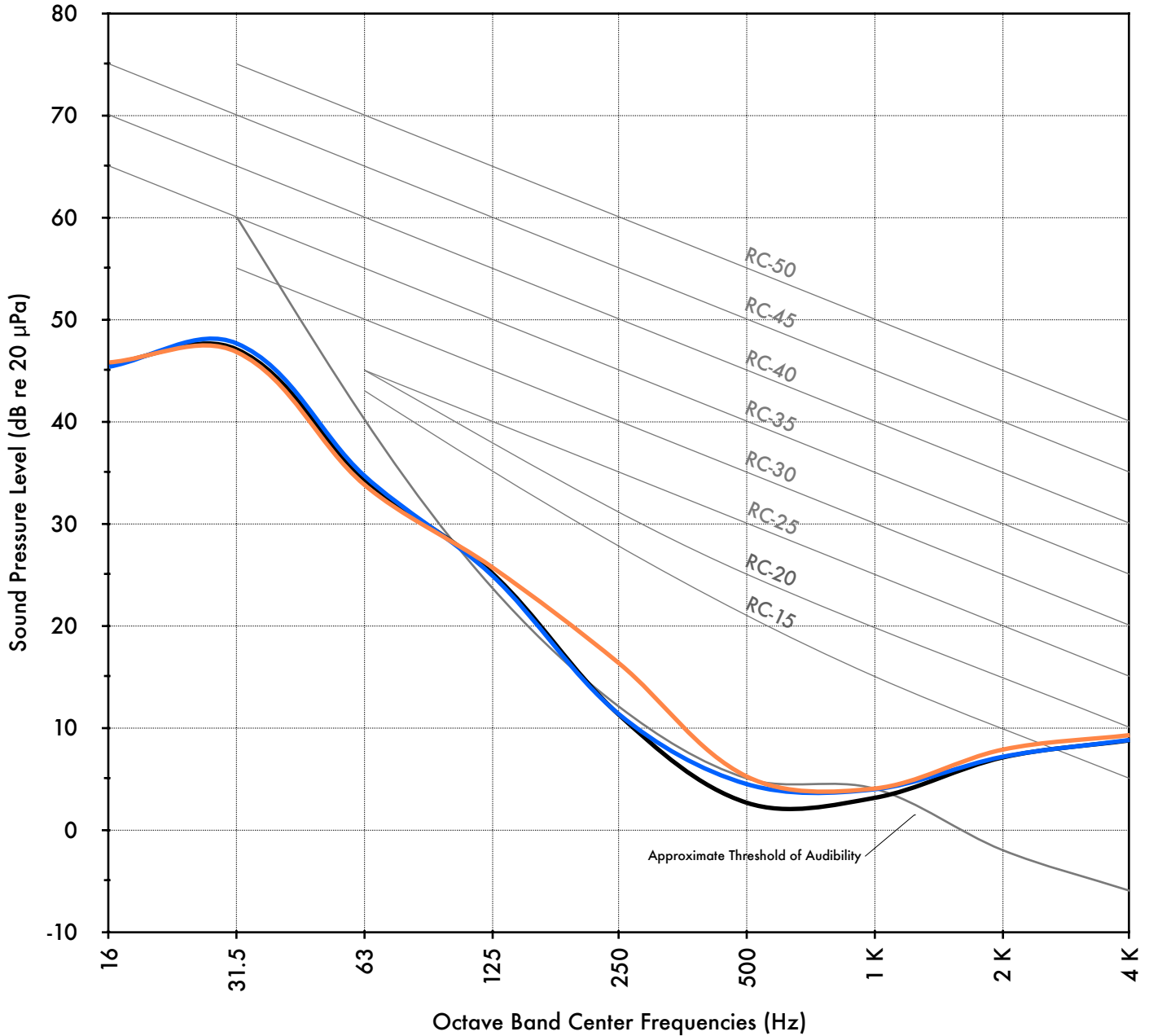
RC 5.7

Main Floor, 5 s

RC 5.2

Main Floor, 5 s

RC 4.3



RC Number is the arithmetic average of the 500, 1000, and 2000 Hz octave bands

RC Spectrum letters appended to RC Number, when applicable, are determined as:

(N) Neutral: levels at 500 Hz and below do not exceed the reference spectrum by more than 5 dB at any point. Levels at 1 kHz and above do not exceed it by more than 3 dB at any point.

(R) Rumbly: a level at 500 Hz or below exceeds the reference spectrum by more than 5 dB.

(H) Hissy: a level at 1000 Hz or above exceeds the reference spectrum by more than 3 dB.

(T) Tonal: a level at any octave band is more than 3 dB above a line drawn between the levels at the two adjacent bands

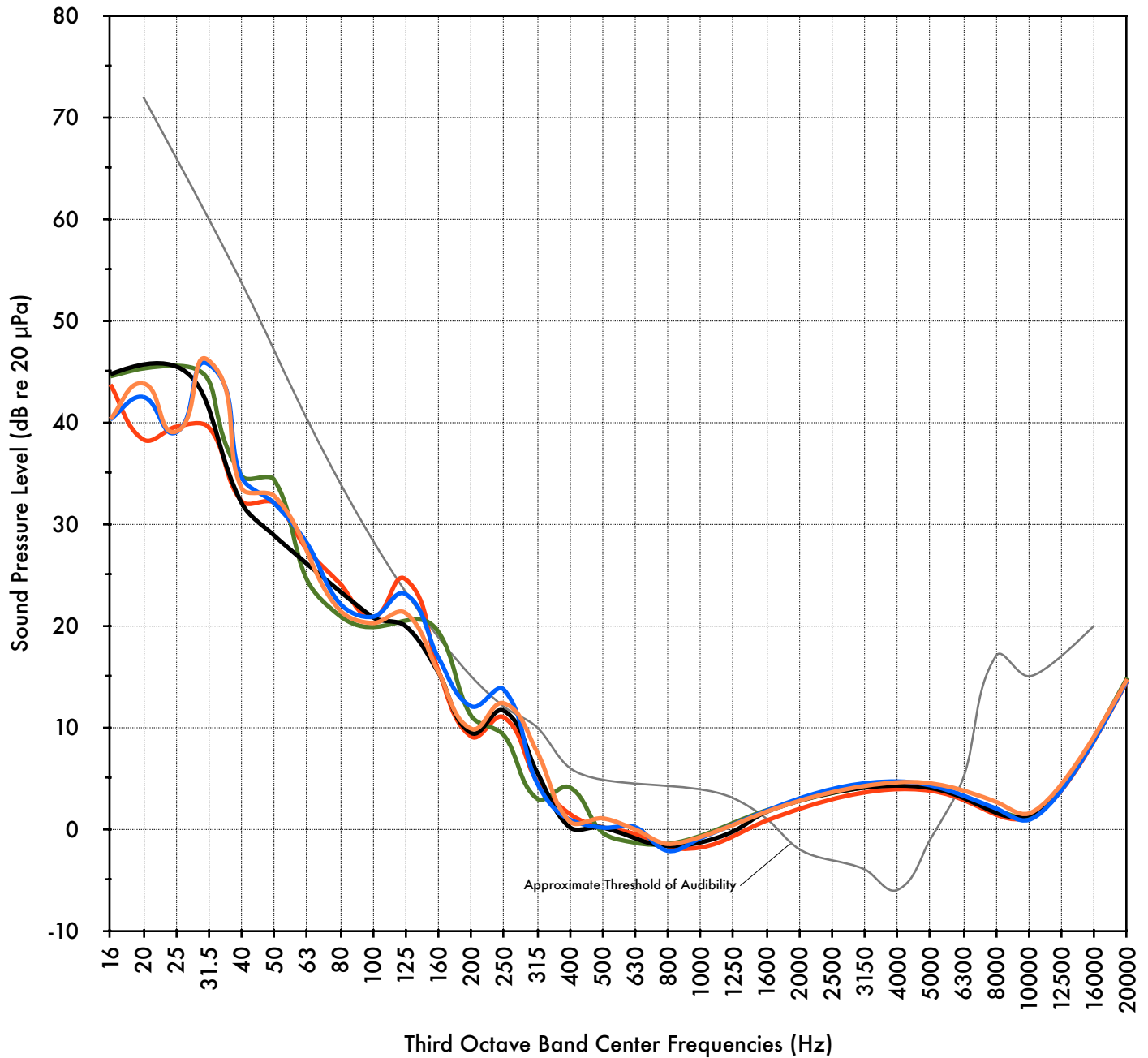
(RV) Acoustically Induced Vibration: sound energy is present within the area indicated on the chart.

EMPAC Background Noise  
 Concert Hall Background Noise [Measurements R1-007, 008, 009, 010, 011]

Venue: Concert Hall

Date of Measurement: 07 Aug 2011

Stage	RC	5.7
Main Floor	RC	5.7
Under Balcony	RC	5.1
House Left Gallery	RC	5.9
Balcony	RC	5.1



EMPAC Background Noise

Venue: Studio 1

Date of Measurement: 17 Aug 2011

Measurement of noise from HVAC settings [Measurements R2-010, 011, 012, 013]

Center of Studio 1, HVAC at Low

RC 7.1

Center of Studio 1, HVAC at Medium

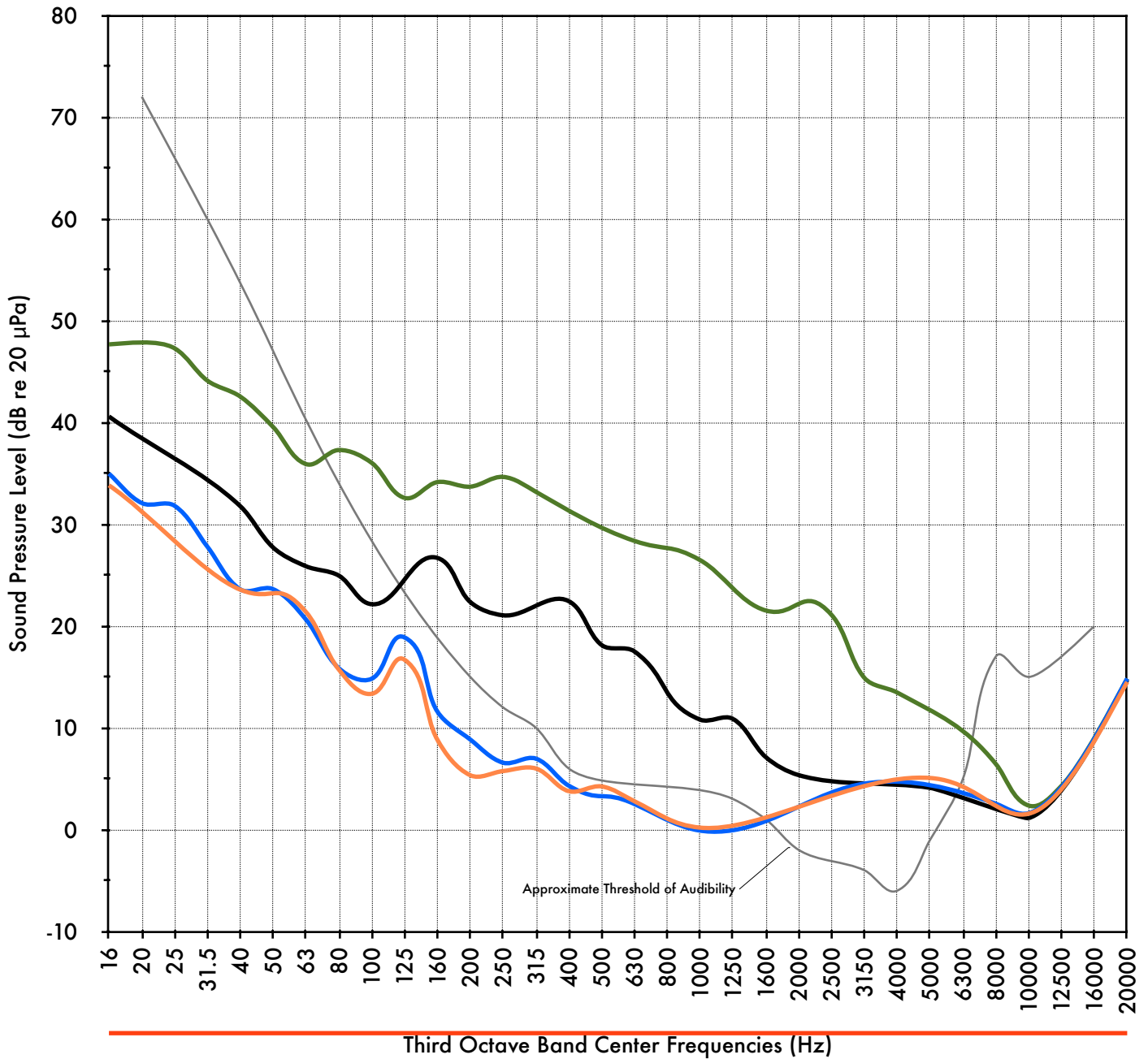
RC 6.8

Center of Studio 1, HVAC at High

RC 17.4 N

Center of Studio 1, HVAC at Full Flow

RC 30.7 N





EMPAC Background Noise

Venue: Studio 2

Date of Measurement: 17 Aug 2011

Measurement of noise from HVAC settings [Measurements R2-006, 007, 008, 009]

Center of Studio 2, HVAC at Low

RC 5.7

Center of Studio 2, HVAC at Medium

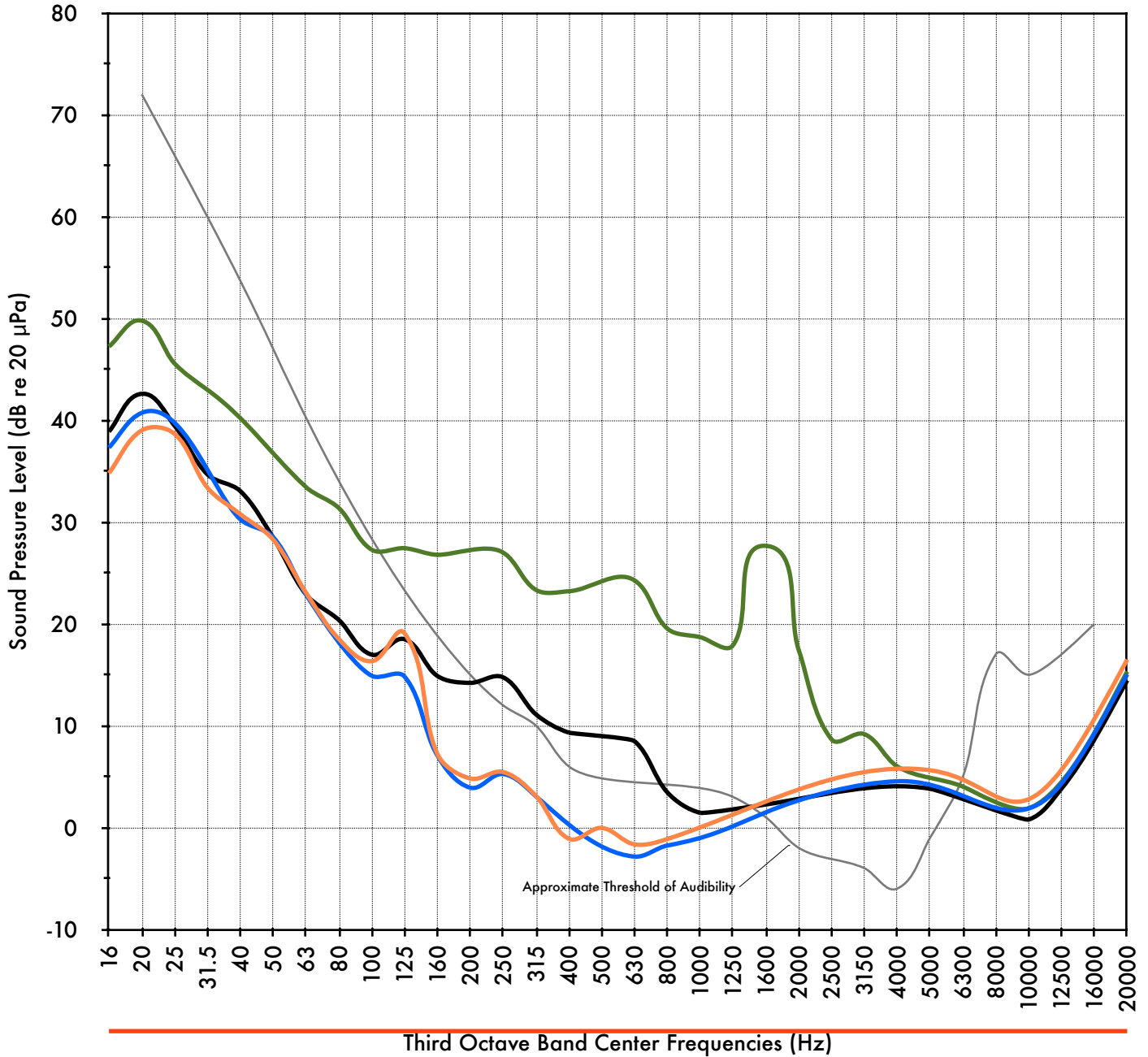
RC 4.8

Center of Studio 2, HVAC at High

RC 9.4

Center of Studio 2, HVAC at Full Flow

RC 26.7 H T



EMPAC Background Noise  
 Measurement Noisy Fire Control Panel [Measurements R2-002, 003, 004, 005]

Venue: Theater

Date of Measurement: 17 Aug 2011

Seat D11 (Front Row, Center)

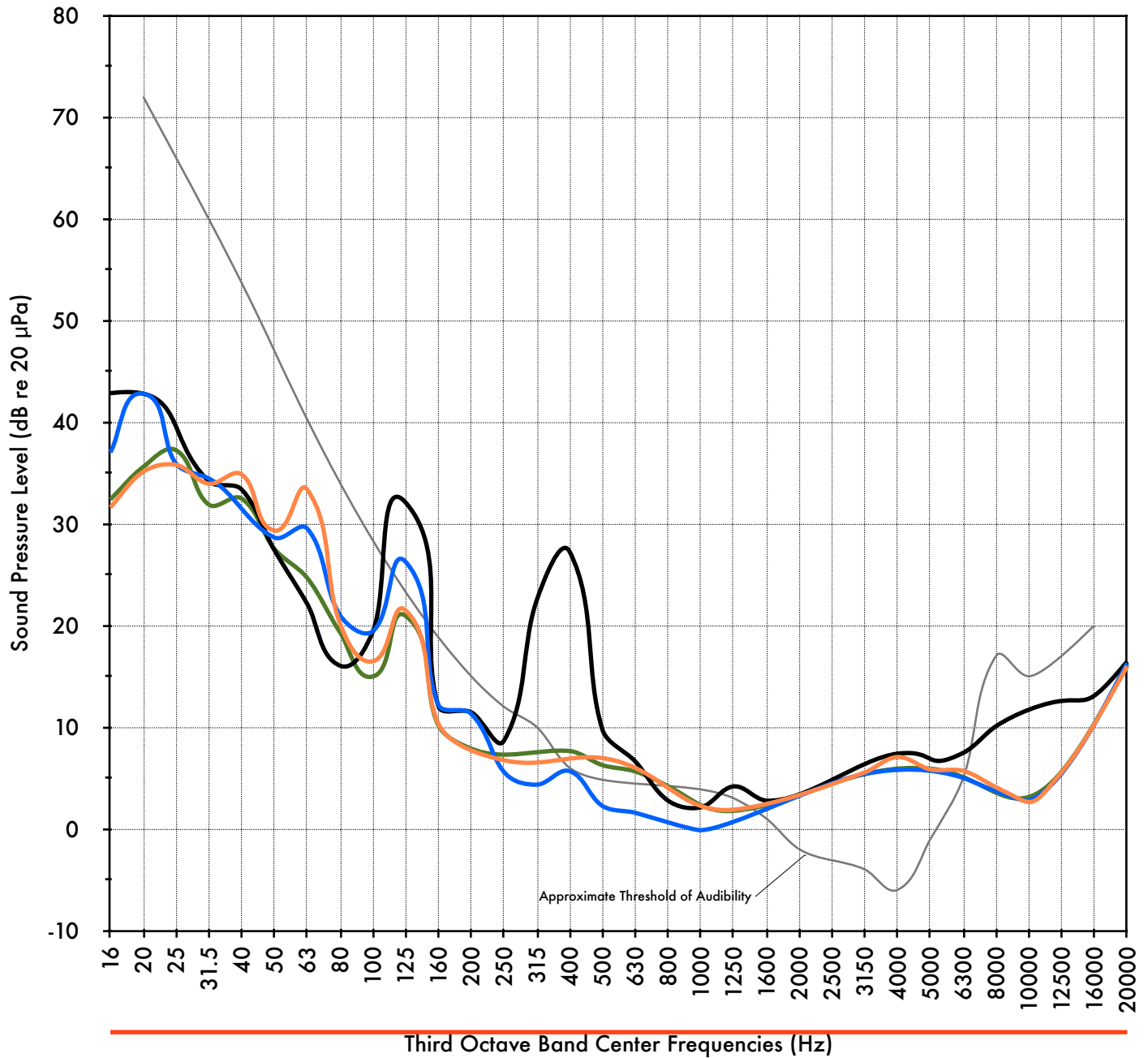
RC 9.2

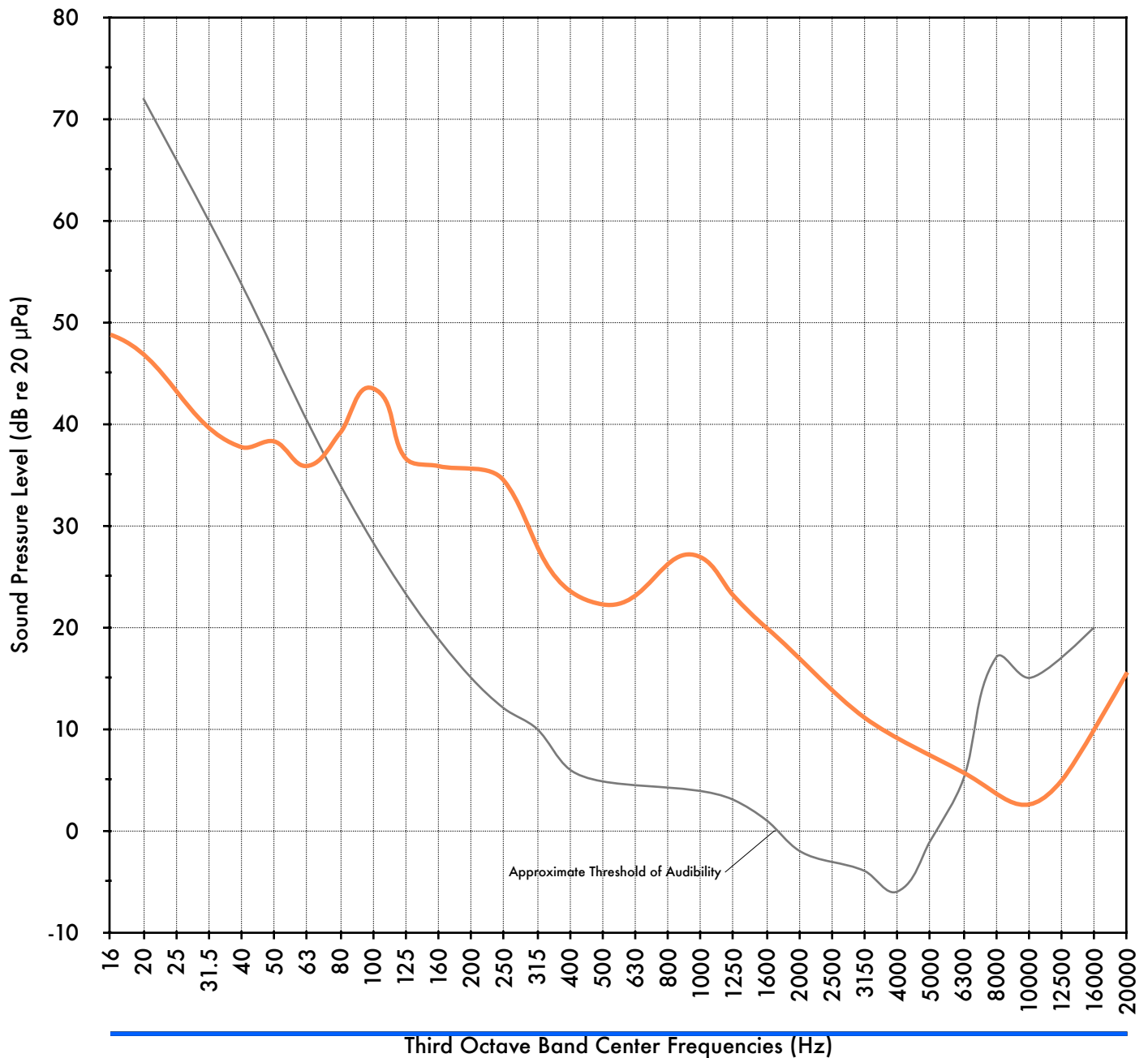
Stage, Center of Flytower

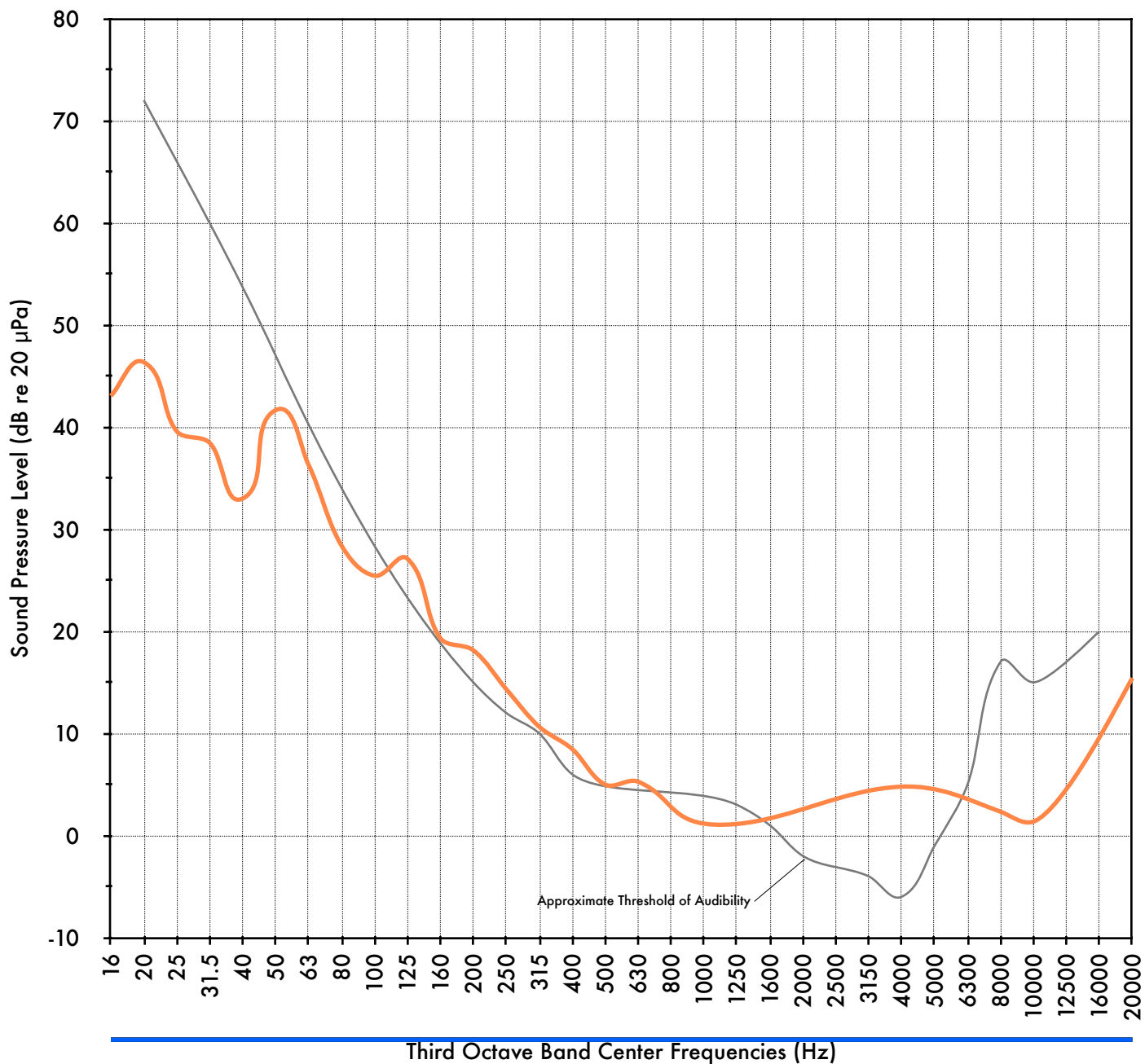
RC 7.3

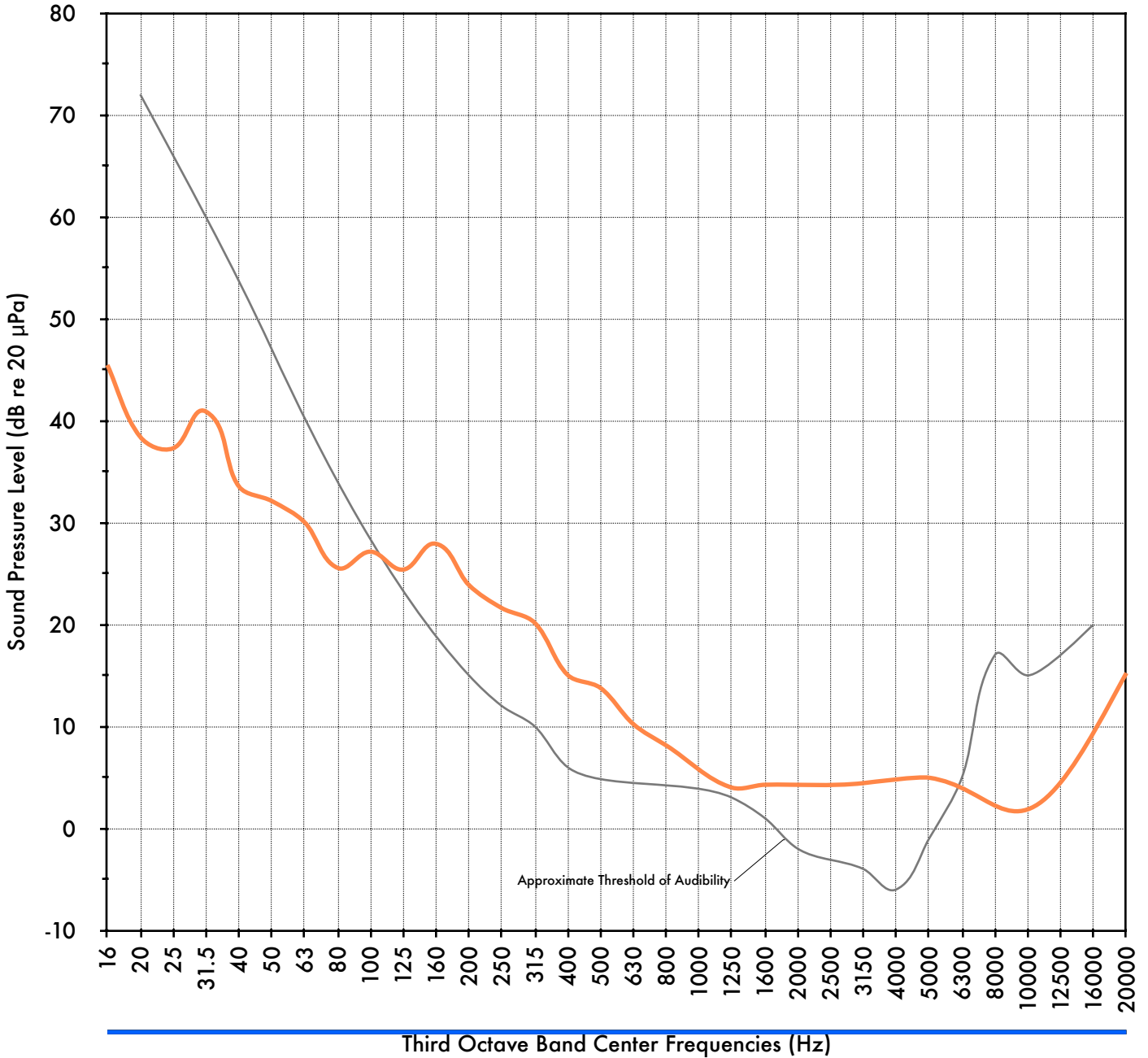
Approximately 1 m from Control Panel

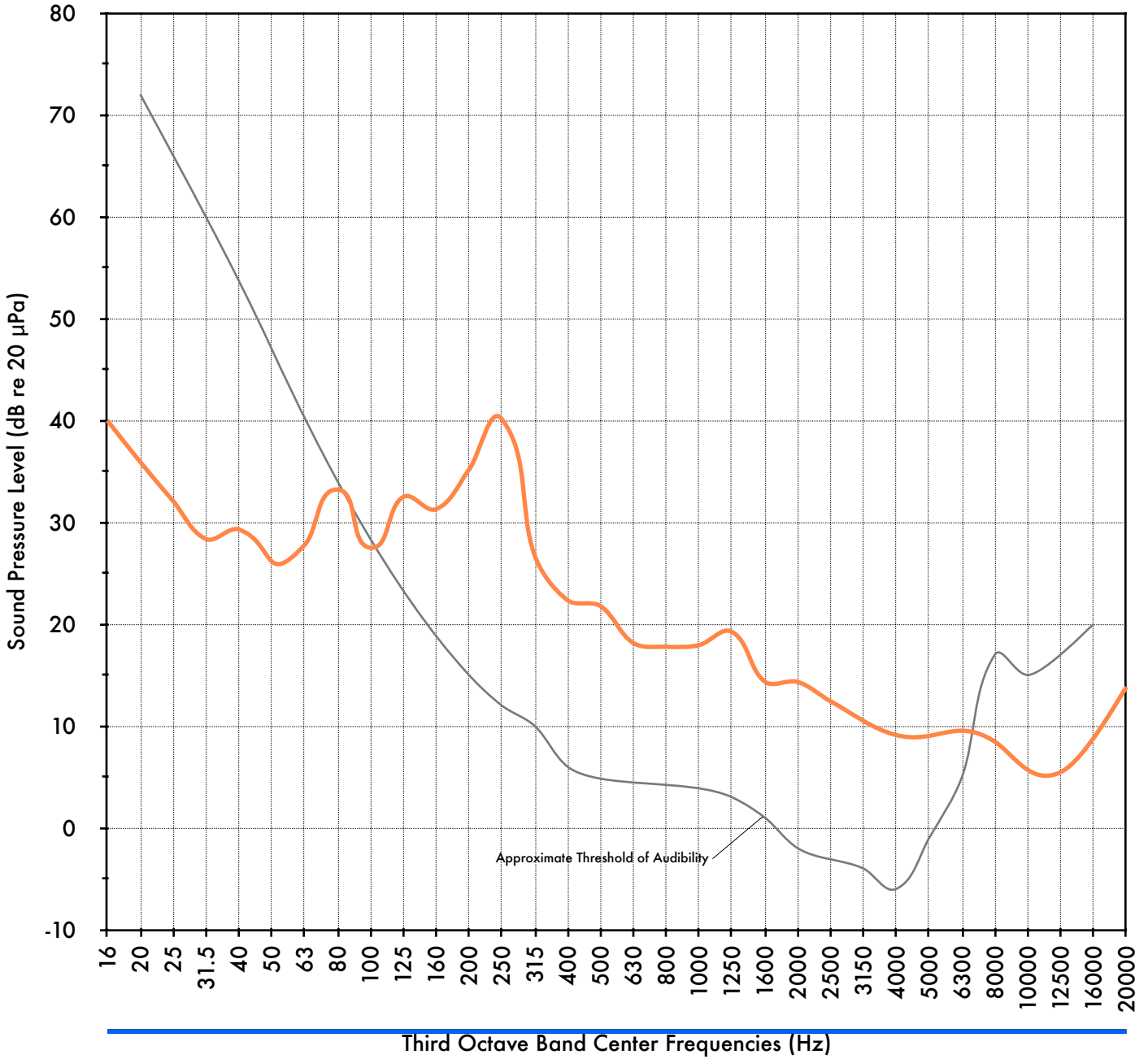
RC 14.6 T





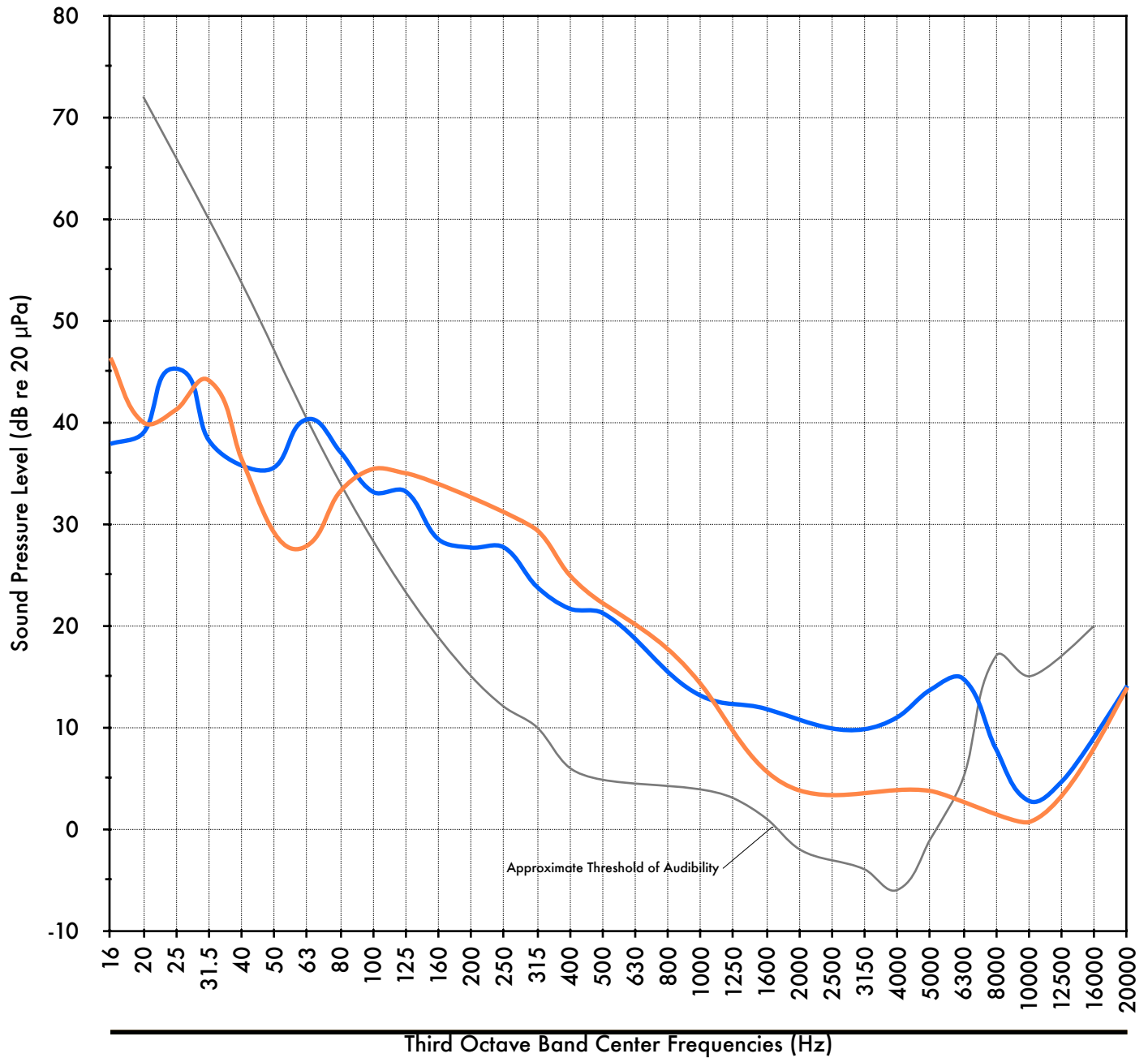


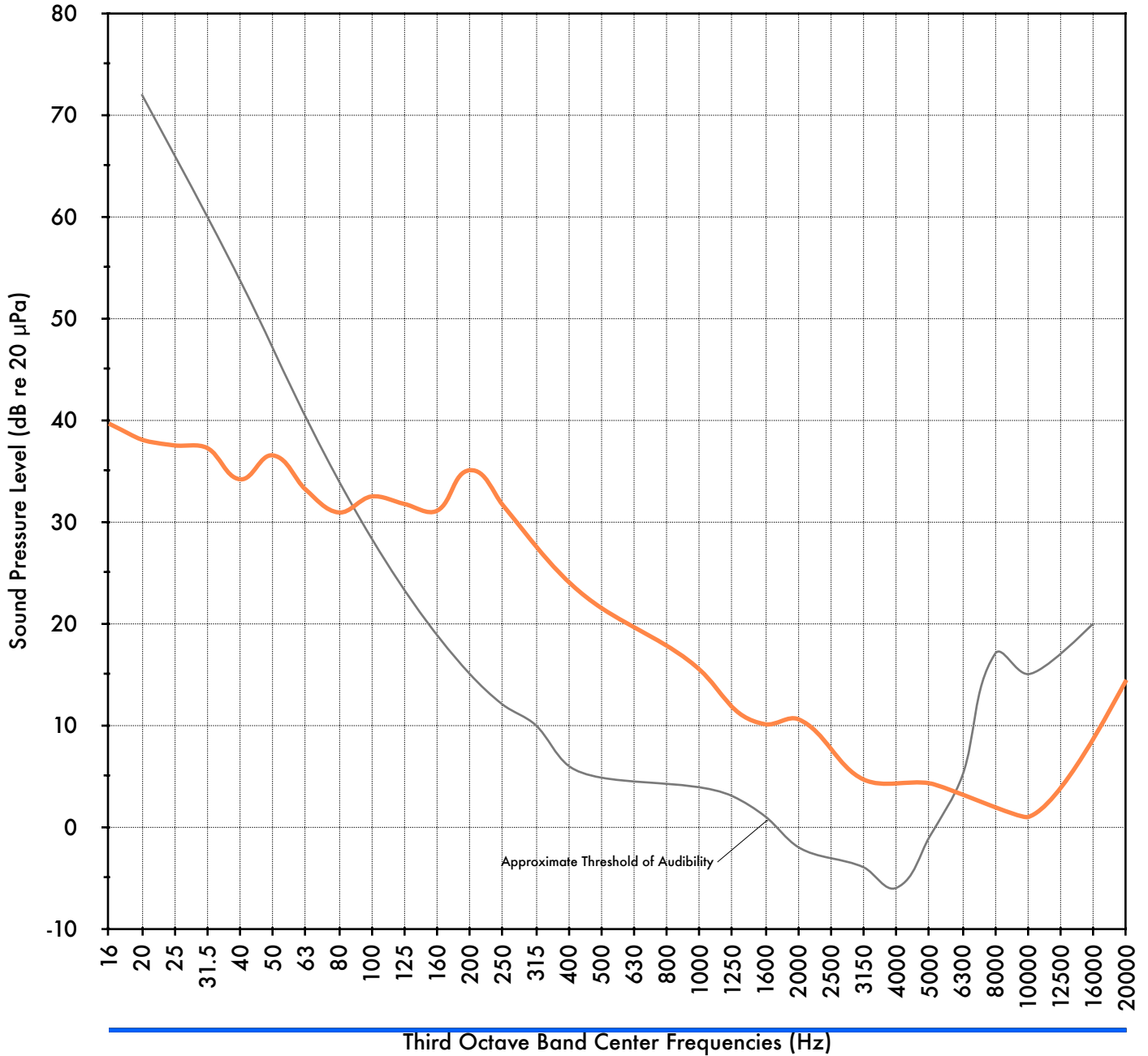




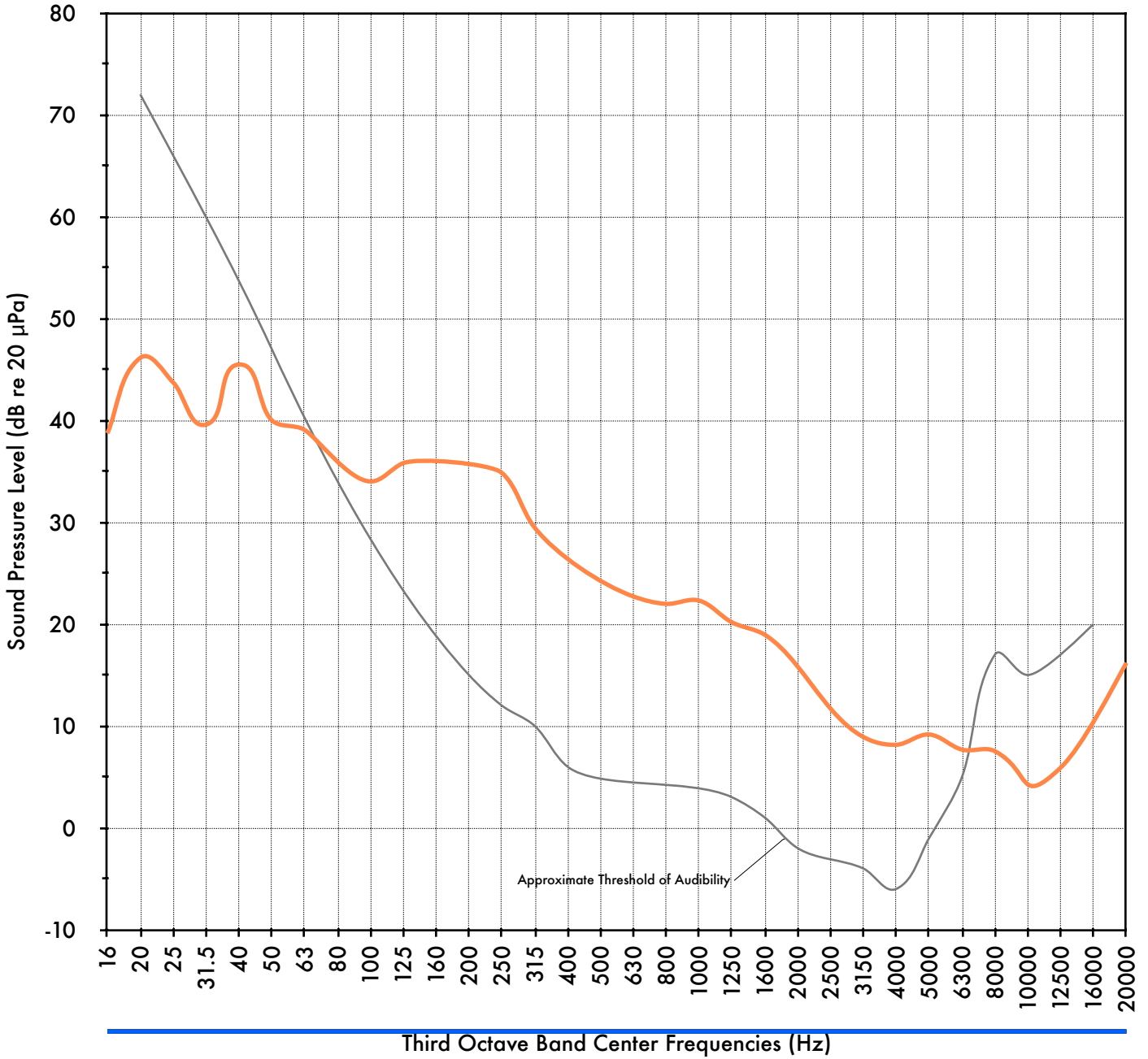
Residency Studio 4 Rm 6609  
Residency Studio 3 Rm 6613

RC 19.0 | N  
RC 19.8 N







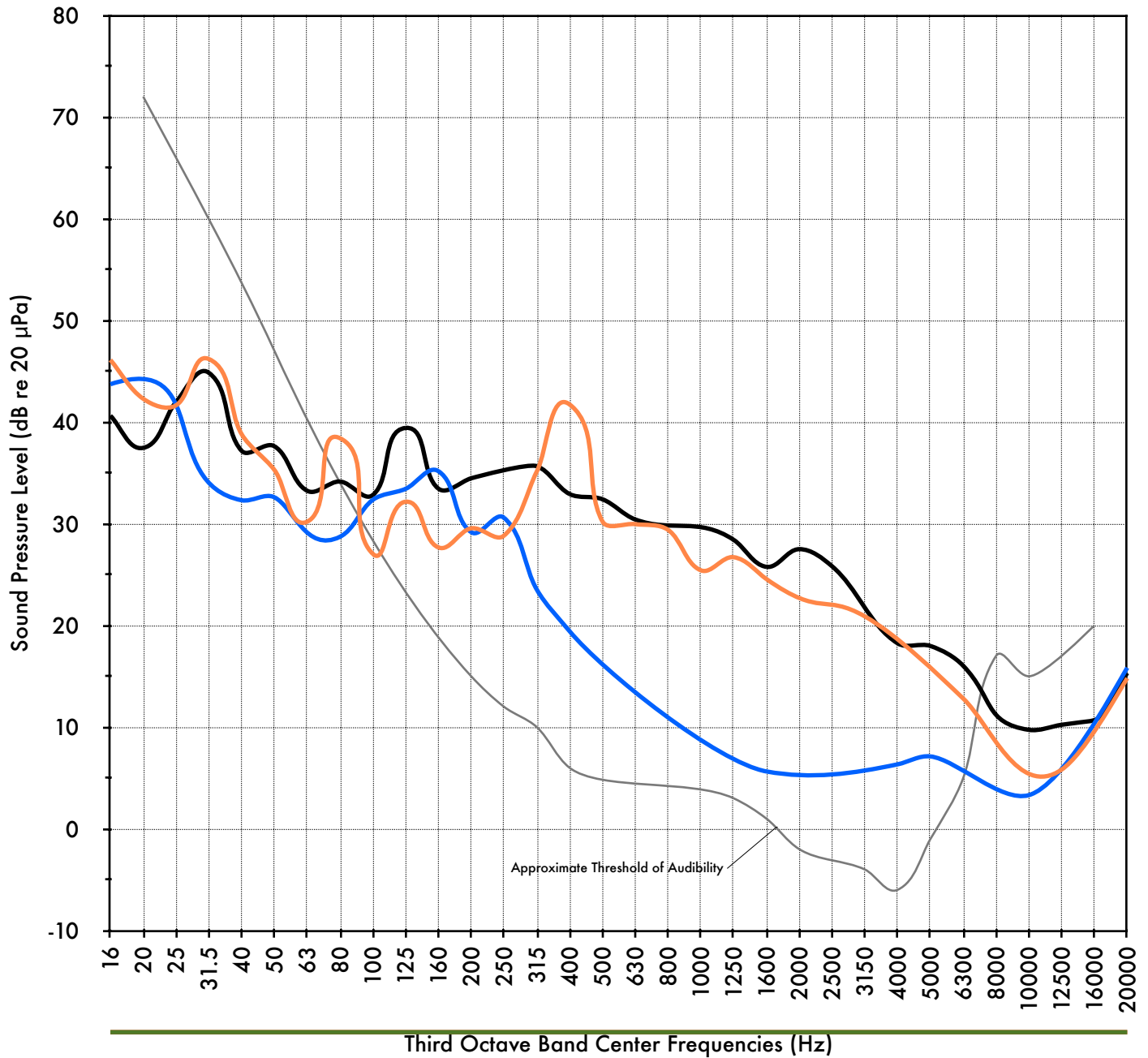


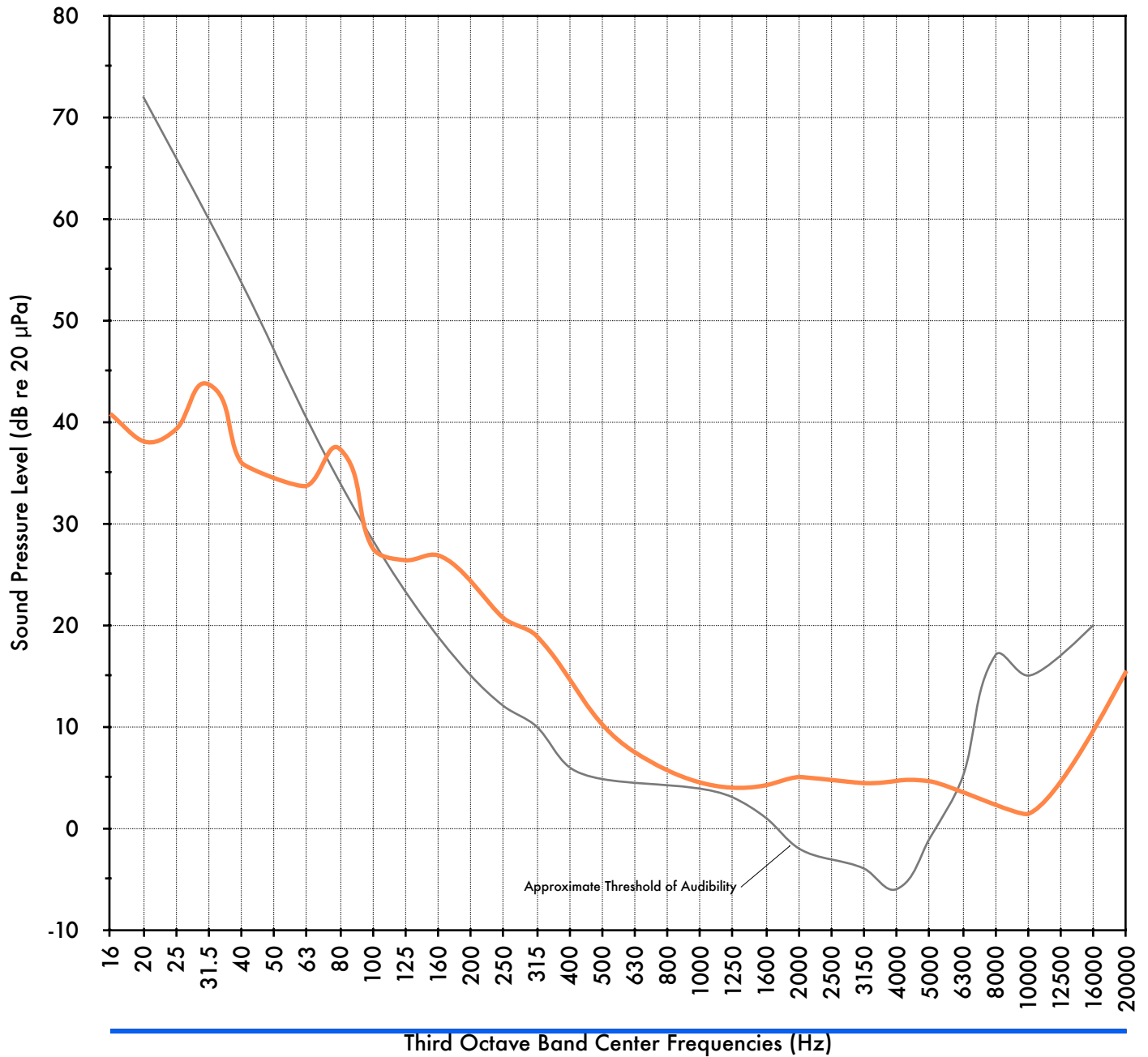
EMPAC Background Noise  
Control Rooms [Measurements R2-020, 021, 022]

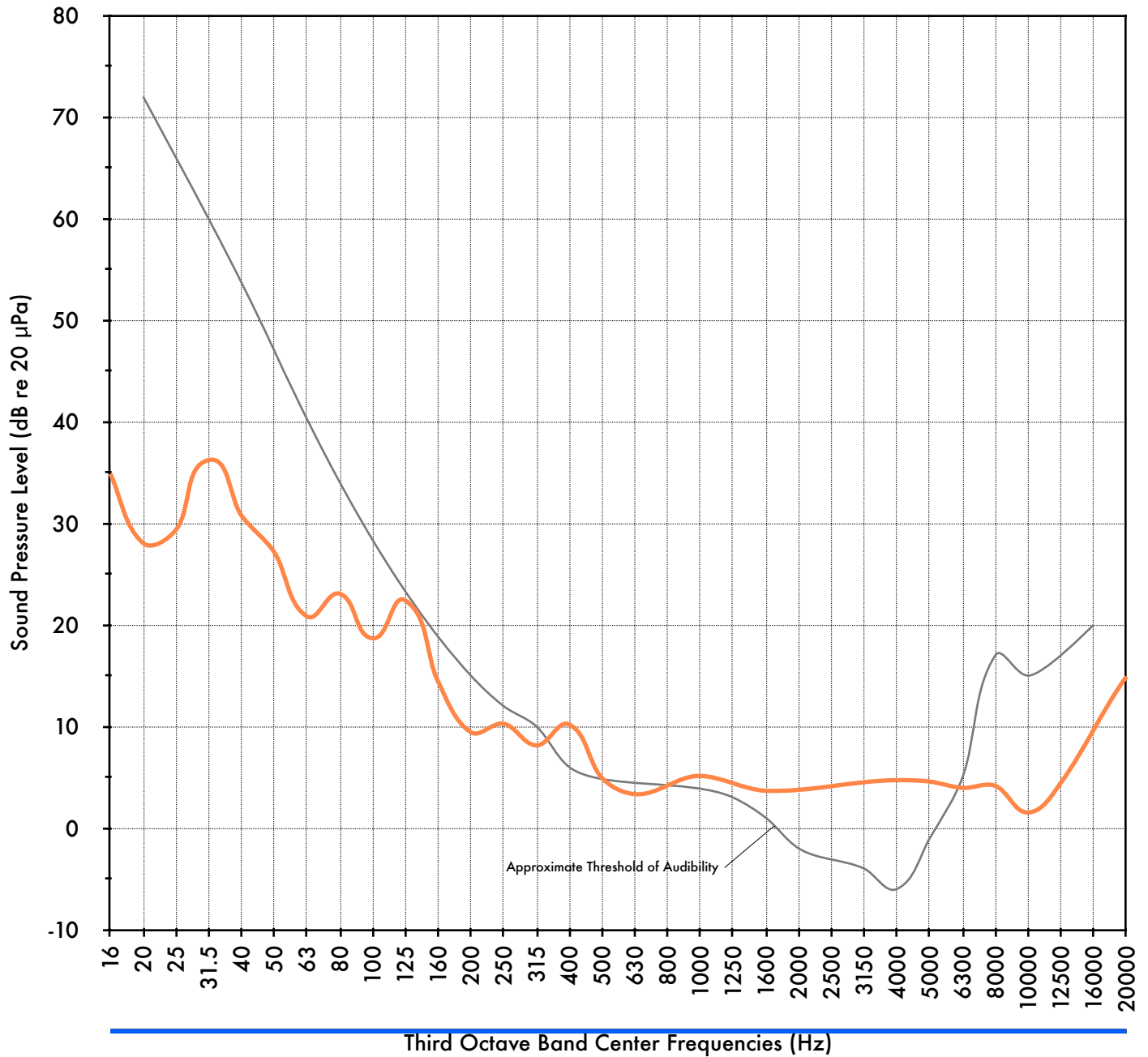
Date of Measurement: 22 Aug 2011

Studio 2 Control Room  
Studio 1 Control Room  
Concert Hall Control Room

RC 34.1 | R T  
RC 15.3 N  
RC 34.1 N





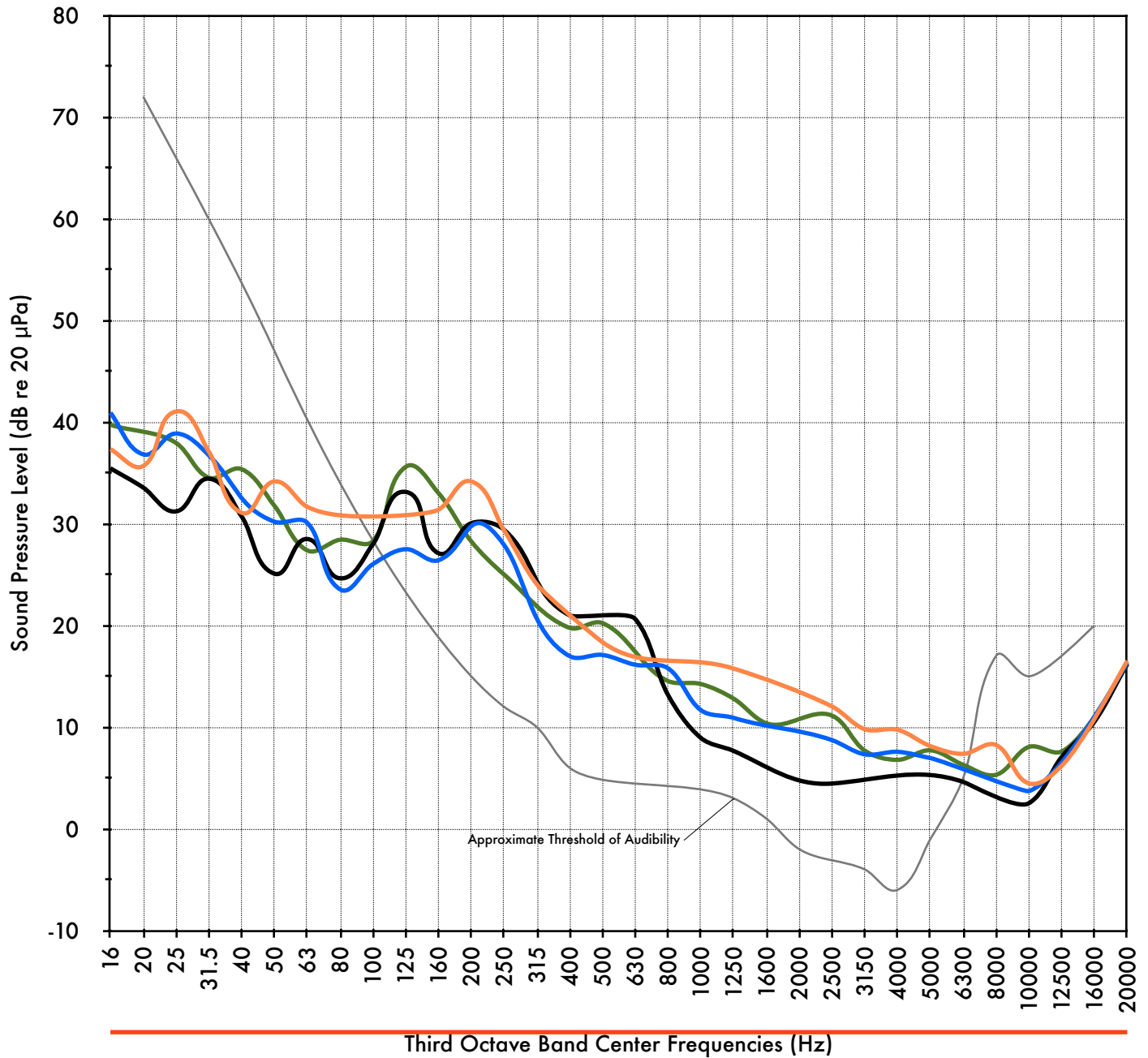


EMPAC Background Noise  
Administrative Offices [Measurements R2-016, 017, 018, 019]

Date of Measurement: 22 Aug 2011

- Director's Office Rm 7418
- Head of Research Rm 7414
- Curator's Office Rm 7408
- Conference Rm 7403

- RC 21.0 | R T
- RC 17.9 N
- RC 17.0 N
- RC 19.4 N

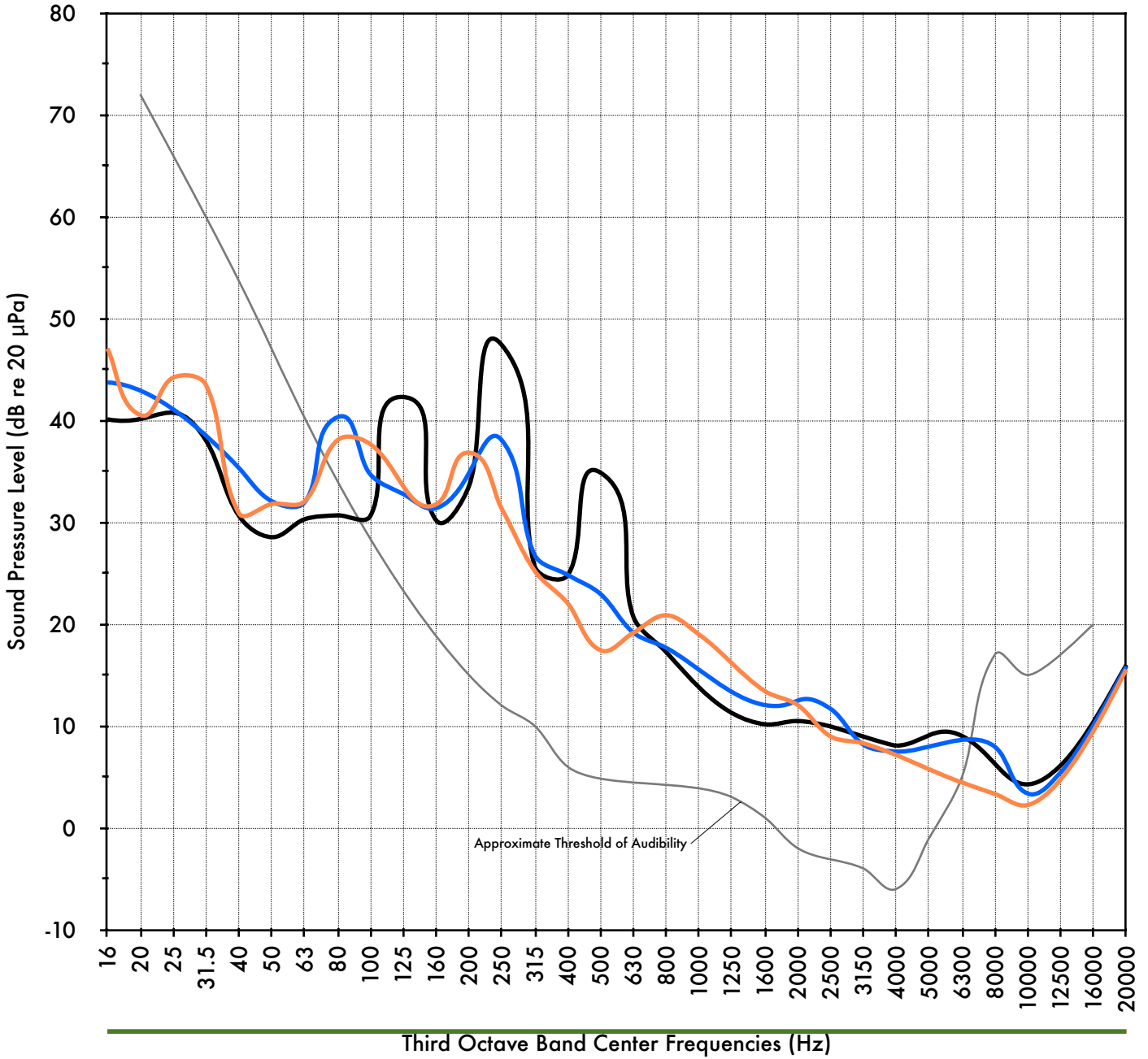


EMPAC Background Noise  
5000 Level Offices [Measurements R2-028, 029, 030]

Date of Measurement: 22 Aug 2011

Room 5615  
Room 5609  
Room 5608

RC 21.7 | R T  
RC 21.7 R T  
RC 23.3 R T



EMPAC Background Noise

Venue: Concert Hall

Date of Measurement: 08 Aug 2011

Stage Measurement of Dimmer and Transformer Noise [Measurements R1-035, 040, 045]

Stage, Transformers Off, Dimmers On

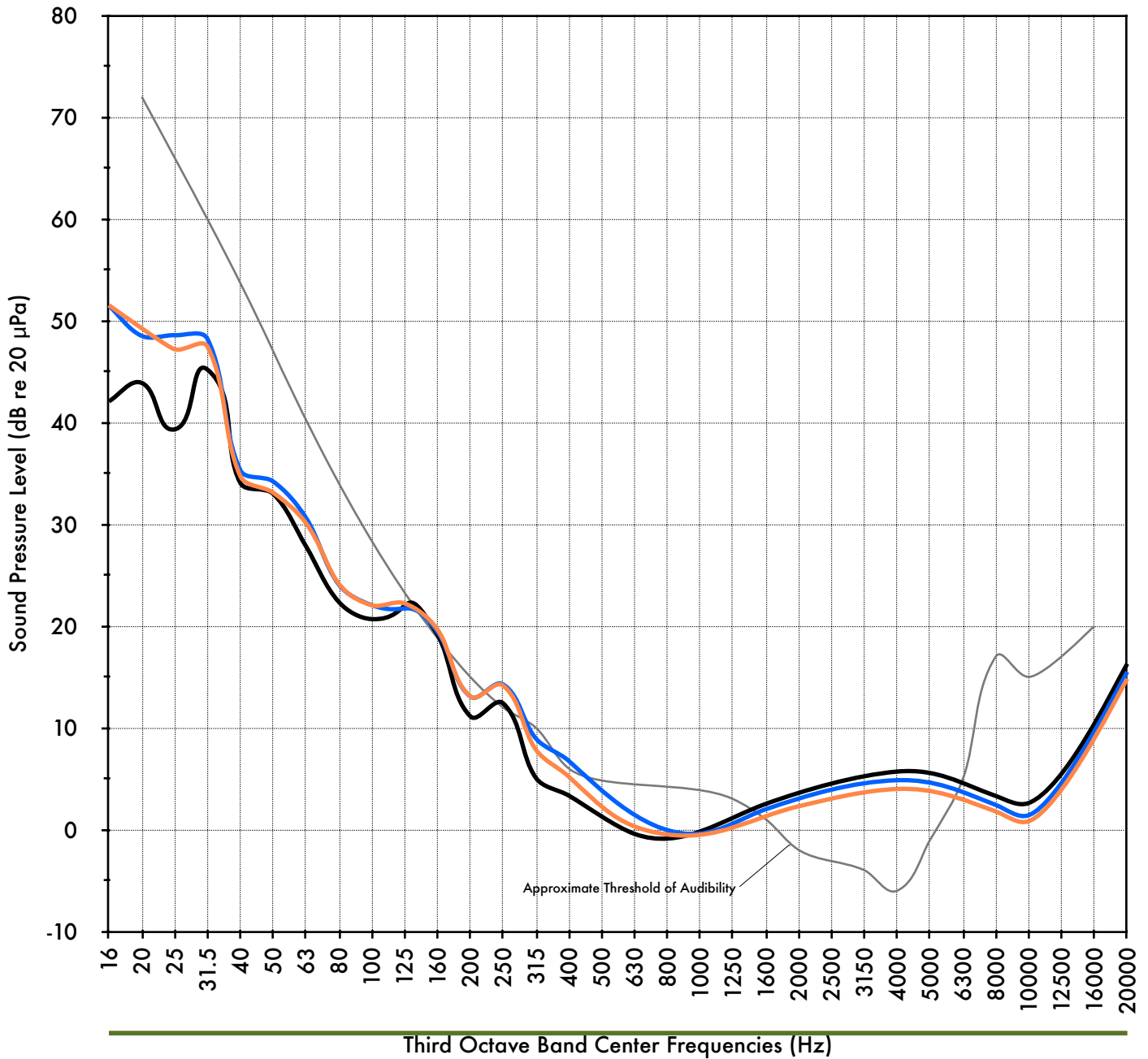
RC 6.4

Stage, Transformers Off, Dimmers Off

RC 7.4

Stage, Transformers On, Dimmers Off

RC 6.5



EMPAC Background Noise

Venue: Concert Hall

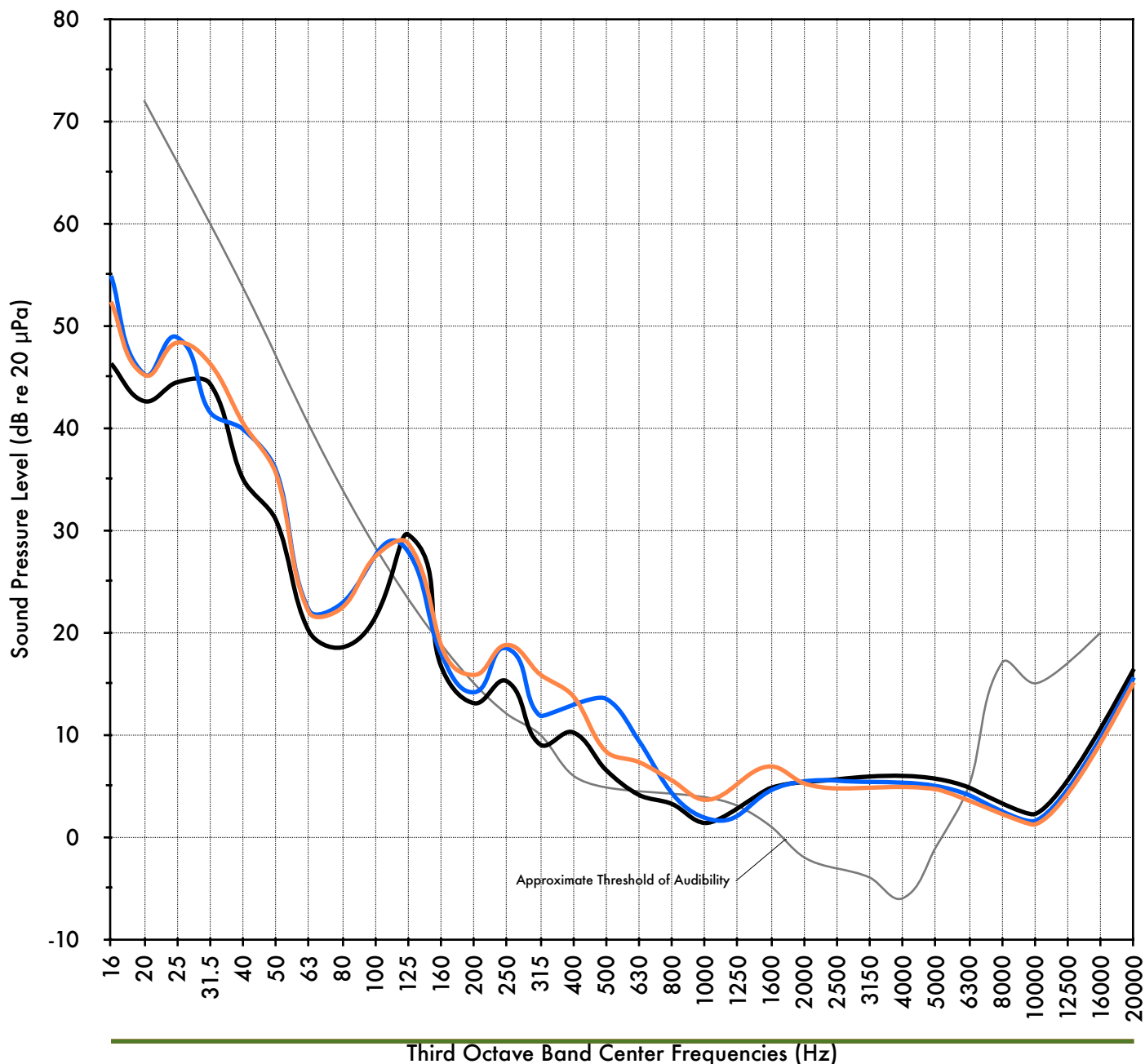
Date of Measurement: 08 Aug 2011

Sound and Light Lock Measurement of Dimmer and Transformer Noise [Measurements R1-038, 043, 048]

Sound and Light Lock, Transformers Off, Dimmers On RC 11.9

Sound and Light Lock, Transformers Blue, Dimmers Off RC 11.5

Sound and Light Lock, Transformers On, Dimmers Off RC 9.9





EMPAC Background Noise

Venue: Concert Hall

Date of Measurement: 08 Aug 2011

Seat C24 Measurement of Dimmer and Transformer Noise [Measurements R1-036, 041, 046]

Seat C24, Transformers Off, Dimmers On

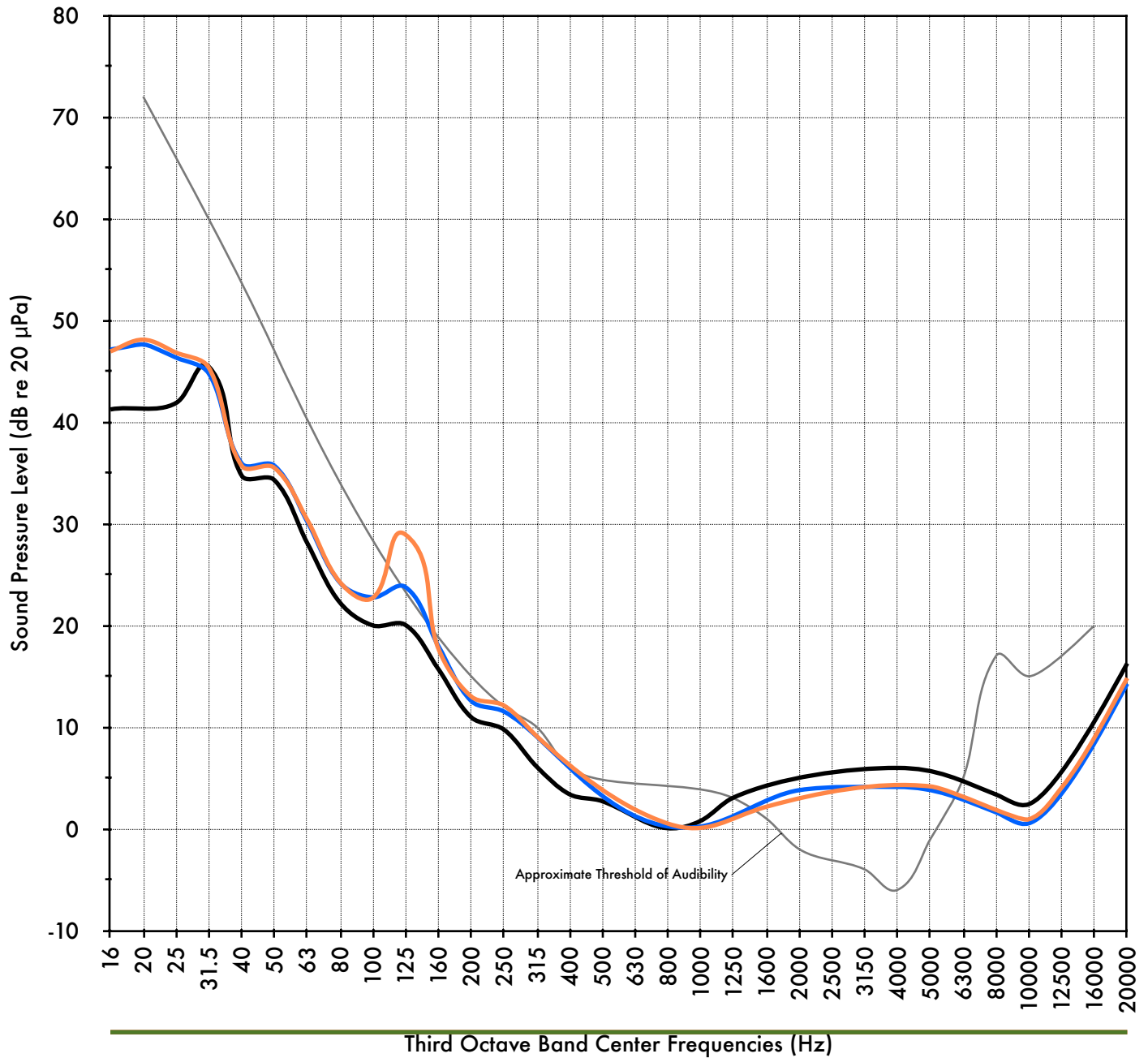
RC 7.3

Seat C24, Transformers Off, Dimmers Off

RC 7.4

Seat C24, Transformers On, Dimmers Off

RC 7.6



EMPAC Background Noise

Venue: Concert Hall

Date of Measurement: 08 Aug 2011

Main Floor Measurement of Dimmer and Transformer Noise [Measurements R1-037, 042, 047]

Main Floor, Transformers Off, Dimmers On

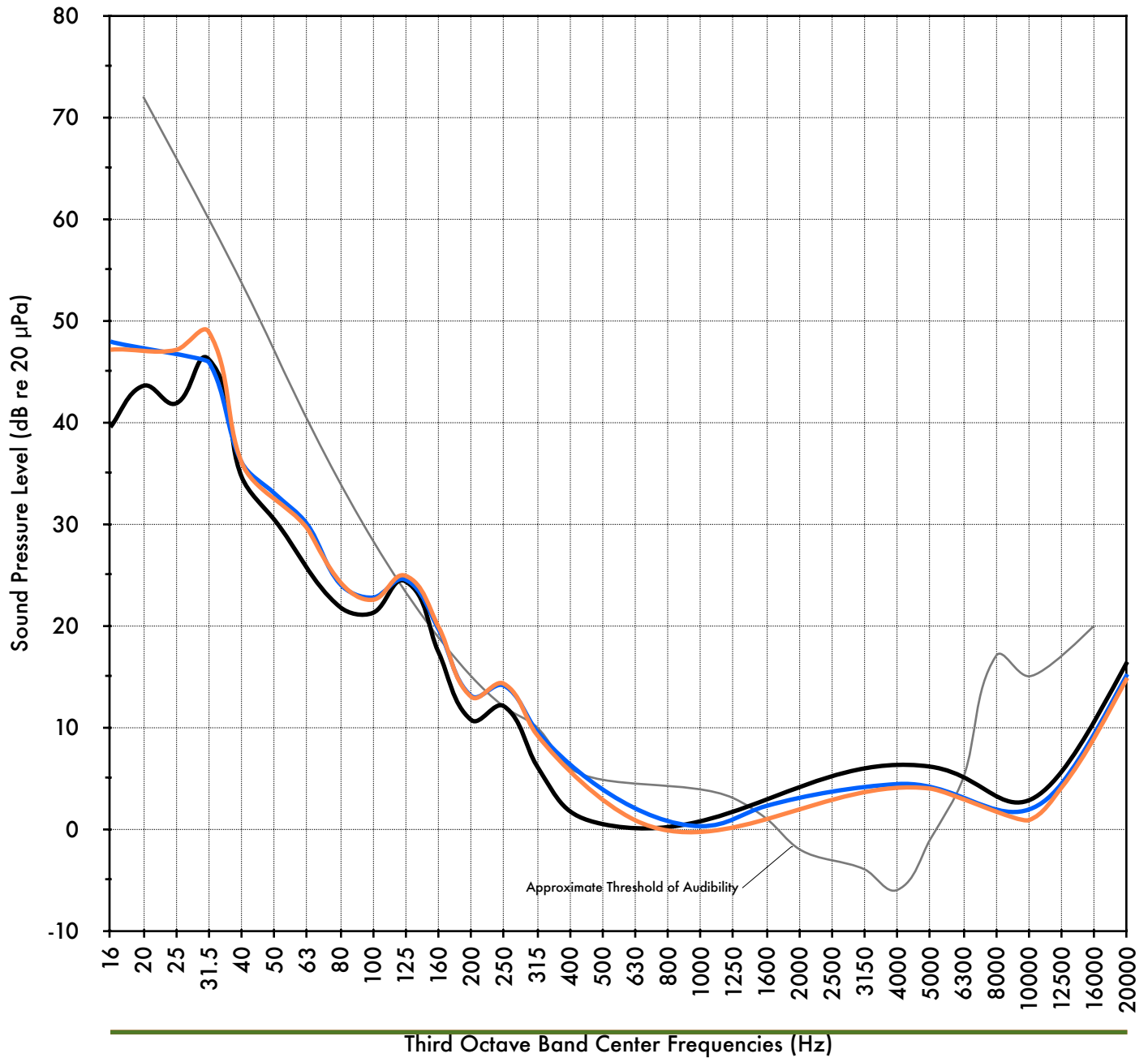
RC 6.7

Main Floor, Transformers Off, Dimmers Off

RC 7.5

Main Floor, Transformers On, Dimmers Off

RC 6.6



EMPAC Background Noise

Venue: Concert Hall

Date of Measurement: 08 Aug 2011

House Left Gallery Measurement of Dimmer and Transformer Noise [Measurements R1-039, 044, 049]

House Left Gallery, Transformers Off, Dimmers On

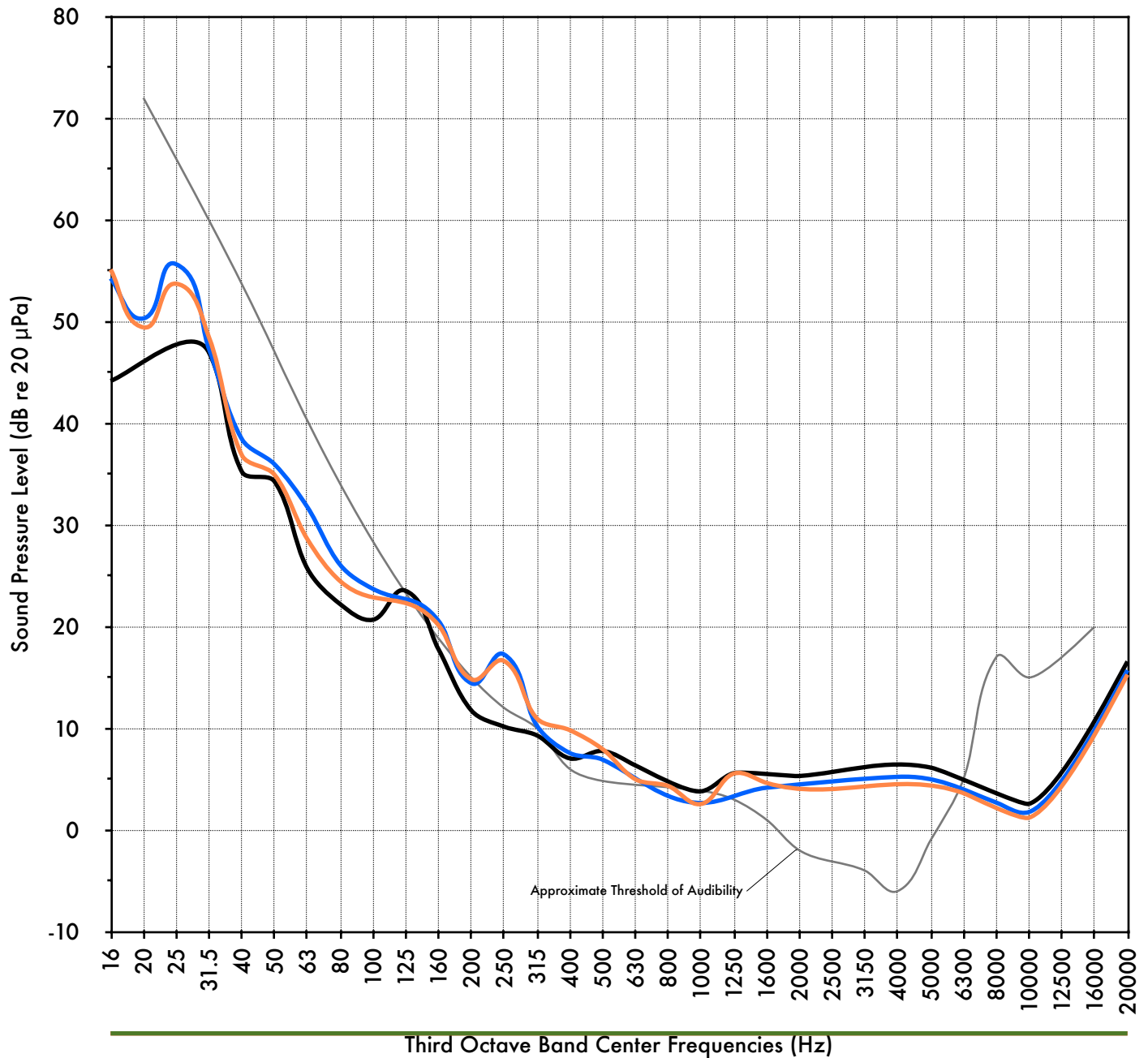
RC 10.2

House Left Gallery, Transformers Off, Dimmers Off

RC 9.5

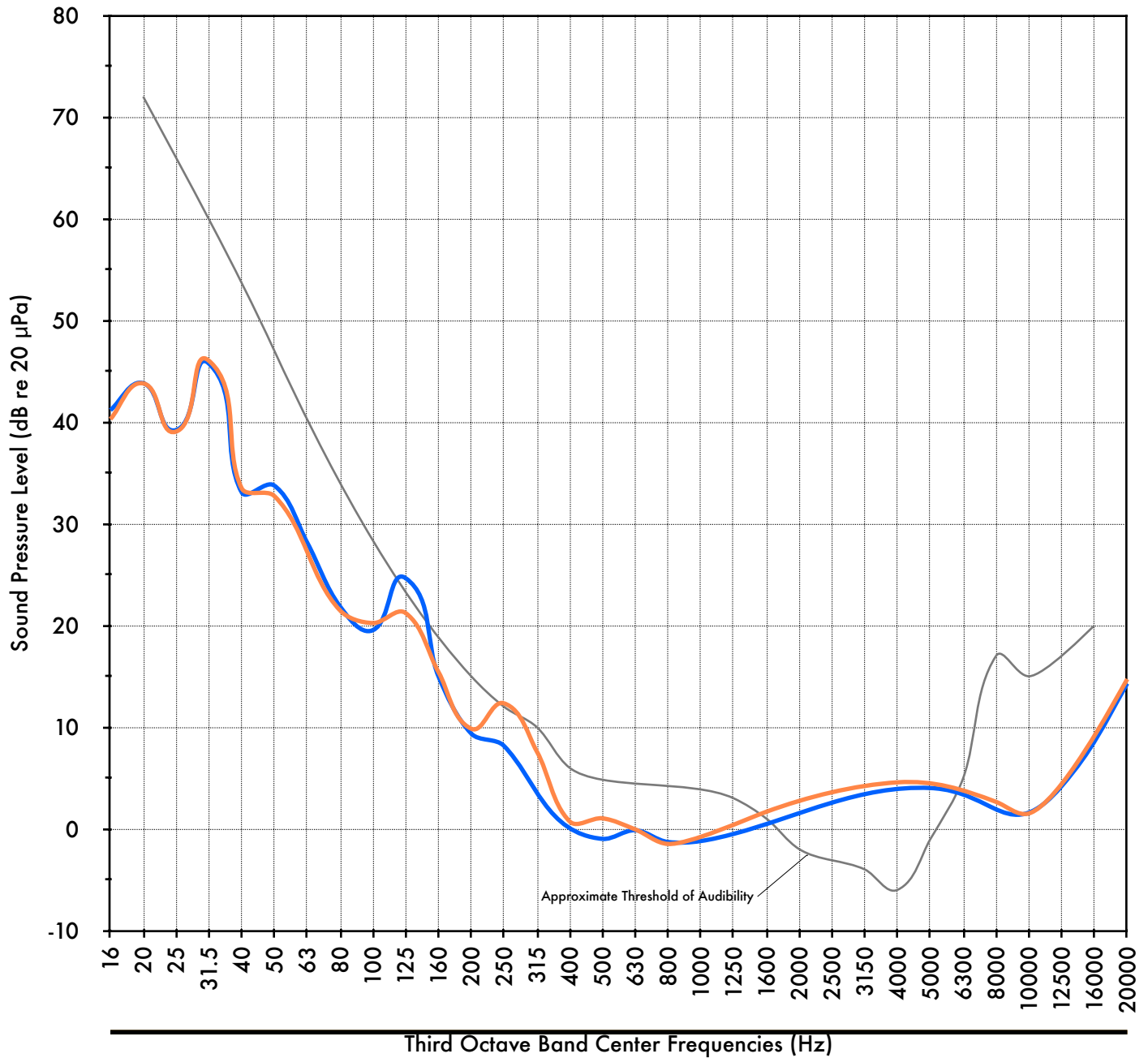
House Left Gallery, Transformers On, Dimmers Off

RC 10.6



Stage, Line Arrays On  
Stage, Line Arrays Off

RC 5.7  
RC 5.0



EMPAC Background Noise

Venue: Concert Hall

Date of Measurement: 07 Aug 2011

Comparison of 30 sec and 5 sec measurements [Measurements R1-008, 018, 019]

Main Floor, 30 s

RC 5.7

Main Floor, 5 s

RC 5.2

Main Floor, 5 s

RC 4.3

