

NEOJIBA Renovation in Parque do Queimado

Salvador (Bahia), Brazil

Acoustical Design Report

March 28, 2016



1990 S. Bundy Dr., Ste. 795
Los Angeles, CA, USA 90025
+1(310)231-7878

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Introduction

This report for the design project of the renovation of existing historic structures in the Parque do Queimado for the Núcleos Estaduais de Orquestras Juvenis e Infantis da Bahia, to be located in Salvador (Bahia), Brazil, aims to identify the current state of the important elements of the acoustical design in the building. These are the elements which have been discussed in meetings, video conferences and e-mails since September 2015.

Part 1:
Acoustical Narrative

A. Room Acoustics

The room acoustics of a space is generally considered the most important acoustical aspect of a building intended for the Performing Arts, especially in spaces designed for unamplified musical performances. The most important architectural elements influencing room acoustics can be generally divided into two broad categories, Room Shape and Materials, both of which play a major role in determining the acoustical result. Both items are also of utmost importance to the architectural impact of the space, and therefore should be developed in close collaboration with the design and project architect.

1. Concert Hall (150 seats)

Room Shape

The existing building gives the basic foundation for shape of the room. The following modifications to the room are advised to ensure the best quality room acoustics, given the existing conditions.

The hall is intended to have a "T"-shape, with the stage forming the cross-bar of the "T", and the audience forming the stem of the "T". The existing archway between the two spaces should be enlarged to create the largest possible opening between the spaces. The intent is to ensure to the greatest extent possible that the two existing volumes are merged into a single volume.

Generally, the ceiling height is one of the most important features of a space for the unamplified performance of music. Therefore, all efforts should be made to ensure that the maximum ceiling height defined by the existing shell of the building is maintained.

The ceiling shape should continue in the direction as has been discussed with the architects, based on the "folded planes" concept discussed in late June 2015.

The stage should be elevated above the level of the audience floor in order to improve sight-lines from the entire audience area to the performers on the stage.

Parallel conditions on the stage should be avoided.

Material Qualities

In order to maintain a “richness” of sound, created by sufficient low-frequency energy, suitably massive materials are required for the majority of surfaces, so that low-frequency energy can be efficiently reflected. Recommended surface densities are as follows:

Ceilings: 120 kg/m^2

Walls and other surfaces: 60 kg/m^2

Surfaces should have some small-to-medium scale surface articulation, in order to diffuse high-frequency reflections.

Floors of the stage should use the Stage Floor Structure diagram in Appendix I.

The stage floor decking should be a massive, durable softwood, such as Alaskan Yellow Cedar, and the substructure should be constructed of softwood as well. The floor surface should be finished with paste wax or tung oil, thinly applied to avoid stiffening the surface. Samples should be reviewed by Nagata Acoustics prior to final approval. Possible local varieties which were investigated but not possible for the stage floor include “Spanish Cedar” and “Loblolly Pine”. The substructure may use a different species of softwood, such as “Loblolly Pine”.

Floors in the audience area should be hard and reflective, such as concrete or wood.

In the case of wood floors, air cavities between the finish floor and the structural floor below should be avoided.

Two areas of curtains are required:

1) South Wall

The entire area of the south wall should be covered by a double heavy velour or wool serge curtain (0.5 kg/m^2 or greater), at all times. The curtain should be flat, and arranged as follows:

40cm air space between first curtain and wall

15cm air space between first and second curtain

Some additional structure may be necessary to maintain the consistent air space between layers.

2) East Wall

The south end of the east wall, above the audience entry, should receive an

additional 14m² of the same double-curtain structure as the South Wall.

3) West Wall

The entire west wall should have an operable curtain mounted to it, for use when the audience area is used as a rehearsal space. The curtain should be heavy velour or wool serge (0.5 kg/m² or greater) and sewn with 100% fullness. When not in use for rehearsals, the curtains should be stored in-place on the walls. The curtains should be fabricated in several separate pieces to allow more flexible usage.

2. Study Rooms

Rooms should be arranged in order to avoid parallel conditions between walls, and between ceilings and floors. When necessary, sound-diffusing elements may be placed on walls to break parallel conditions. A difference in angle of more than 10° with a distance from the wall of at least 40cm are required for breaking parallel. Regular repeating patterns in sound-diffusing elements should be avoided.

Variable acoustics in the form of heavy, sound absorbing curtains (weighing 0.5 kg/m² or greater, sewn with 100% fullness) should be provided in all study rooms as follows:

- Study rooms 1, 5, and 6: The entire west wall. The curtains should be divided into several separate sections for flexibility.
- Study rooms 2, 3 and 4: The entire west wall and one adjacent (north or south) wall

Sound-absorbing materials are required on the ceiling in all spaces. A 300-mm air space should be provided between the materials and the hard, reflective ceiling behind. Amounts and thicknesses for the different rooms are as follows:

- Study room 1: 50% of the ceiling; 50mm thick fiberglass
- Study room 2: 100% of the ceiling; 50mm thick fiberglass
- Study room 3: 100% of the ceiling; 50mm thick fiberglass
- Study room 4: 100% of the ceiling; 50mm thick fiberglass
- Study room 5: 50% of the ceiling; 50mm thick fiberglass

- Study room 6: 50% of the ceiling; 50mm thick fiberglass

50mm thick fiberglass may be composed by stacking two layers of 25mm fiberglass on top of each other.

Rooms which have only a portion of the ceiling covered with fiberglass should have the fiberglass placed in 3 or 4 large blocks evenly distributed through the room.

Floors in the study rooms should be a hard material, such as concrete or wood.

3. Audio/Visual Production

Ceilings should be acoustically absorptive.

50% of the walls should 50mm fiberglass applied to the area.

4. Control Room

Ceilings should be acoustically absorptive.

Walls should have 50% of their area covered with 50mm fiberglass absorption, evenly distributed.

5. Restrooms, Lobby

Ceilings should be acoustically absorptive.

6. Hallways

Ceilings should be acoustically absorptive.

Walls should have 50% of their area covered with 50mm fiberglass absorption, evenly distributed.

7. Sound/Light Locks

Walls and Ceilings should be clad in 50mm fiberglass absorption.

B. Sound Isolation

The Sound Isolation defining the majority of the structure of the building is defined as the level difference of sound in decibels (at mid-frequencies) between the

outside environment and the space in question, as below. Subjective Impressions of the Level Differences is described in Appendix II. The conceptual strategy for achieving high sound isolation between spaces is shown in Appendix III.

Sound Isolation Key Plans are included in Part 2. Acoustical requirements for doors are identified on the plans. Door types "ISOL-B" and "ISOL-C" are detailed in Part 3. Door types STC-43 are intended to be supplied as a package unit (including leaf, frames and hardware) from a single manufacturer who will guarantee the listed STC rating.

Details for maintaining acoustical isolation between spaces while allowing necessary services (e.g. electrical, mechanical) to penetrate wall partitions are included in Appendix V.

1. Concert Hall (150 seats)

- Level difference from: Concert Hall ↔ Outside: 50 dB (at mid-frequencies)
- Level difference from: Concert Hall ↔ Music Rooms: >80 dB (at mid-frequencies)

In order to reach the sound-isolation target listed above, the existing historical windows must be augmented with additional interior glazing, which is fully gasketed and sealed. The new windows should be built up as follows:

- 16mm laminated glass
- 100mm air space
- 12mm laminated glass

Hollow window frames should be packed with rockwool.

Existing openings between interior spaces which will be separated in the renovation (e.g. between Concert Hall and Lobby, Concert Hall and stairway, and Stage and Sound/Light Lock) should be closed with concrete, 150mm thick.

Glazing between the Stage and Control Room (1st Floor) should use the same overall structure as above. The interior layer of glass should be tilted so that the two panes of glass are not parallel to each other. The size of the glass should be reduced to the minimum practical area.

To maintain the sound isolation between the lobby and the Hall, the walls of the newly-constructed sound-and-light-lock (SAS) should be constructed using the detail in part 3 of this report. The Floor, Ceiling and two larger walls should be clad in sound absorbing materials.

2. Music Rooms

- Level difference between adjacent Music Rooms: 70-80 dB (at mid-frequencies)
- Note: To maintain this level of sound isolation, a Sound Lock is required for rooms which are enclosed by high isolation walls. Since sound locks are not possible in the academic portion of the building due to the constraints of the existing structure, high-performance sound-isolating doors as package units must be used. The distribution of these doors is shown on the plans in Part 2.

With this strategy, 65dB sound isolation (at mid-frequencies) may realistically be expected between adjacent music rooms.

All Music Rooms should be fully enclosed (walls and ceilings) using 150mm thick concrete walls as a base. Care should be taken to ensure that the new 150mm thick walls and ceilings are solidly attached to each other and also to the existing structure, creating airtight joints.

A resiliently supported interior wall and ceiling system of 3 layers 16mm gypsum wallboard should be added to Study Rooms 1 and 3, according to the plans in Part 2. Those rooms should also receive a floating concrete floor, 120-150mm thick. The overall detail for this structure is included in Part 3.

Glazing in Study Rooms 5 and 6 should be composed of the following structure, at the interior face of the room, which is fully gasketed and sealed. The new windows should be built up as follows:

- 16mm laminated glass
- 100mm air space
- 12mm laminated glass
- (variable air space)
- 12mm laminated glass at exterior face of masonry wall

Hollow window frames should be packed with rockwool.

3. Other Sound Isolation Considerations

Floors in the hallways, on top of ducts, should have a base structure of solid 6-8mm steel to prevent noise from entering the ducts.

C. Mechanical Noise Control

The Guidelines for the Control of Noise and Vibration from HVAC Systems is located in Appendix IV.

1. Sound Isolation Targets

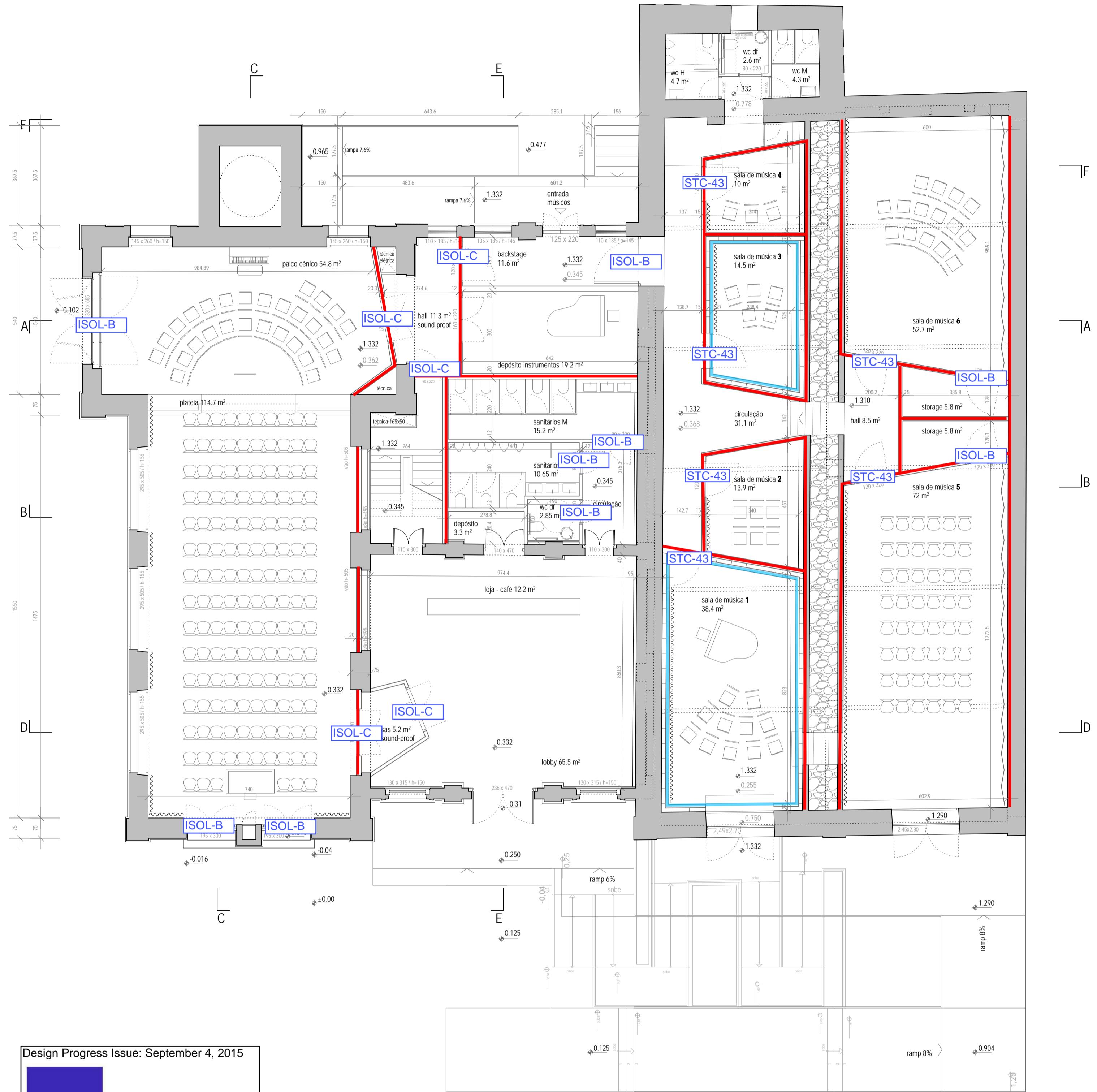
Background noise ratings determining the amount of noise and vibration control required are set as follows:

- a. Concert Hall (150 seats)
NC-15 to NC-20
- b. Study Rooms
NC-20 to NC-25
- c. Control Room, Audio-Visual Production (1st Floor)
NC-20 to NC-25

2. Sound Isolation of Ducts

Certain ducts will require sound isolation to prevent noise-break in. Selected ducts are shown in Part 5. The ducts should be wrapped with 50mm fiberglass, then the fiberglass should be encased in two layers of 12mm gypsum wallboard.

Part 2:
Sound Isolation Key Plans



Design Progress Issue: September 4, 2015



1990 S. Bundy Dr., Ste. 795
Los Angeles, CA, USA 90025
+1(310)231-7878

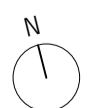
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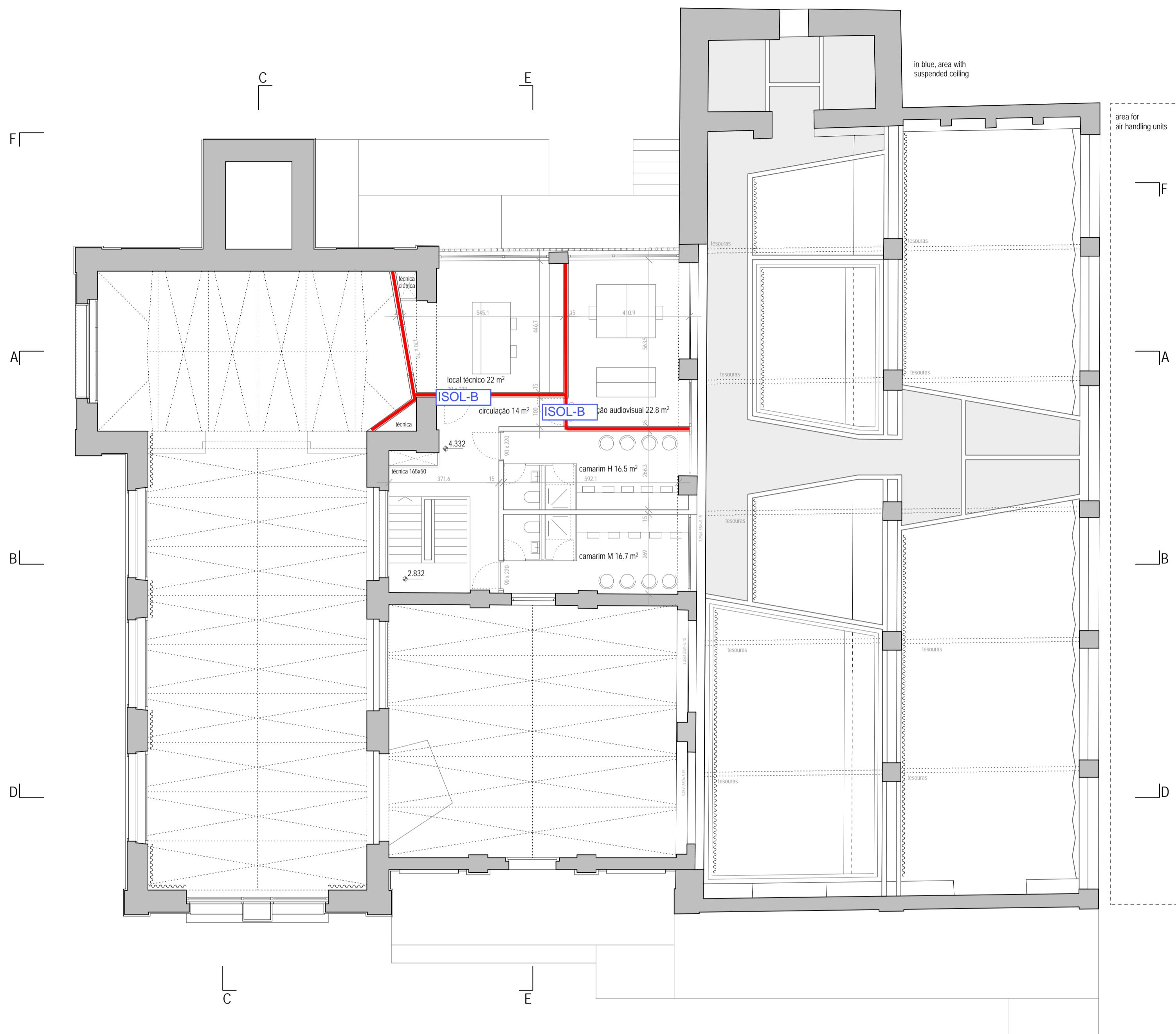
Blue tags indicate sound isolation door type

Blue lines indicate Box-in-box structure, shown in Part 3

Red lines indicate new 150mm thick concrete walls for sound isolation

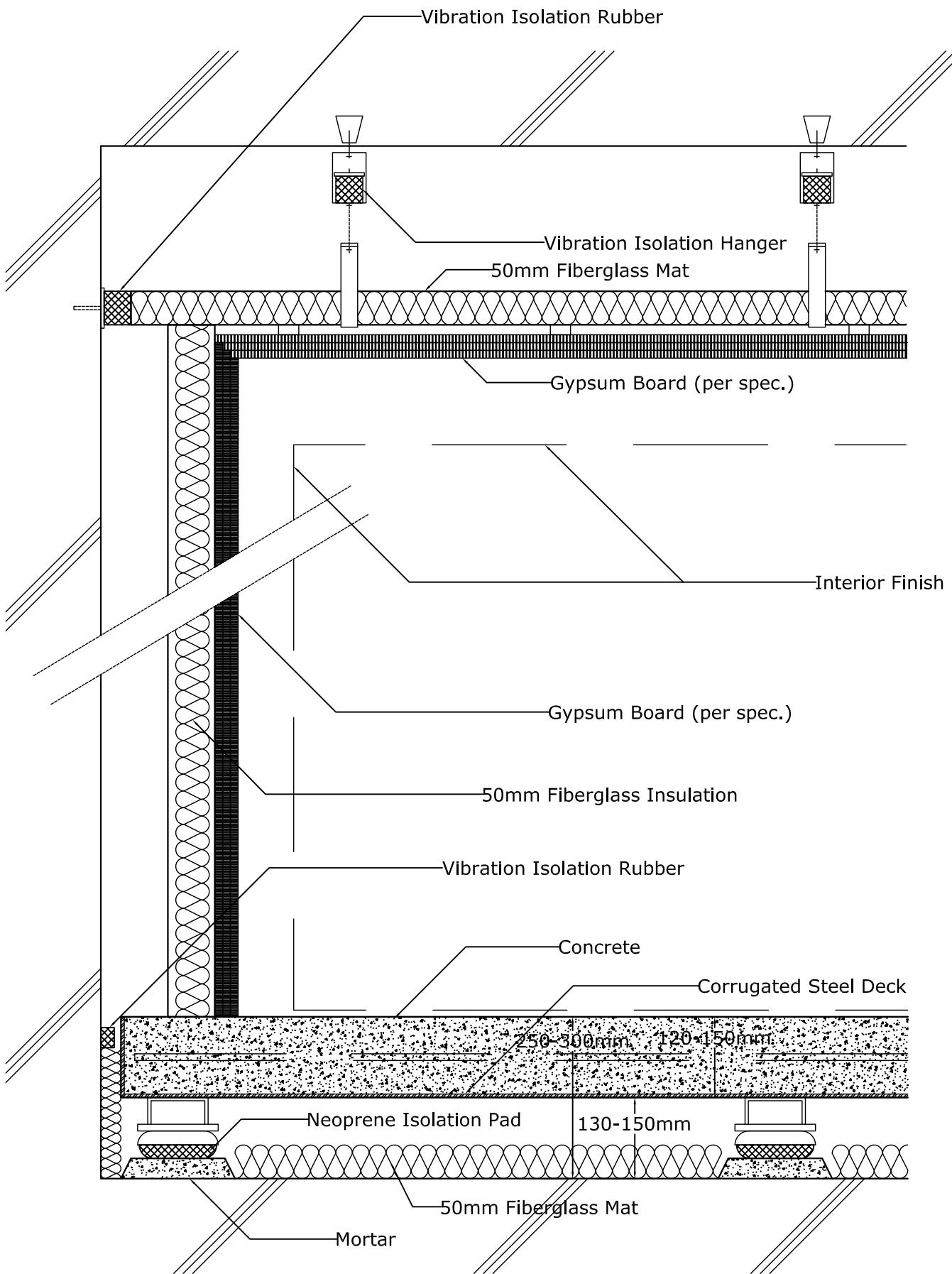
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Part 3:

Box-in-Box Detail
Acoustical Doors Detail
SAS Wall Type Detail

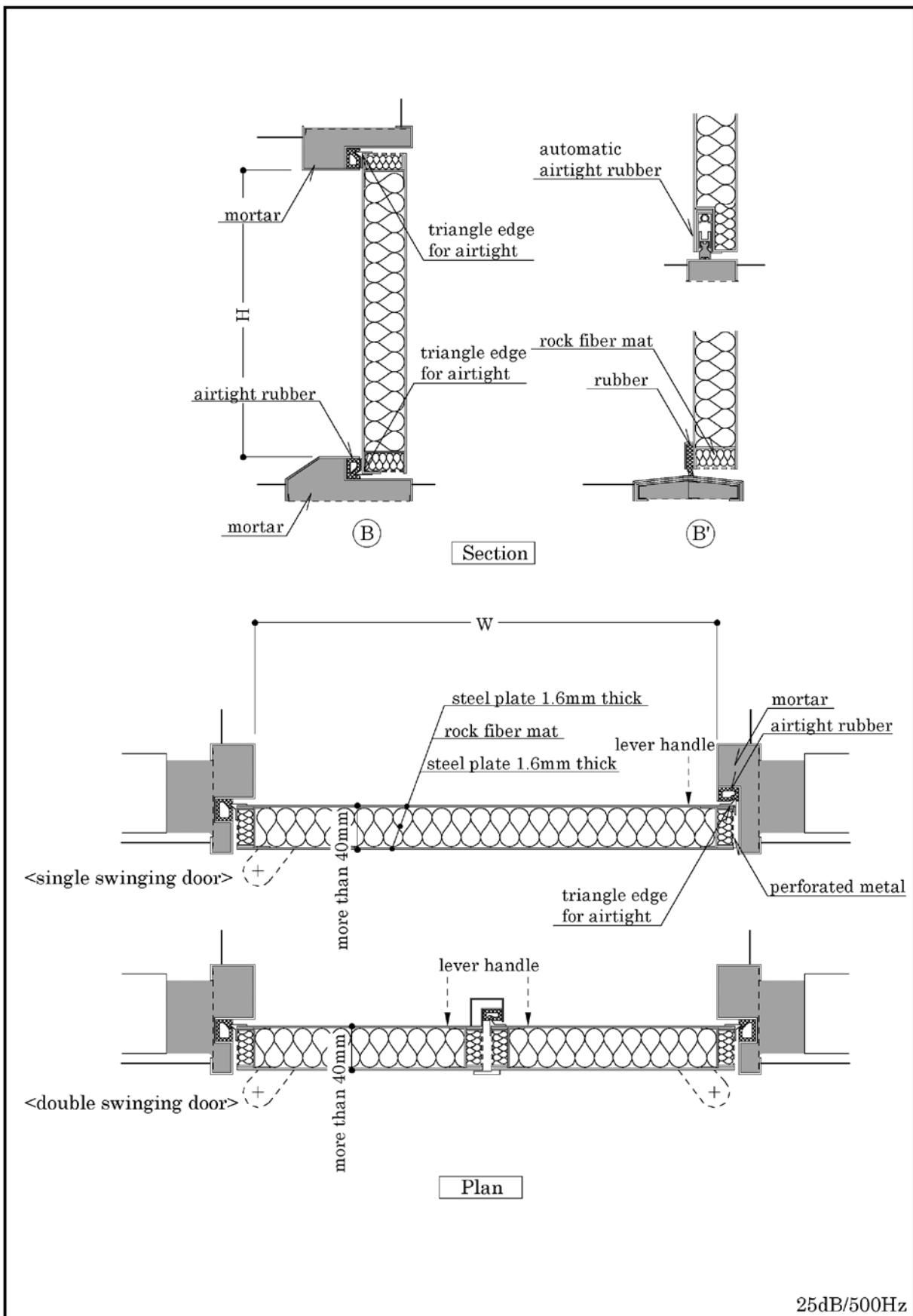


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SOUND ISOLATION STRUCTURE

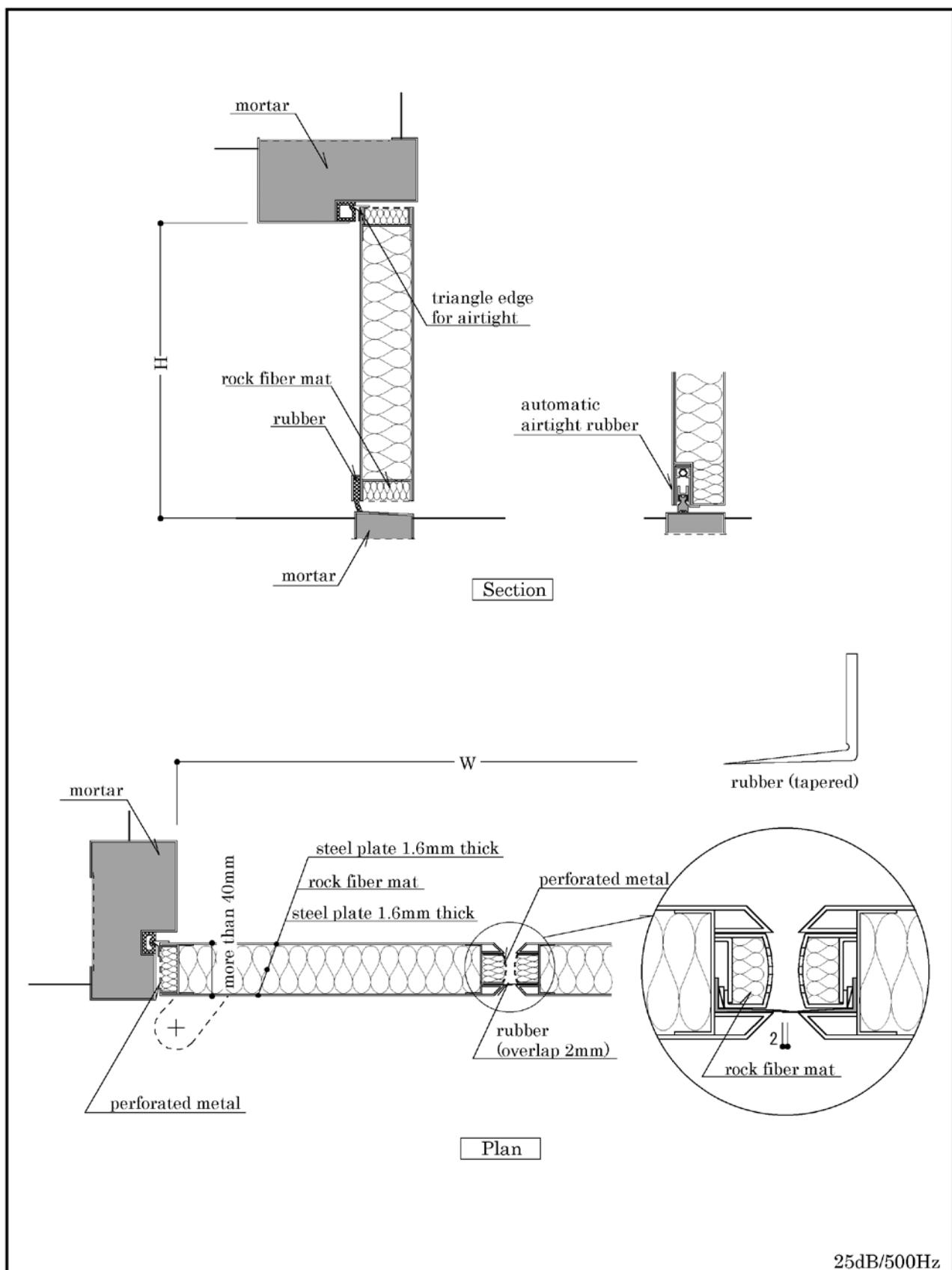
NAGATA ACOUSTICS

1990 S. BUNDY DR.
SUITE 795
LOS ANGELES, CA 90025
U.S.A
TEL: (310) 231-7878
FAX: (310) 231-7816

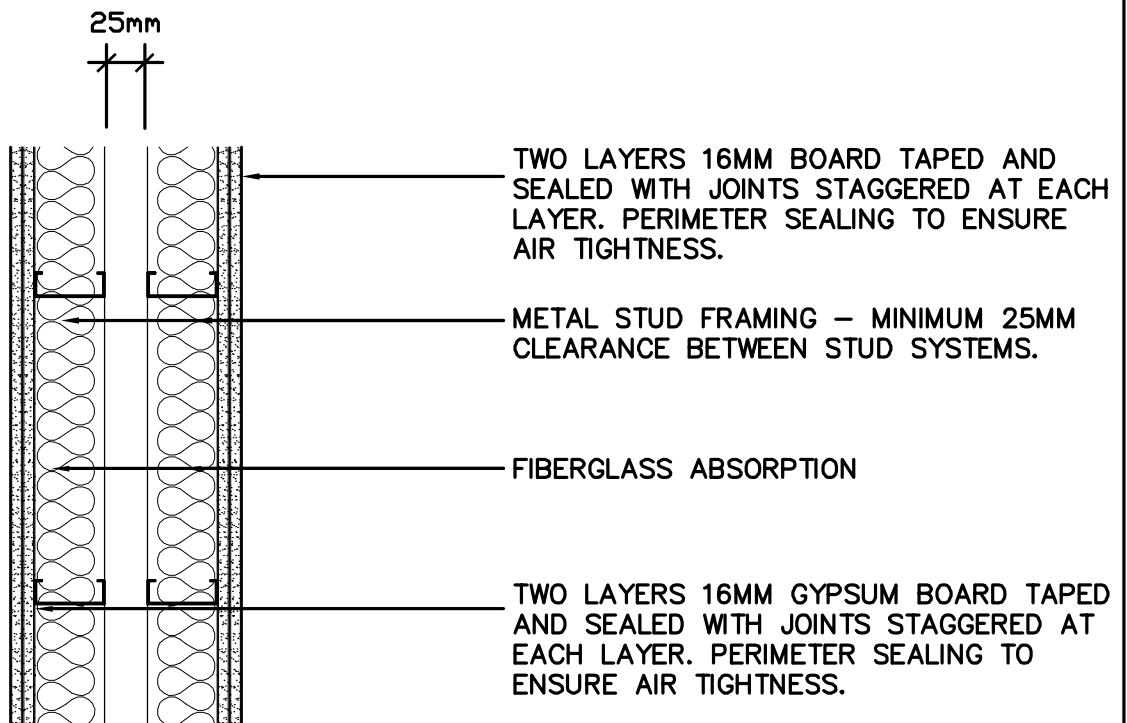


Sound Proofing Door Specification (general use (B) (B))

NAGATA ACOUSTICS



Sound Proofing Door Specification (for auditorium entrance ⓒ)



Dec 3 2015

Scale 1:10



NEOJIBA

SAS Walls/Ceiling

NAGATA ACOUSTICS

AMERICA, INC.

2130 SAWTELLE BLVD. SUITE 308

LOS ANGELES, CA 90025

U.S.A.

TEL: (310)231-7878

FAX: (310)231-7816

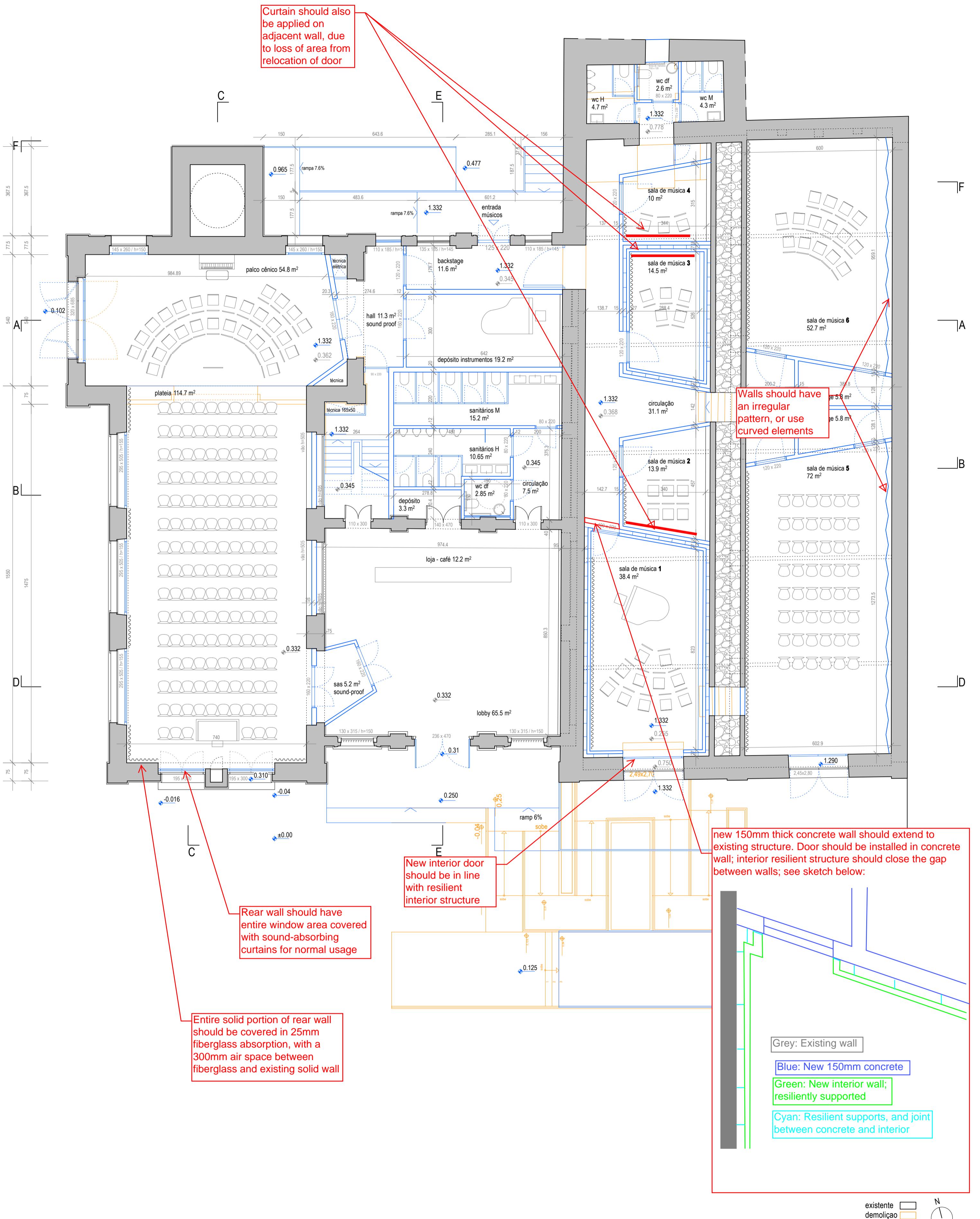
Part 4:
Comments on Issued Drawings

Review of Drawings, 2015-08-20

Review of Drawings, 2015-09-14

HVAC Commentary, 2015-10-01

Review of Drawings, 2015-11-20




Review of Drawings, 2015-08-20

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Review of Drawings, 2015-11-20



Review of Drawings, 2015-08-20

Review of Drawings, 2015-09-14

HVAC Commentary, 2015-10-01

Review of Drawings, 2015-11-20

Subject: Re: HVAC NEO_R01
From: Daniel Beckmann <beckmann@nagata.co.jp>
Date: 10/1/2015 6:56 PM
To: sergio ekerman <sergioekerman@yahoo.com.br>
CC: Motoo Komoda <komoda@nagata.co.jp>, butikofer de oliviera vernay sàrl <contact@b-o-v-arch.ch>, Olivia Oliveira <olivia@compo-site.ch>
BCC: beckmann@nagata.co.jp

Dear Sergio,

Thank you for the new HVAC drawings. It's difficult for us to find the difference between the previous version.

Also, I've noted that most of the comments from the very first version (with the underground gallery) were not incorporated. So, we would appreciate it if you could share the following comments on this version with the mechanical engineer:

General comments:

1) For all grilles, the transition between the branch speed of 3 m/s and 1 m/s is missing. The air must be flowing at 1 m/s for a distance of 3-5 duct diameters before it reaches the grilles. Also, all of the grilles have a face velocity which is too high. According to the free area data provided in the attached brochure (p. 15 & 18) from the grille manufacturer, generally the face velocity exiting the grille is 1.7-2 m/s (the requirement is 1-1.15 m/s).

2) Grilles should not be equipped with dampers. (The suffix /AG or /DG in all of the grille tables indicate that a damper is a part of the unit.)

3) The sound-absorbing elbow detail drawn in page 6 of our guidelines should be shown in the duct path for all rooms with a NC-rating.

4) For all of the ducts supplying the study rooms, the velocities are generally much in excess of the requirements laid out on p. 7 of our guidelines.

5) For the air supply into the study rooms, the drawing indicates that the face of the grille is coplanar with the face of the wall. Given the very tight space between the rooms, this results in a very large opening in the sound-isolating walls. We should minimize the size of the penetration through the wall as much as possible, so that only two ducts (supply and return) are passing through the wall. After the medium-small ducts pass through the wall, they should grow in size to accommodate the final velocity transition to the terminal device.

6) Please confirm that the dimensions for each duct are the clear internal dimensions, exclusive of the required internal lining.

7) Round ducts should be metal, and equipped with internal lining.

8) On both the lower and upper floors, the restroom exhaust duct should not pass over quiet spaces. On the ground floor, the exhaust passes over the sound/light lock. On the mezzanine, the

exhaust passes over both the A/V room and the technical room.

9) On p. 3, please clarify the "recessed ceiling" in the concert hall.

10) On the upper level, the small units supplying the A/V room and the technical room should be moved over the hallway. Please also provide the octave-band power level data for these units, as well as the specific product data. Are these the quietest possible units? Please also provide the product data for the diffusers specified - "ADLK-SZR-III"

Specific comments for the re-configured Performance Hall duct-work:

1) Some of the branch ducts supplying the stage have velocities which exceed the limit in the guidelines.

2) Please clarify the return air solution. At the stage side, is the return air being taken from a high level? How is it connected to the plenum below? How is it balanced with the grilles at the front face of the stage?

3) The velocity of the air entering the large, open return duct under the stage is too high. As drawn, the velocity is 5.4 m/s - but it should transition down to 3m/s and then 1 m/s before the mouth of the duct is reached under the stage.

Please let me know if you have any questions, or if you would like to arrange a video conference for next week for discussion.

Sincerely,

--

Daniel Beckmann beckmann@nagata.co.jp
Nagata Acoustics

1990 S. Bundy Dr.
Suite 795
Los Angeles, CA 90025
USA
+1 (310) 231 7878 Main
+1 (310) 231 7816 Fax

On 9/29/2015 1:02 PM, sergio ekerman wrote:

Dear Daniel and Motoo,

This is the new version for the HVAC project, which I had the idea of discussing personally. Once it will not be possible, we should probably have a conference about it, but please take a look first.

Hope it gets closer to the main things we have gone over the first version.

Best,

Sergio

arq.º sergio ekerman
rua da graça | 22 fundo | 1ºPAV | casa da graça | 40150-055 | ssa ba

professor assistente - Núcleo de Tecnologia, Projeto e Planejamento
Faculdade de Arquitetura da Universidade Federal da Bahia

www.sergioekerman.com.br
71 8847 0717

—Attachments:

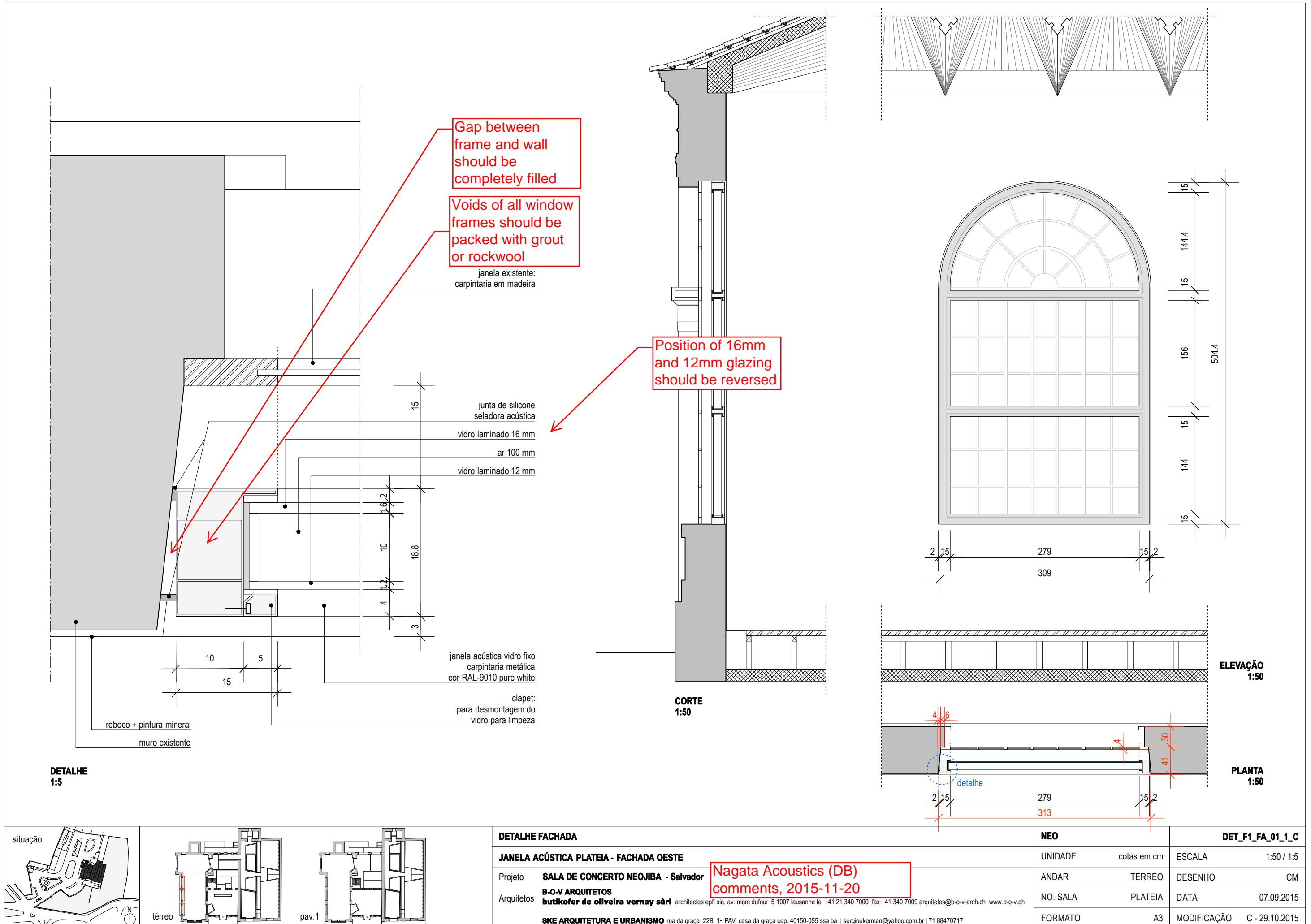
Trox Grilles.pdf	1.4 MB
NA HVAC Guideline-Metric.pdf	351 KB

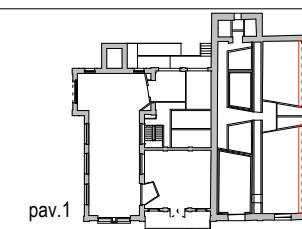
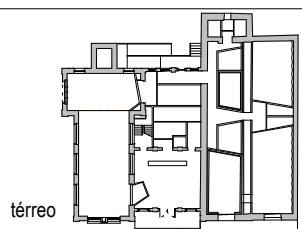
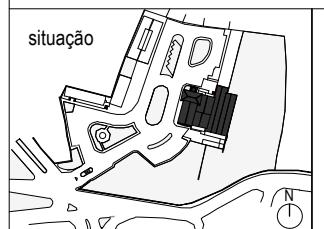
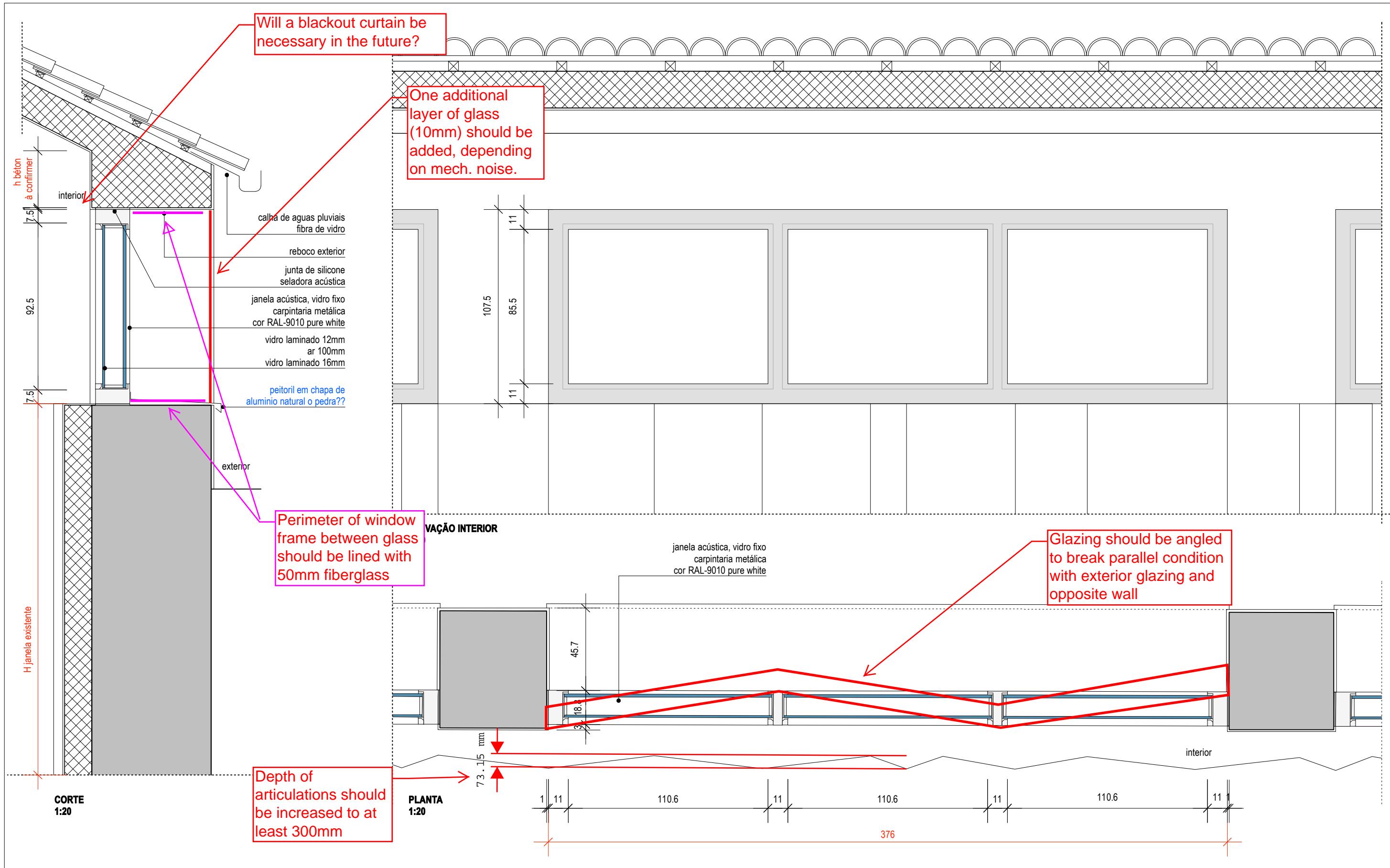
Review of Drawings, 2015-08-20

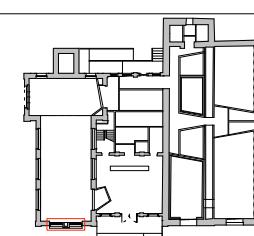
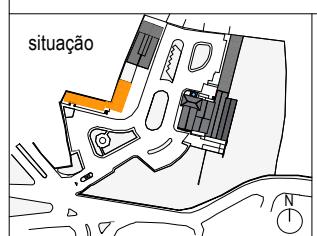
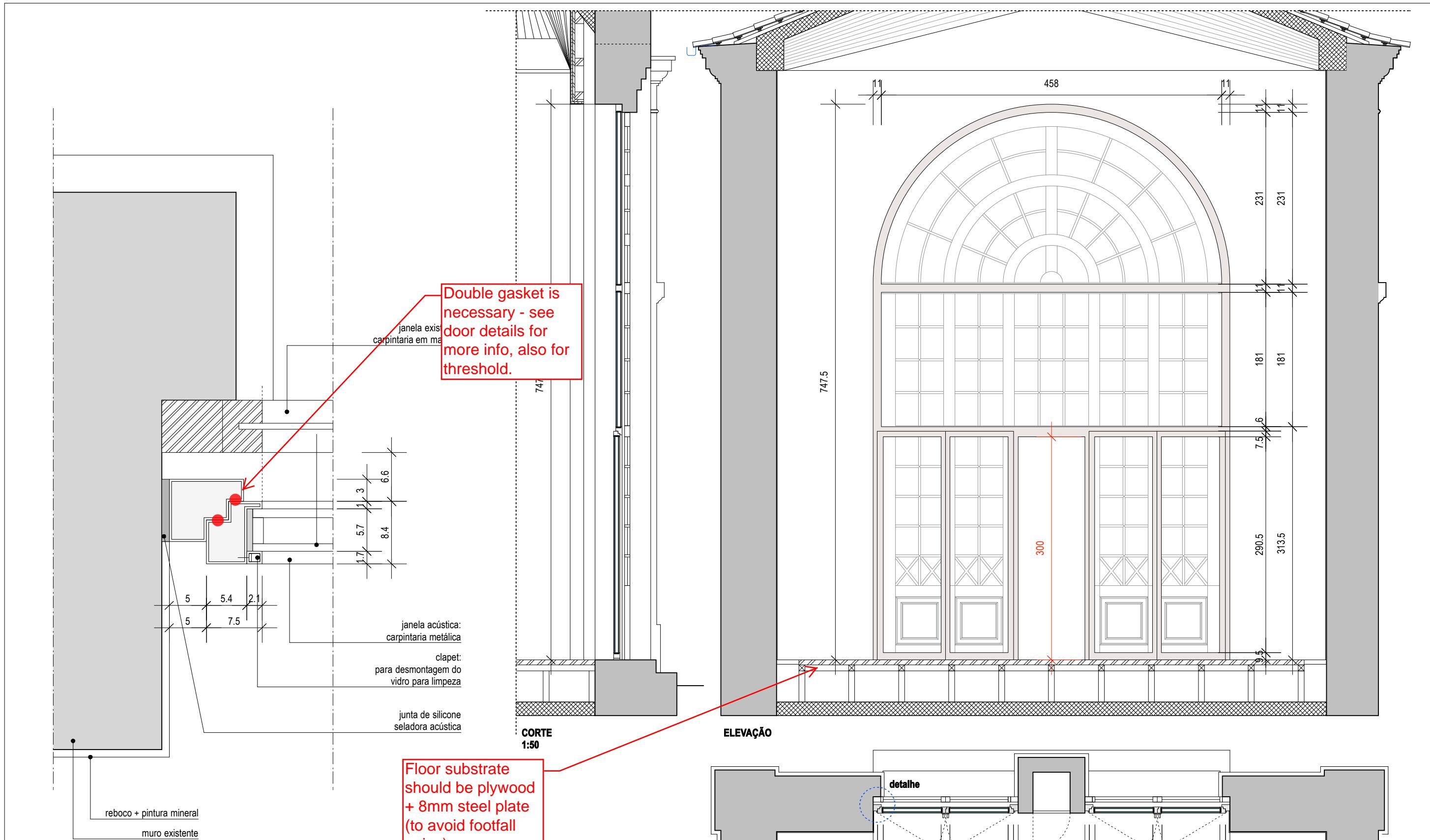
Review of Drawings, 2015-09-14

HVAC Commentary, 2015-10-01

Review of Drawings, 2015-11-20







DETALHE FACHADA

JANELA ACUSTICA PLATEIA - FACHADA SUL

Projeto **SALA DE CONCERTO NEOJIBA - Salvador**
Arquitetos **B-O-V ARQUITETOS
butikofer de oliveira vernay sàrl** architectes epfl sia, av. marc dufour 5 1007 lausanne tel +41 21 340 7000 fax +41 340 7009 arquitetos@b-o-v.arch.ch www.b-o-v.ch

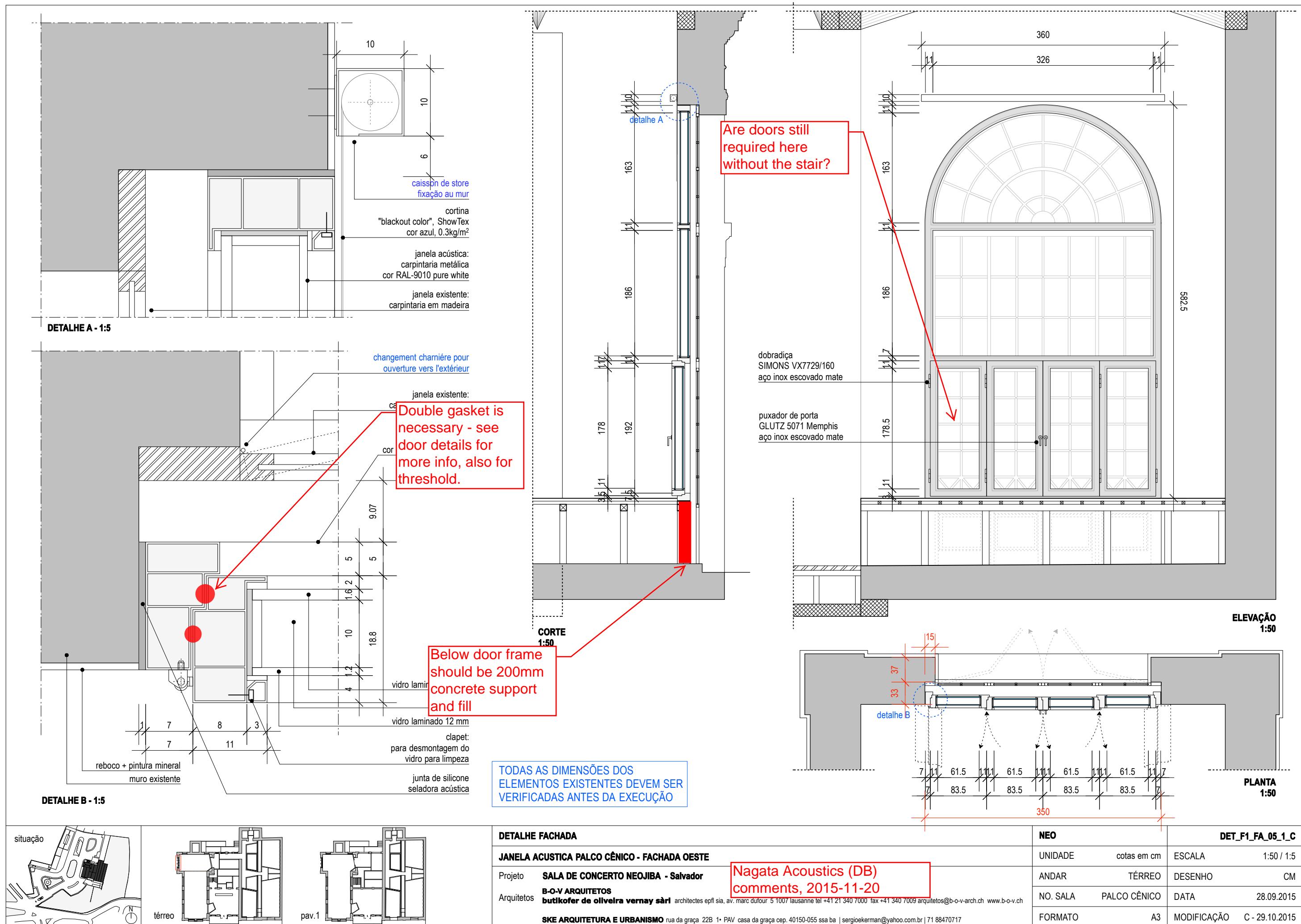
SKE ARQUITETURA E URBANISMO rua da graça 22B 1º PAV casa da graça cep. 40150-055 ssa ba | srgoekerman@yahoo.com.br | 71 88470717

Nagata Acoustics (DB)
comments, 2015-11-20

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
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comments, 2015-11-20

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www.b-o-v.ch
SKE ARQUITETURA E URBANISMO
rua do grago 226 - lapa - São Paulo - SP - 05030-001
www.ske.com.br
e-mail: info@ske.com.br



ANTA PAVIMENTO 01

TE Instituto de Ação Social pela Música
RIETARIO Empresa Baiana de Águas e Saneamento S.A. - Embasa
TETOS B-O-V ARQUITETOS + SKE ARQUITETURA E URBANISMO

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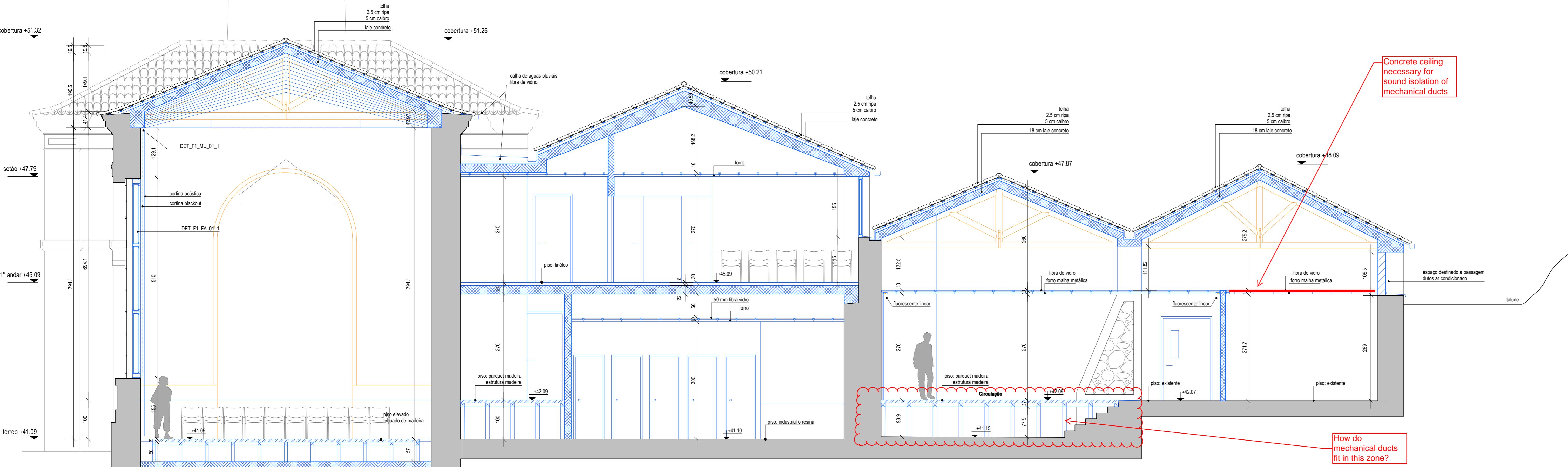
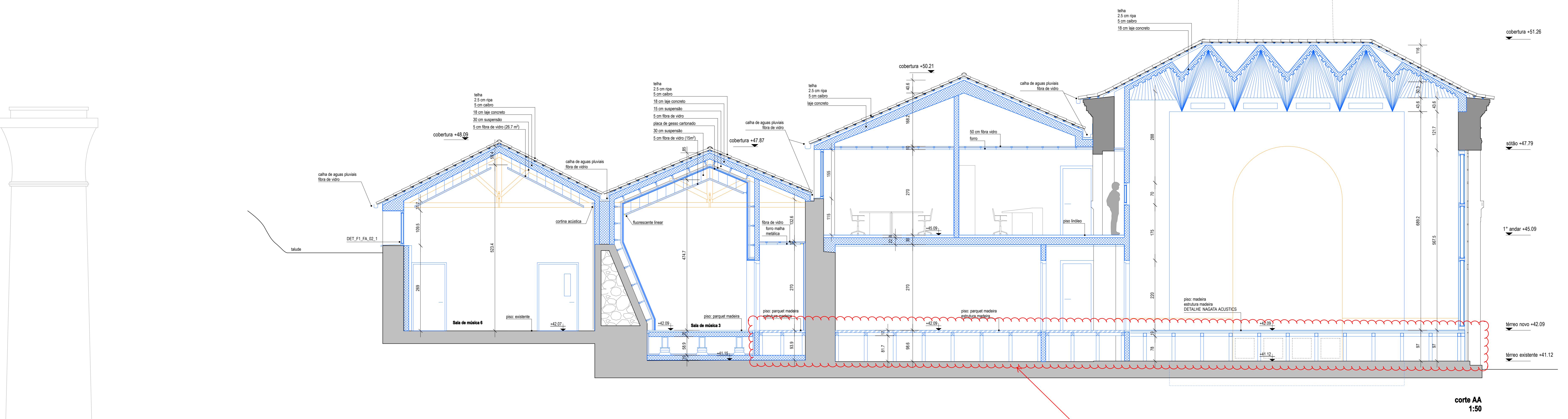
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O - SALA DE CONCERTOS NEOJIBA

ata Acoustics (DB)
ments, 2015-11-20

V ARQUITETOS butikofer de oliveira vernay sàrl
tes epfl sia, av. marc dufour 5 1007 lausanne tel +41 21 340 7000 fax +41 340 7009 arquitetos@b-o-v-arch.ch www.b-o-v.ch

ARQUITETURA E URBANISMO
raca, 22B, 1º PAV, casa da graca cep: 40150-055 scs ba, l.sergioekerman@yahoo.com.br | 71 88470717



**CORTE AA - CORTE GG
1:50**

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ARQUITETOS	B-O-V ARQUITETOS + SKE ARQUITETURA E URBANISMO
FAZ	projeto executivo

LUGAR, DATA

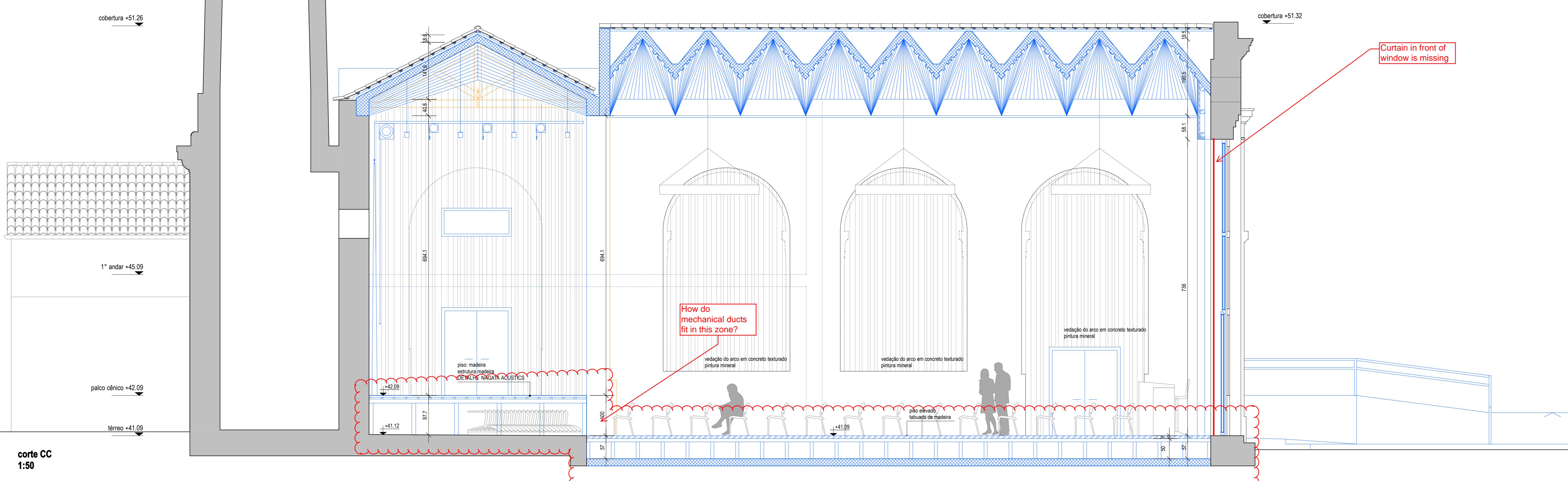
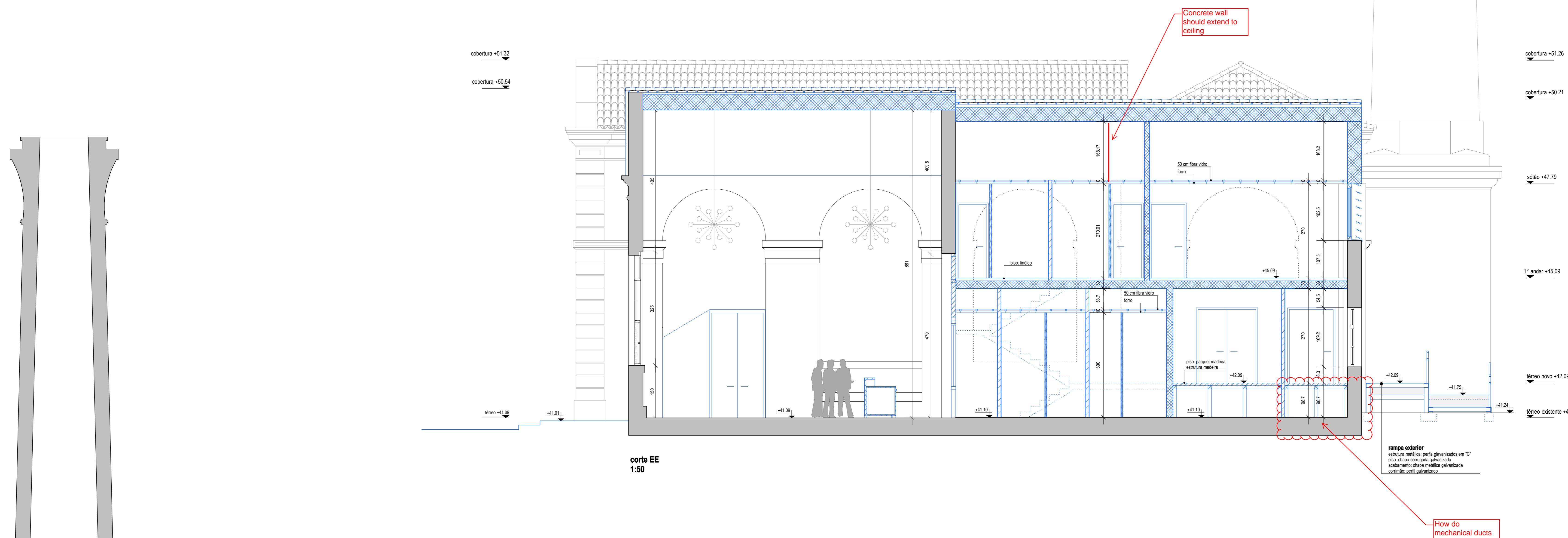
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ARQUITETOS
ENGENHEIROS TECNICOS

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projeto

NEO - SALA DE CONCERTOS NEOJIBA

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architectes epfl sia, av. marc dufour 5 1007 lausanne tel +41 21 340 7000 fax +41 340 7009 arquitetos@b-o-v-arch.ch www.b-o-v.ch
EKE ARQUITETURA E URBANISMO
rua da graca 22B 1º PAV casa da qraca cep. 40150-055 ssa ba | sergioekerman@yahoo.com.br | 71 88470717



CORTE CC - CORTE EE
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CLIENTE	Instituto de Ação Social pela Música
PROPRIETARIO	Empresa Baiana de Águas e Saneamento S.A. - Embasa
ARQUITETOS	B-O-V ARQUITETOS + SKE ARQUITETURA E URBANISMO
FASE ESCALA	projeto executivo 1:50

LUGAR, DATA
PROPRIETARIO
ARQUITETOS RESPONSAVEIS TECNICOS

arq. olivia fernandes de oliveira | cau A87299-7

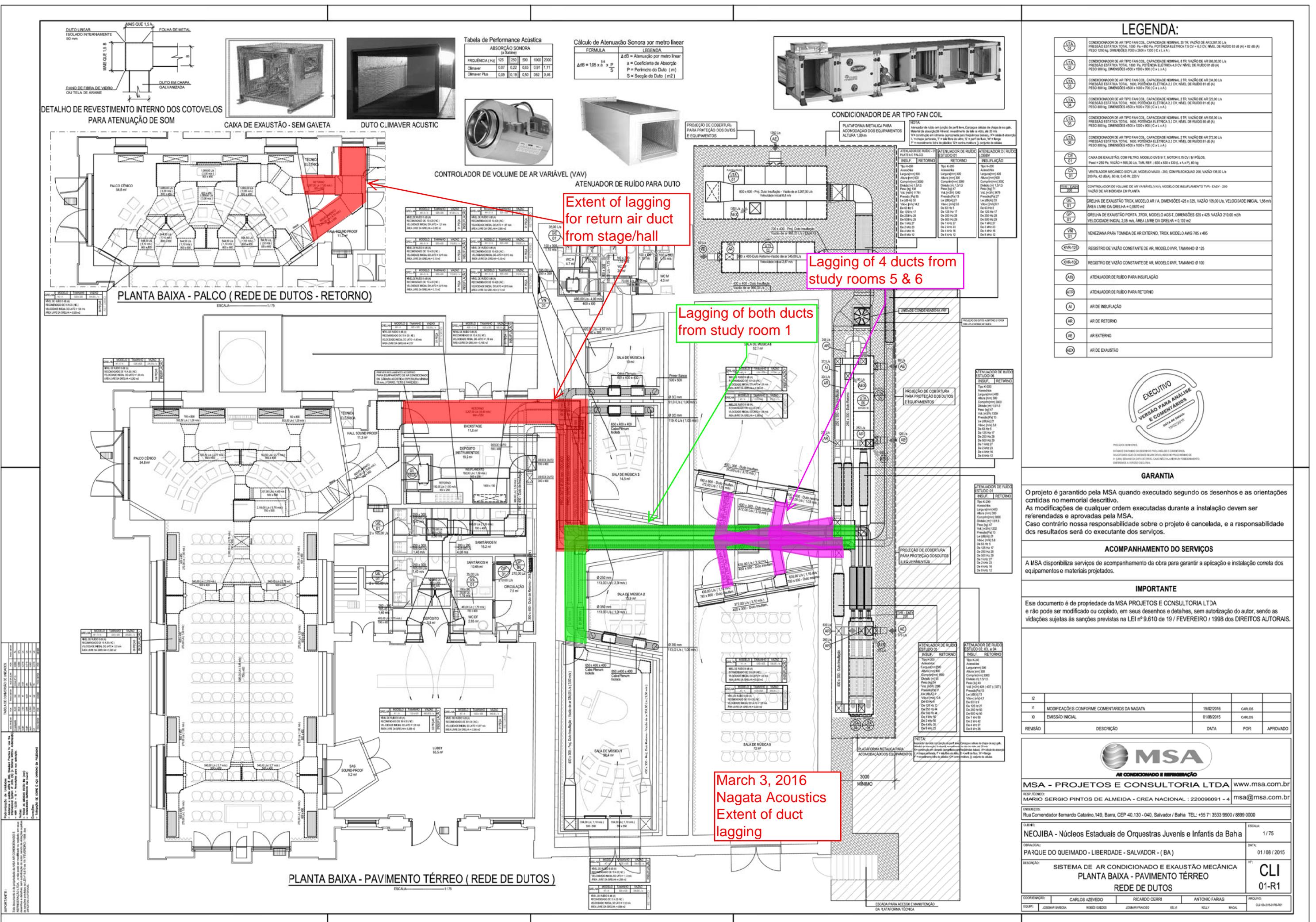
A horizontal bar chart with three bars. The first bar is grey and labeled 'existente'. The second bar is orange and labeled 'demolição'. The third bar is blue and labeled 'projeto'.

NEO - SALA DE CONCERTOS NEO-JIBA

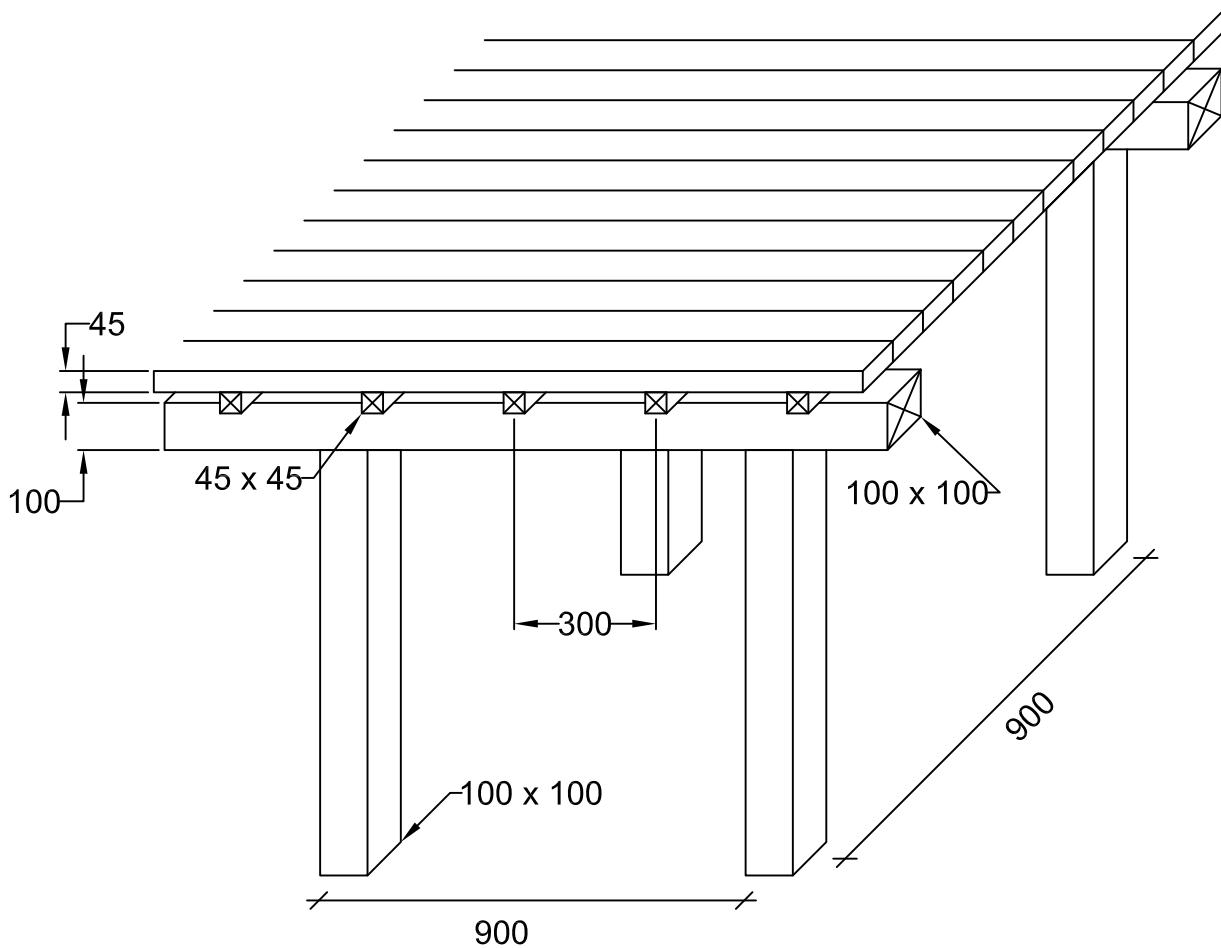
B-O-V ARQUITETOS butikofer de oliveira vernay sàrl
architectes epfl sia, av. marc dufour 5 1007 lausanne tel +41 21 340 7000 fax +41 340 7009 arquitetos@b-o-v-arch.ch www.b-o-v.ch

SKE ARQUITETURA E URBANISMO
rua da graca, 22B, 1º PAV, casa da graca cep: 40150-055 cca ba, l.sergioekerman@yahoo.com.br l.71.88470717

Part 5:
Required Lagging of HVAC Ducts



Appendix I:
Nagata Acoustics Stage Structure Detail



Notes:

1. Planking should be a stiff softwood. For example, Alaskan Yellow Cedar or Oregon Pine are two species which meet these criteria. Samples should be submitted to Nagata for review.
2. Sleepers and Beams should be softwood.
3. Wooden posts may be omitted when resting on steel frame for orchestra riser lift mechanism.

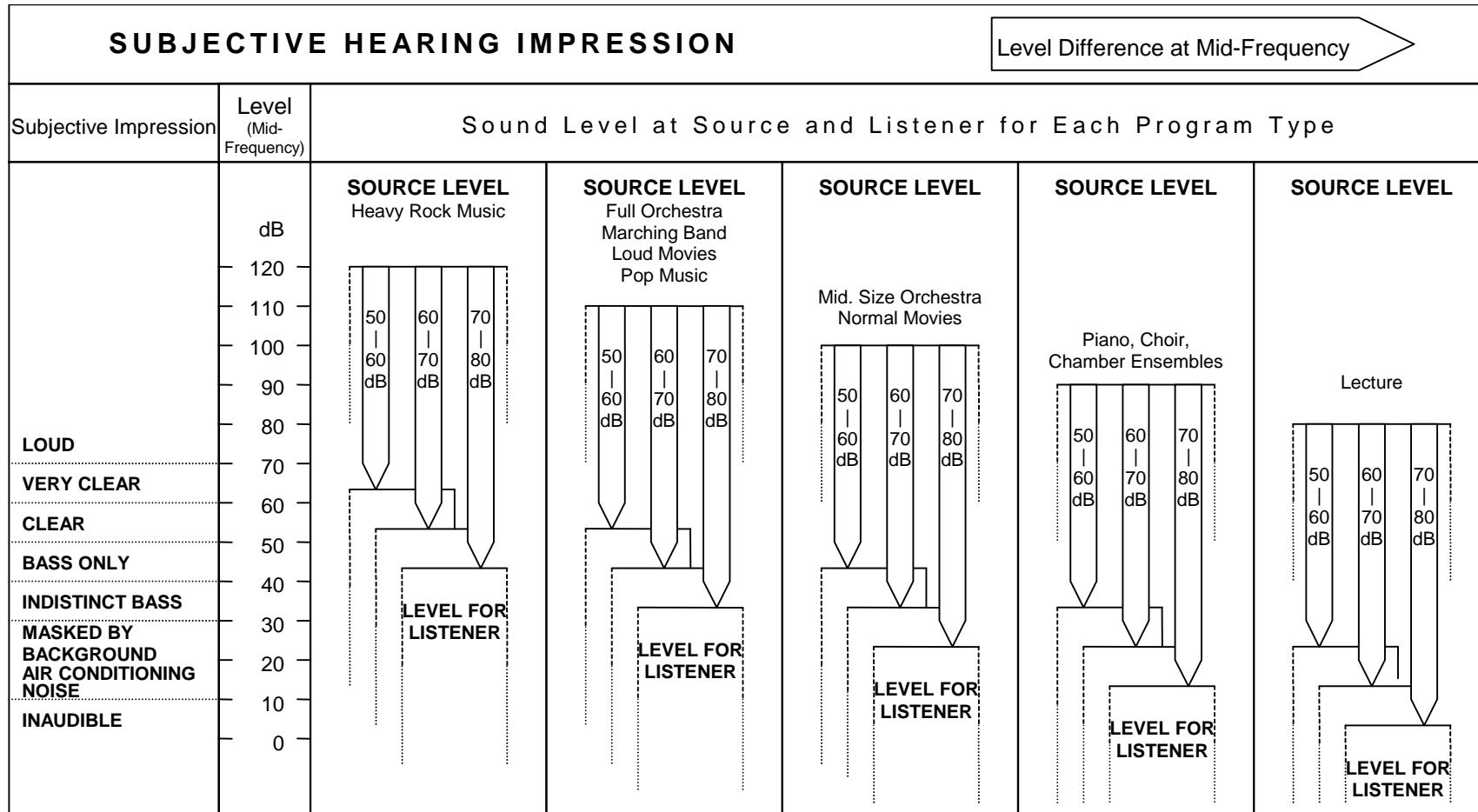
ALL DIMENSIONS IN MM

SCALE: N/A	STAGE STRUCTURE SKETCH (INFO ONLY)	NAGATA ACOUSTICS 1990 S. BUNDY DRIVE SUITE 795 LOS ANGELES, CA 90025 U.S.A. TEL: (310) 231-7878 FAX: (310) 231-7816
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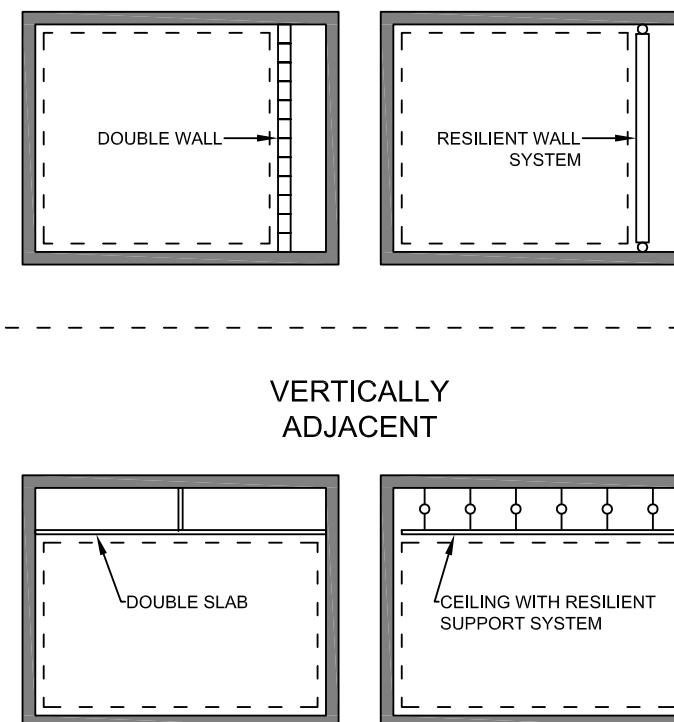
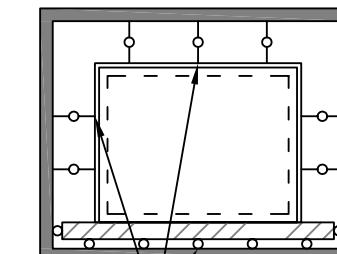
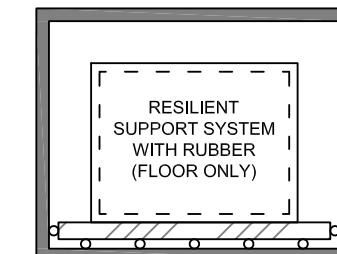
Appendix II:

Subjective Listening Impression
versus Sound Isolation

Figure 1: Subjective Hearing Impression versus Sound Isolation (Level Differences)



Appendix III:
Sound Isolation of Various Structures

50 ~ 55 dB	60 ~ 65 dB	70 ~ 80 dB	80 ~ 90 dB
 <p>STRUCTURE: CONCRETE >200mm TO BE USED AS BASE FOR ALL OTHER CASES</p>	<p>HORIZONTALLY ADJACENT</p>  <p>VERTICALLY ADJACENT</p>	 <p>RESILIENT SUPPORT WITH RUBBER</p>	 <p>RESILIENT SUPPORT SYSTEM WITH RUBBER (FLOOR ONLY)</p>

- dB: Level difference in the middle frequencies
- Airborne sound only
- Dashed lines represent interior surfaces inside the sound isolating structure

SOUND ISOLATION FOR VARIOUS STRUCTURES

Appendix IV:

Nagata Acoustics Guidelines for the Control of
Noise and Vibration from HVAC Systems
including Velocity Transitions Strategy

Guidelines for the Control of Noise & Vibration Due to HVAC Systems



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Los Angeles, CA, USA 90025
+1 (310) 231-7878

Noise and vibration from HVAC systems are the principal noise sources in acoustically sensitive rooms. To achieve a quiet environment at minimum cost, this text summarizes the acoustical principles for designing suitable HVAC systems for such spaces.

The design standards are expressed in terms of the older Noise Criteria, NC, which sets maximum sound pressure levels that must not be exceeded. Since it does not require minimum levels nor explicitly exclude pure tones, there is no assurance that the resulting noise will indeed be "neutral." Any space assigned an NC rating of 25 or less is considered "Acoustically Critical."

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1. Design of Mechanical Equipment Rooms (MER's)	2
2. Duct Chases and Duct Rooms	3
3. Fan and Pump Selection Guidelines	3
4. Duct Work.....	3
5. Controlling Air Turbulence Noise in Quiet Spaces	5
6. Vibration Isolation of Equipment, Ducts and Piping.....	6
7. Mechanical System Notes	9
9. Electrical System Notes	9
Reference Material.....	9

1. Design of Mechanical Equipment Rooms (MER's)

1. MER's should generally be fabricated using concrete masonry and poured in place concrete slabs.
2. Machine rooms should be located far from acoustically sensitive performance halls, rehearsal rooms, meeting rooms, etc., where a quiet environment is required. If it is impossible to do so, then it is imperative to provide adequate sound isolation through measures such as double concrete walls and/or isolated floors and ceilings. The following table, taken from Mark Shaffer's excellent book *A Practical Guide to Noise and Vibration Control*, (ASHRAE, Atlanta, 1991) is a useful preliminary guide.

**Table 1: Recommended Slab Thickness (mm)
For 2400 km/m³ concrete (from Schaffer, op cit. p.11)**

	Separating Very Noise-Sensitive Spaces (NC 30 or less)	Separating Moderately Noise-Sensitive Spaces (NC 31-40)
Reciprocating Chiller All Sizes	200	200
Centrifugal Chiller ≤ 300Tons	200	150
> 300 Tons	200	200
Unducted Fan of AHU ≤ 7.5 Max.kW	100	80
7.5 to 22 Max.kW	150	100
> 22 Max.kW	200	150
Ducted Fan of AHU ≤ 22 Max.kW	100	80
> 22 Max.kW	150	100
Pumps ≤ 19 Max.kW	100	80
19 to 75 Max.kW	150	100
> 75 Max.kW	200	100
Cooling Towers, Evaporative Coolers and Air-Cooled Condensers ≤ 22 Max.kW	150	100

3. Floors of equipment rooms should be no less than 200mm of normal weight concrete and should be designed so that under full load the slab deflection at the rotating or vibrating equipment never exceeds 6mm.
4. Ceilings and walls of a machine room should be treated with sound absorptive materials, such as 50mm thick fiberglass duct liner.
5. Provide enough space within the MER to install sound attenuating devices such as internally lined duct elbows and/or silencers.
6. Consider influences of outside noises that may enter the MER through external louvers.
7. Doors serving the MER's should have an acoustical rating comparable to that of the MER's architectural enclosure. In instances where very high transmission loss is required of the MER envelope, multiple doors and an acoustical vestibule may be required.

2. Duct Chases and Duct Rooms

1. Walls of the duct chases and duct rooms may need to be CMU or massive drywall, depending upon specific conditions.
2. The degree of acoustical isolation between duct chases, duct rooms and the MER may be considerable, depending upon the details of the system layout.
3. Access doors, where required, should have an acoustical rating comparable to the walls, floors and ceilings of these spaces.

3. Fan and Pump Selection Guidelines

1. Choose well-balanced and quiet fans. A very high degree of fan efficiency is extremely important to insure quiet operation.
2. Be careful not to overestimate the performance requirements of the fans.
3. Select operating conditions so that fans will operate at less than 1,000 rpm.
4. Sound power levels of each fan (inlet, discharge and radiated) should be submitted beforehand and approved.
5. Measured SPL of each AHU serving a noise-sensitive space must be submitted to this office for review and incorporation with the duct design, to verify that no noise will be audible in the spaces served.
6. HP and KW ratings for all rotating and vibrating equipment must be submitted.

4. Duct Work

For initial design purposes and estimating external static pressure, assume (2) 2.1m long, low-pressure drop silencers will be required on both supply and return duct systems associated with any air handler that serves "Acoustically Critical" spaces. The final design may include a combination of lined elbows, acoustical expansion plenums and sound attenuators (silencers).

1. Duct work should be self-balancing as possible to provide an even distribution of airflow, see Figure 1.
2. Avoid routing supply and return ducts serving sensitive spaces close to other noise sources such as fresh air intake shafts and exhaust air shafts.
3. Noisy ducts should not pass through the ceilings and the walls of quiet spaces, such as halls, see Figure 2.
4. Both supply and return ducts serving acoustically sensitive spaces have internal lining no less than 25mm. The lining thickness should be 50mm if either duct dimension (or duct diameter) exceeds 600mm; otherwise, 25mm thick internal lining is sufficient.
5. Ducts serving such sensitive spaces should be designed to have the minimum number of internally lined elbows shown in the following chart, based on the specified acoustical design goals. The exact number of required elbows will be provided based on noise control analysis of the specific plan layouts. The distance between any two elbows should be at least three times the larger duct dimension.
6. Do not locate the required number of elbows together in one place. For example, if seven elbows are required they should be distributed throughout the system: three elbows in the mechanical room, one elbow in the duct space and three elbows in the room being conditioned.
7. If two quiet rooms are served by a common duct, provide at least two internally lined elbows in the portion of the duct that connects them.

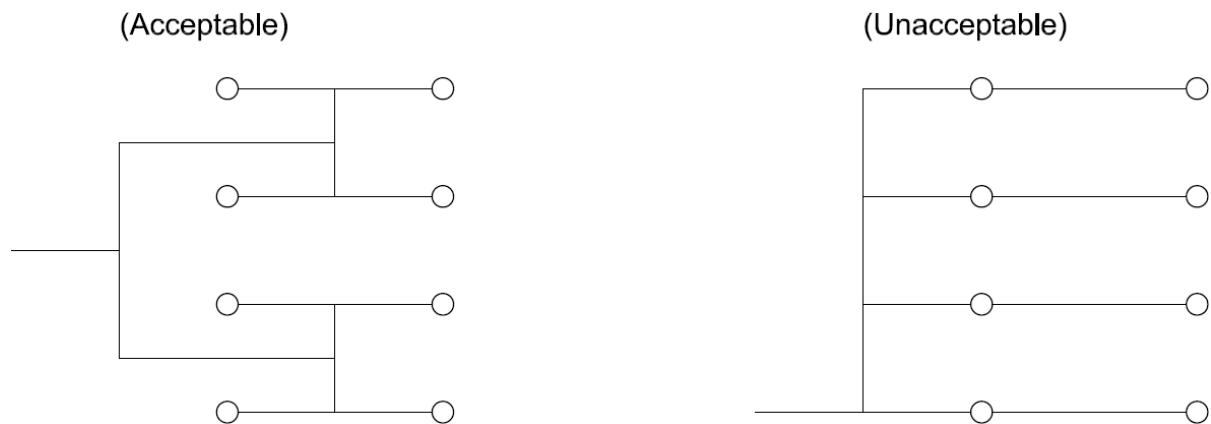


Figure 1: Acceptable and Unacceptable Examples of Duct Distribution Schemes

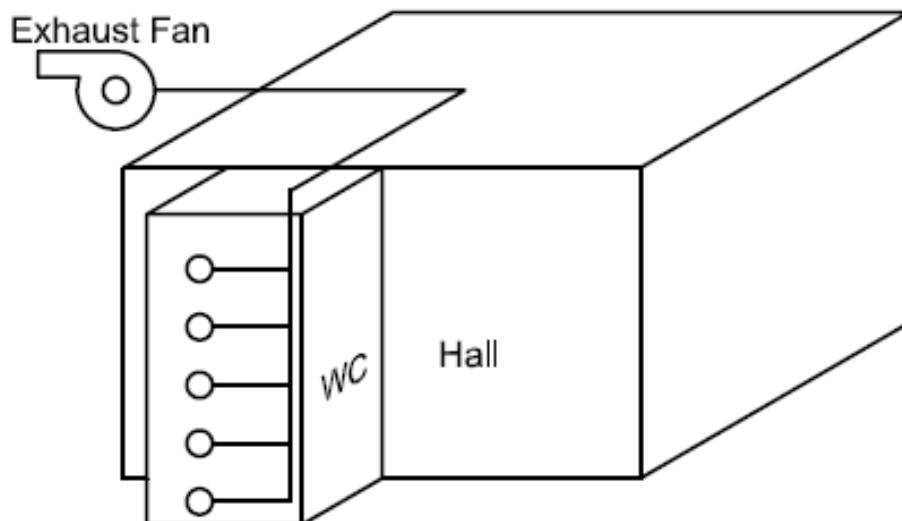


Figure 2: Bad example of noisy ducts running through a quiet space

**Table 2: Minimum number of internally lined elbows required, based on space function
(Valid for both supply and return air ducts)**

Space	Design Goal (NC)	Min. No of Elbows
Concert Hall	15-20	5-8
Multi-Purpose Hall	20-25	4-7
Conferences or Ass'y Space	25-30	3-5
Foyers, Lobbies, Etc.	35	2-4
Offices	30-35	1-4

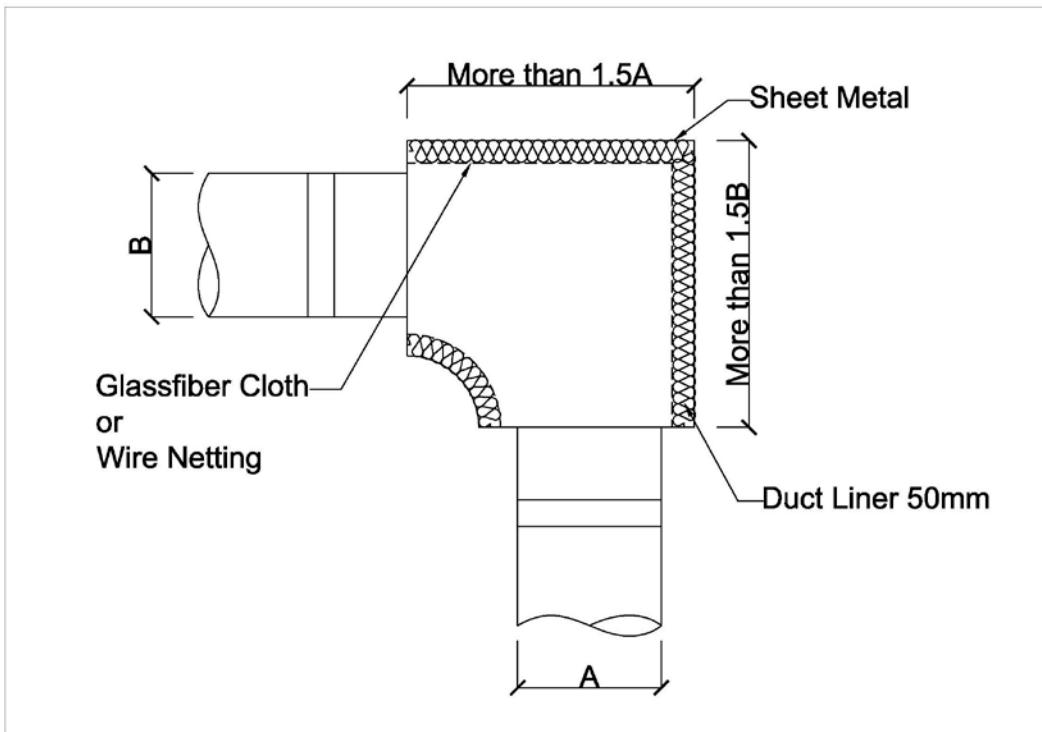


Figure 3: Detail of internally lined elbow for sound attenuation purposes

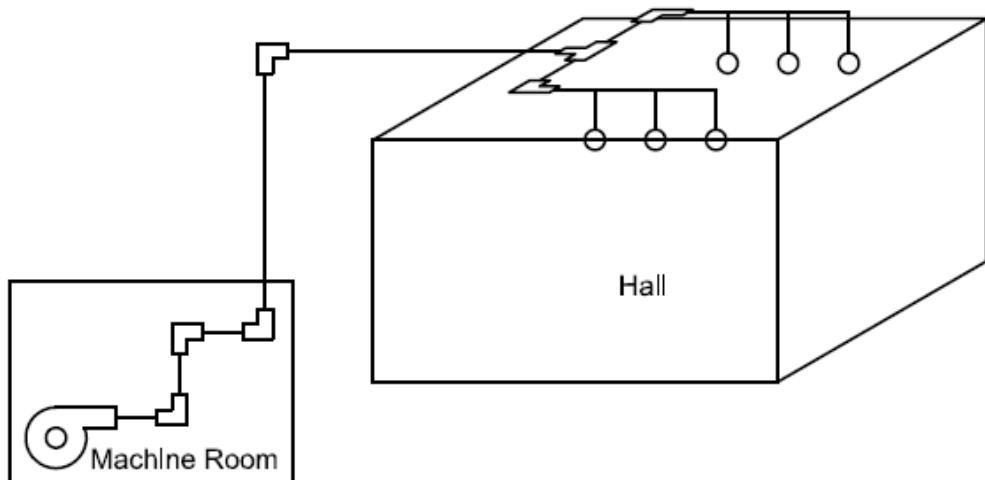


Figure 4: Conceptual sketch showing the distribution of sound attenuation duct elbows

5. Controlling Air Turbulence Noise in Quiet Spaces

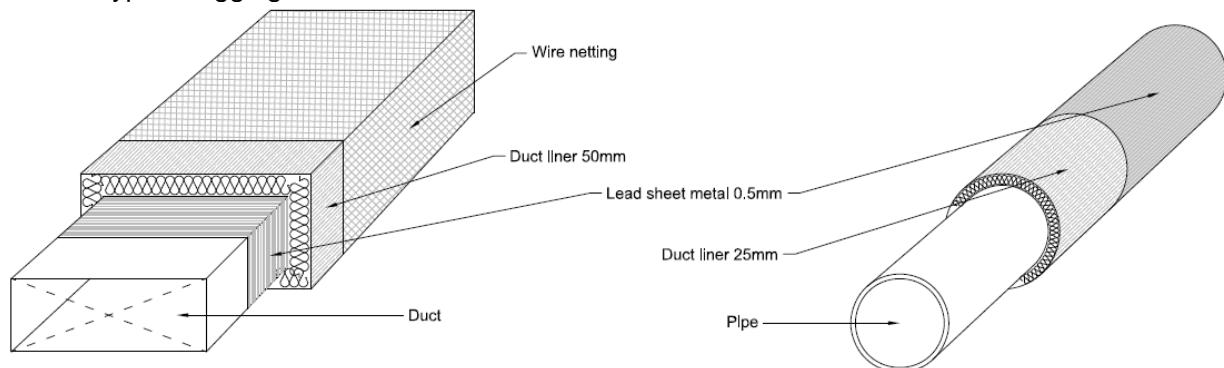
1. To prevent air turbulence noise ducts should be designed to the velocity criteria in Table 3.
2. Other considerations:
 - a. No balancing dampers within five equivalent duct diameters of terminal devices.
 - b. Air intake/discharge velocities must be calculated on actual free area of grille, diffusers, or open end.
 - c. High aspect ratios of duct terminations are desirable.
 - d. Maintain at least five equivalent duct diameters between velocity transitions.
 - e. Three equivalent duct diameters of internally lined duct must separate each velocity transition or velocity transition and terminal device.

Table 3: Duct Design Criteria, Maximum Air Velocity (m/s)

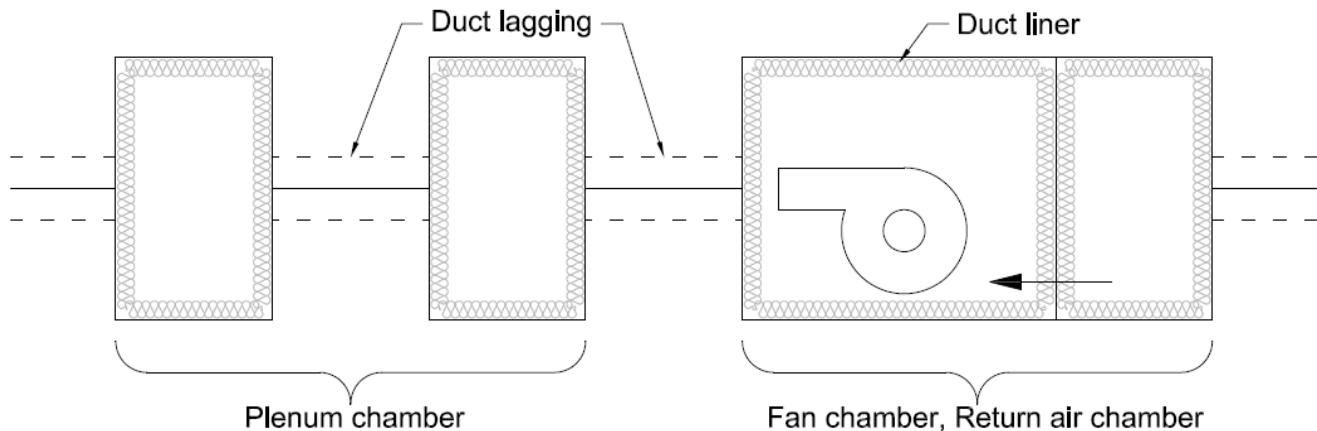
NC	15	20	25	30	35
At terminal device	1.0	1.15	1.3	1.5	1.7
Last branch duct	3.0	3.1	3.2	3.3	3.4
Distribution ducts	5.0	5.2	5.3	5.4	7.0
Main trunk ducts	7.0	7.0	7.0	7.0	7.0

6. Vibration Isolation of Equipment, Ducts and Piping

1. All ducts and piping except for fire sprinkler and vent stacks must be vibration isolated if they are:
 - a. Within an MER
 - b. Within 6m of an MER
 - c. Within an "Acoustically Critical" space
 - d. Supported from structure that is part of the support of an "Acoustically Critical" space.
2. To prevent break-in or break-out noise problems, whenever a duct or pipe serving a quiet space must pass through a noisy one (or, conversely, when a noisy duct or pipe must unavoidably pass through a quiet space) the duct or pipe must be lagged. See Figure 5 for typical lagging details.

**Figure 5: Typical details for duct and pipe lagging**

3. All fans should be located in a Mechanical Equipment Room with suitable acoustical isolation properties. If circumstances require that a fan be located outside an isolated MET, then the fan should be enclosed in a sound isolation chamber with 50mm thick internal duct liner as shown in Figure 6. The floor walls and ceiling of the chamber will be determined by the Architect and Acoustician based on specific circumstances.

**Figure 6: Sound isolation chamber for fans not in an MER**

4. All rotating machines such as fans (excluding the emergency fans) should be installed with a resilient support system as shown in Figure 7. The natural frequency of the resilient support system should be no greater than 5 Hz.

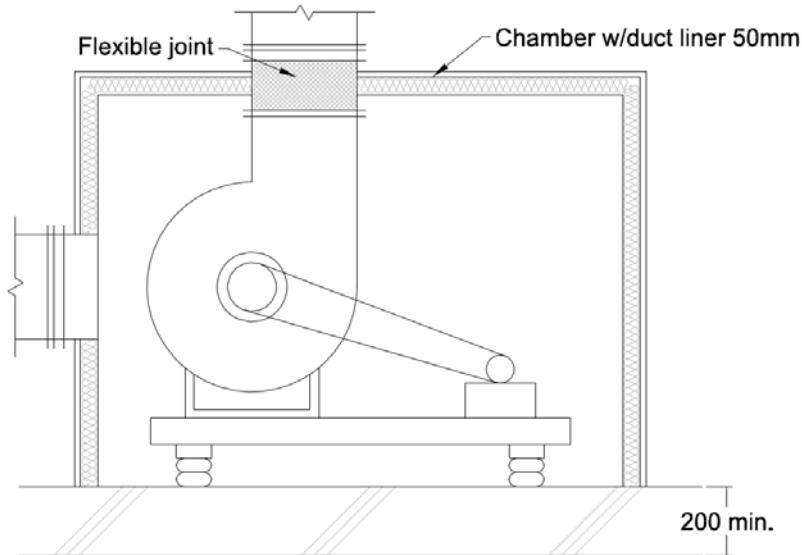


Figure 7: Typical fan isolation detail

5. Pumps should be placed on an inertia base with a weight equal to 1.5-2.0 times that of the service weight of the pumps themselves. The inertia bases should be resiliently supported as shown in Figure 8. The natural frequency of the resilient support system should be less than 5 Hz.

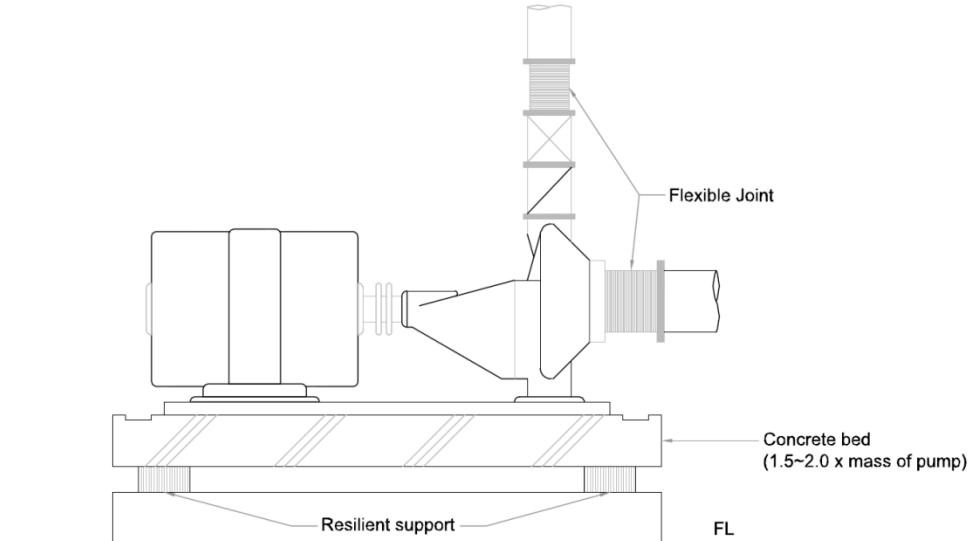


Figure 8: Pump isolation detail

6. Ducts and pipes should be supported with resilient hangers as shown in Figure 9 according to the following guidelines:

- Size: Resilient support is required for all ducts with one dimension greater than 500mm (excluding emergency smoke exhaust ducts), and all pipes greater than 25mm in diameter, (excluding the fire sprinkler pipes).

- b. Applicable locations: Isolate all such ducts and pipes within MER's, within any acoustically sensitive room and within 5m of such sensitive rooms. The natural frequency of the resilient support system should be less than 20 Hz

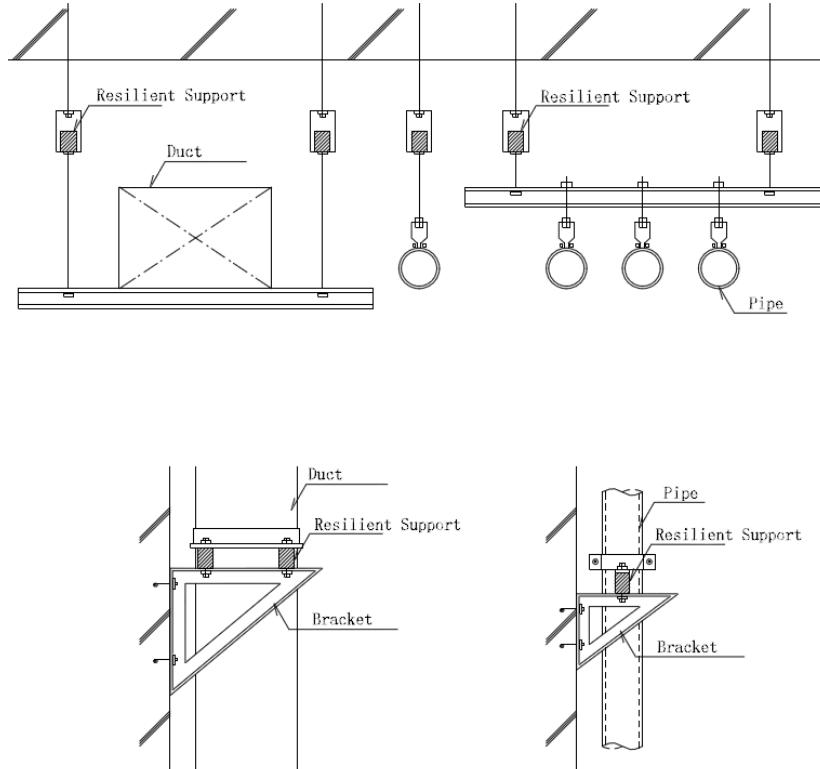


Figure 9: Typical resilient support for ducts and piping

7. Wall penetrations of ducts and pipes should be detailed as shown in Figure 10 according to the following guidelines:
- Size: All ducts with one dimension greater than 500mm (excluding emergency smoke exhaust ducts); all pipes (regardless of size, but excluding fire sprinkler pipes).
 - Applicable locations for ducts: All walls, floors and ceilings of MER's; all walls, floors and ceilings of acoustically sensitive rooms.
 - Applicable locations for piping: All walls, floors, and ceilings in the building.

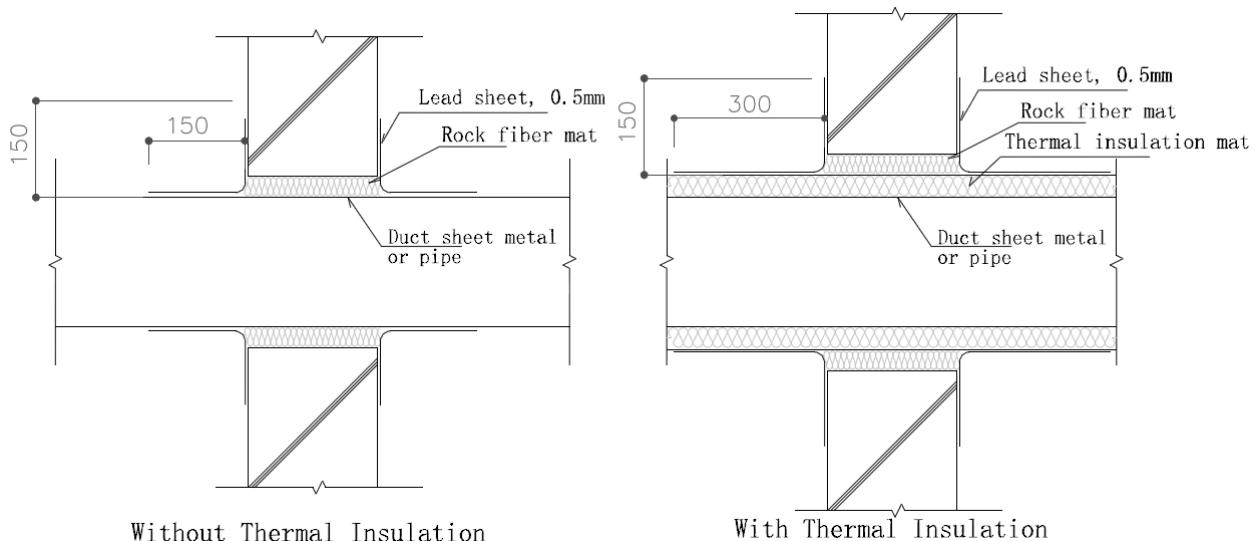


Figure 10: Typical resilient wall penetration detail

-
8. All pipes for lavatories and miscellaneous sinks around acoustically sensitive spaces must be resiliently supported. See Figure 9.

 9. Refer to table below for acceptable pipe flow velocities.

Table 4: Pipe Flow Velocities

Nominal Pipe Size (mm)	Maximum Waterflow Velocity (m/s)
20	0.6
25	0.9
50	1.2
80	1.5
100	1.8
125	2.1
150	2.4
200	2.75
250	2.9
300	2.95
≥350	3.0

(These recommendations are based on those provided in Schaffer1991 *A Practical Guide to Noise and Vibration Control*, Atlanta, ASHRAE, p. 47.)

7. Mechanical System Notes

1. Cooling towers should be installed on resilient support system. The natural frequency of the resilient support system should be less than 5 Hz.
2. Local noise ordinances may require sound attenuation on the fresh air intake and exhaust openings to protect neighboring properties from noise generated on site. When necessary, noise reduction with silencers and/or lined elbows may be required.
3. Smoke exhaust ducts can be a sound path between the outside and noise sensitive spaces. At least three acoustically lined elbows with 50mm internal acoustical lining, or silencers with corresponding noise reduction may be necessary.
4. Housekeeping pads are required for all rotating equipment.

8. Electrical System Notes

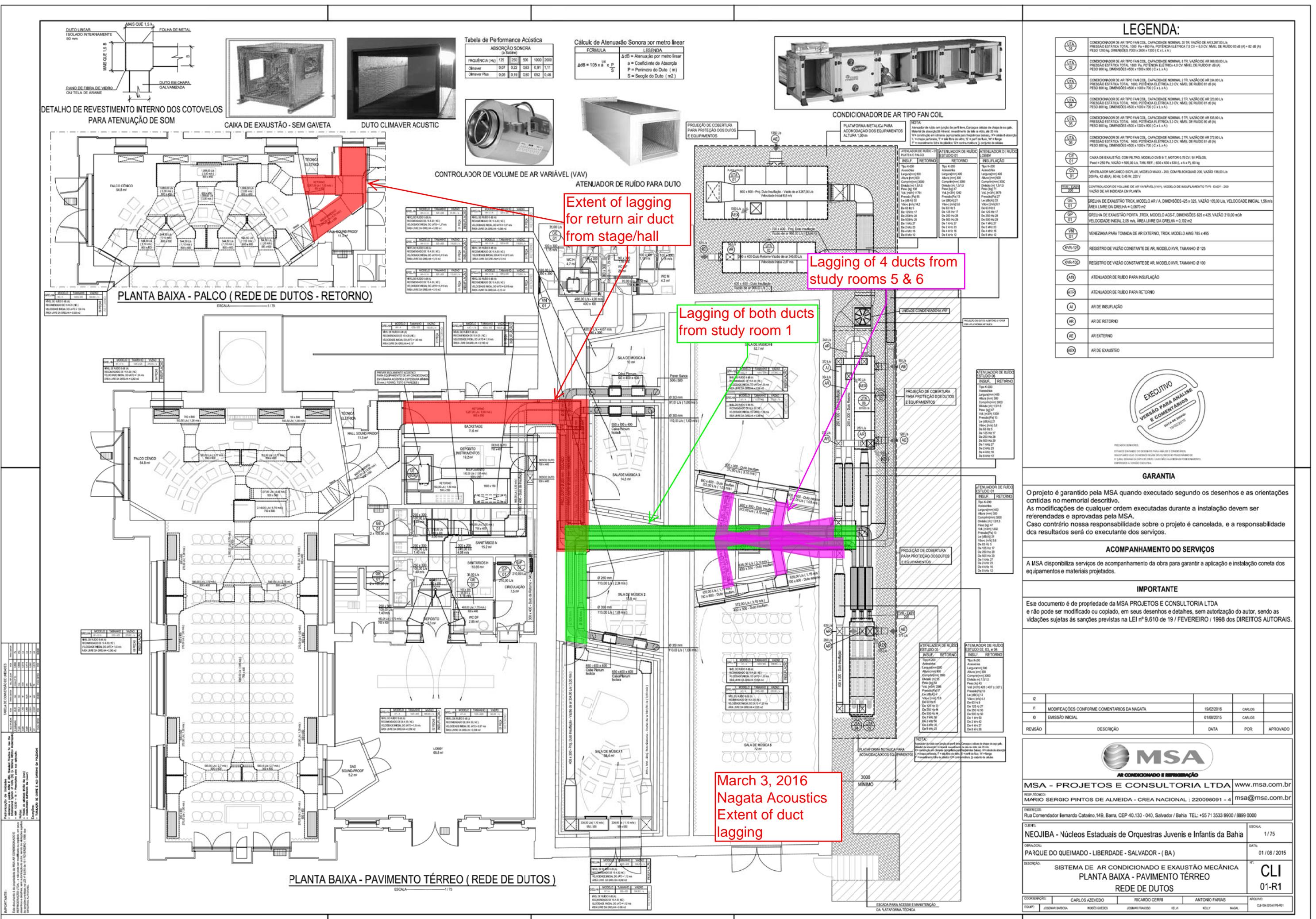
1. Ballasts for fluorescent lights should be located outside the volume of noise-sensitive space.
2. HID-lamps should not be used in any noise-sensitive space.
3. Transformers should be floor-mounted on a resilient base.

Reference Material

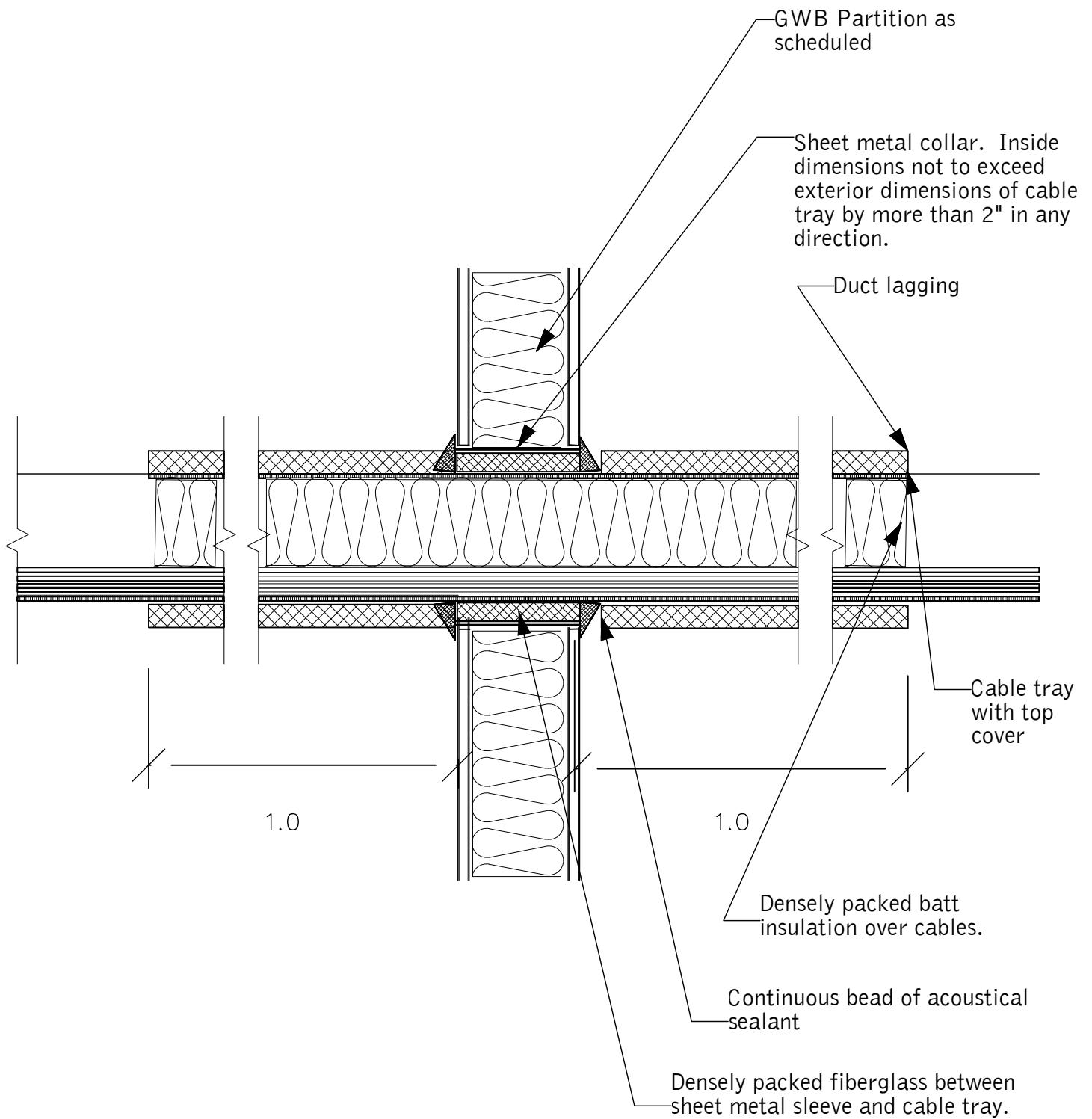
Chapter 52 of the ASHRAE *HVAC Systems and Applications Handbook* is the basic reference for much of the material in these Guidelines. A less theoretical and eminently practical interpretation of the noise control principles that follow is Mark Schaffer's book, *A Practical Guide to Noise and Vibration Control for HVAC Systems*, also published by ASHRAE.

NC Curves are available in LL Beranek, "Revised Criteria for Noise Control in Buildings," *Noise Control*, vol.3, 1957, pp. 19-27.

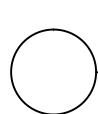
RC Curves are available in WE Blazier, Jr., "Revised Noise Criteria for Application in the Acoustical Design and Rating of HVAC Systems," *Noise Control Engineering*, vol. 16, 1981, pp. 64-73.)



Appendix V:
Penetration Details for Isolating Structures



Not To Scale



Penetration Detail GWB/Cable Tray

NAGATA ACOUSTICS

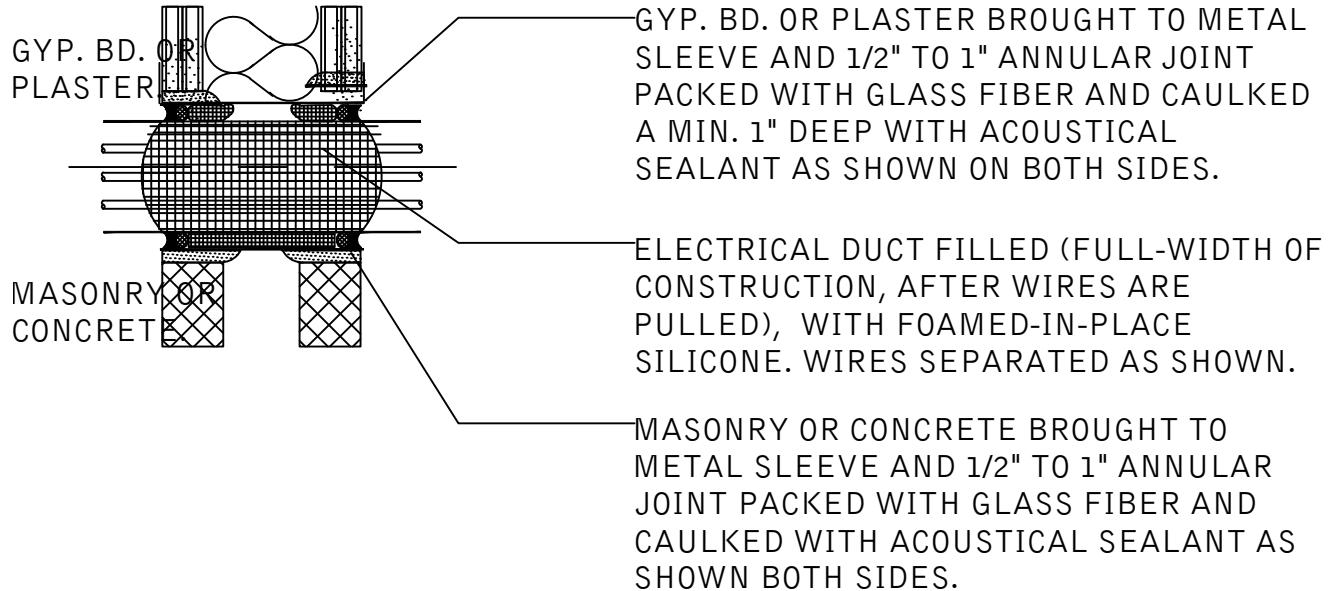
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U.S.A.

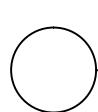
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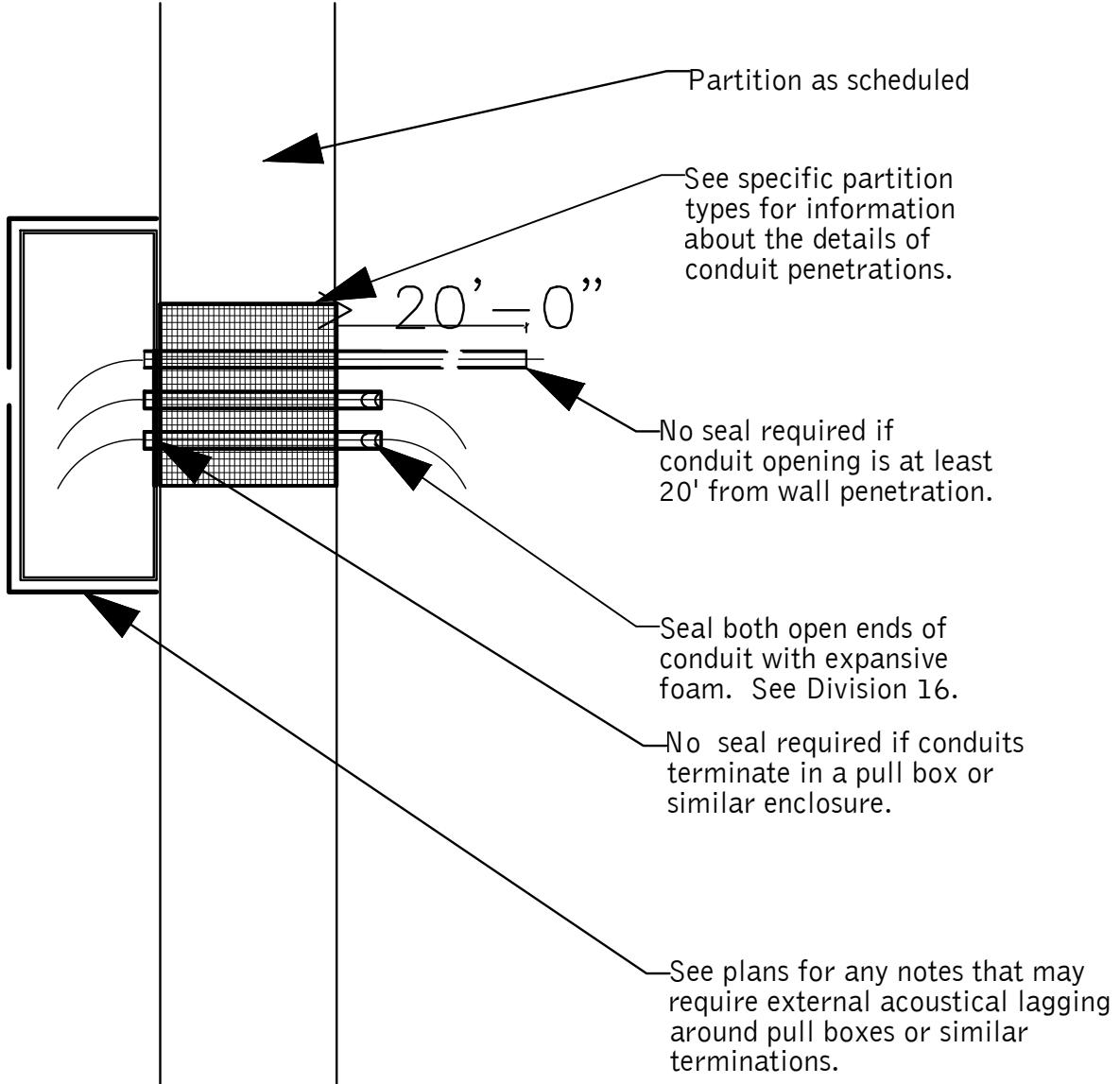
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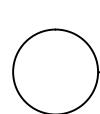


Penetration Detail Cable Tray

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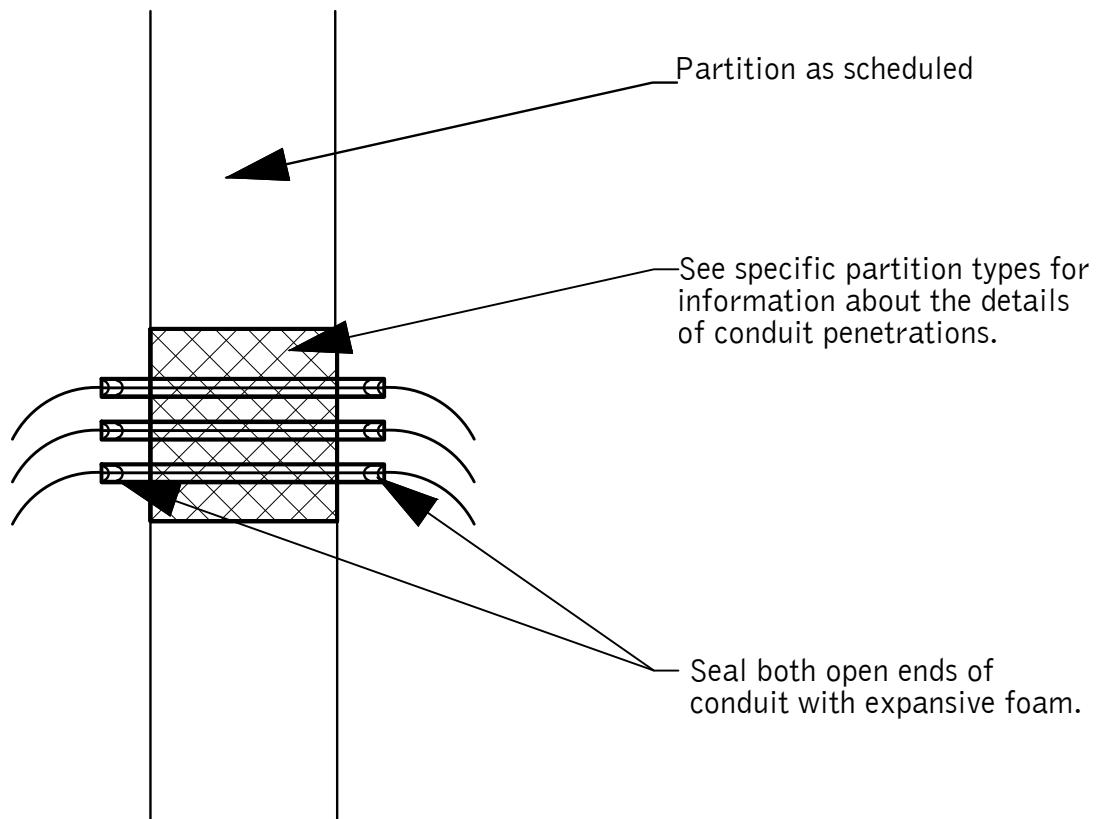


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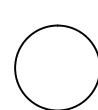


Penetration Detail Conduit with Pull Box

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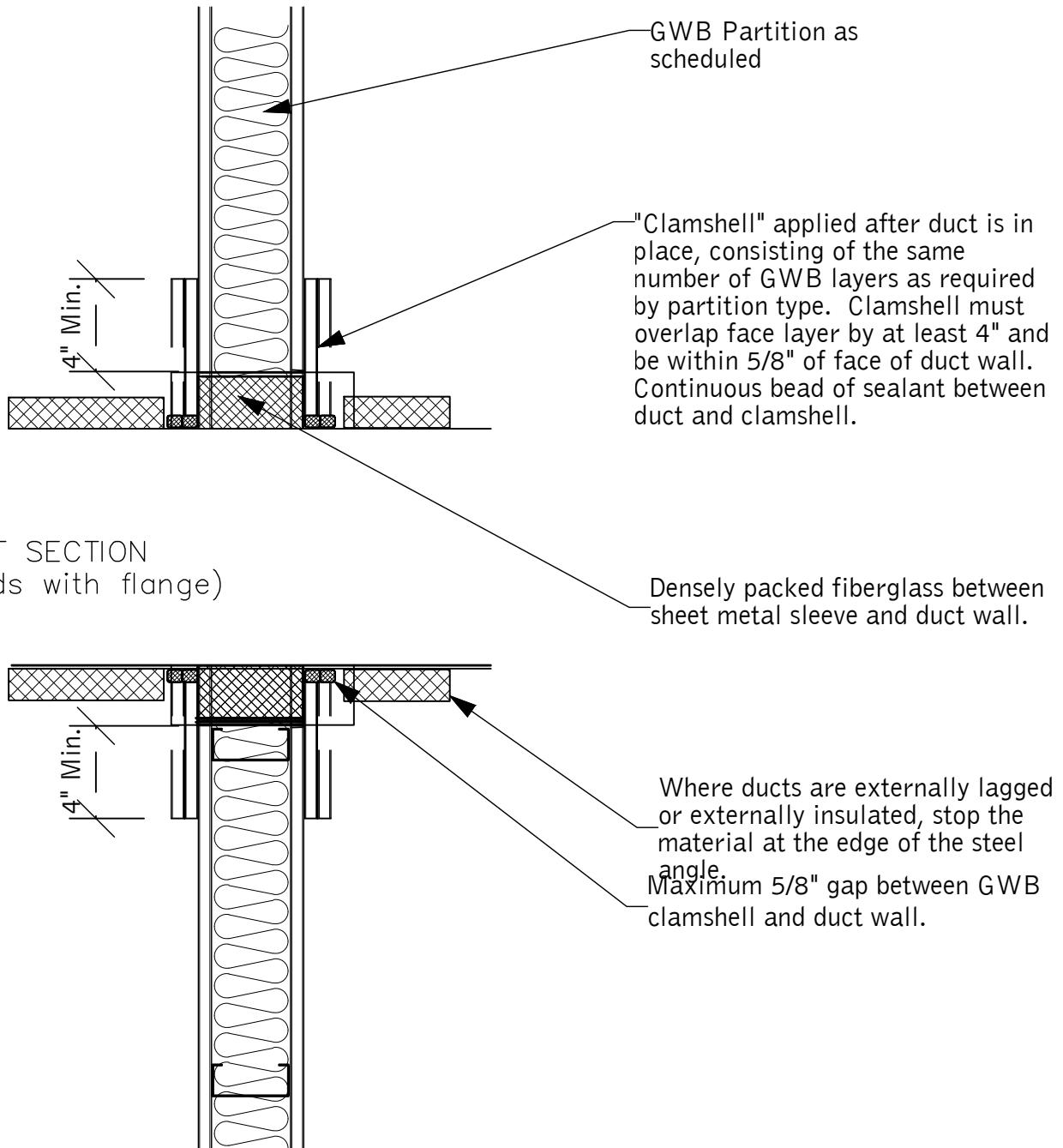


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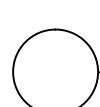


Penetration Detail Conduit Sleeves

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Not To Scale



Penetration Detail

GWB/Double-Flanged Duct Segment

NAGATA ACOUSTICS

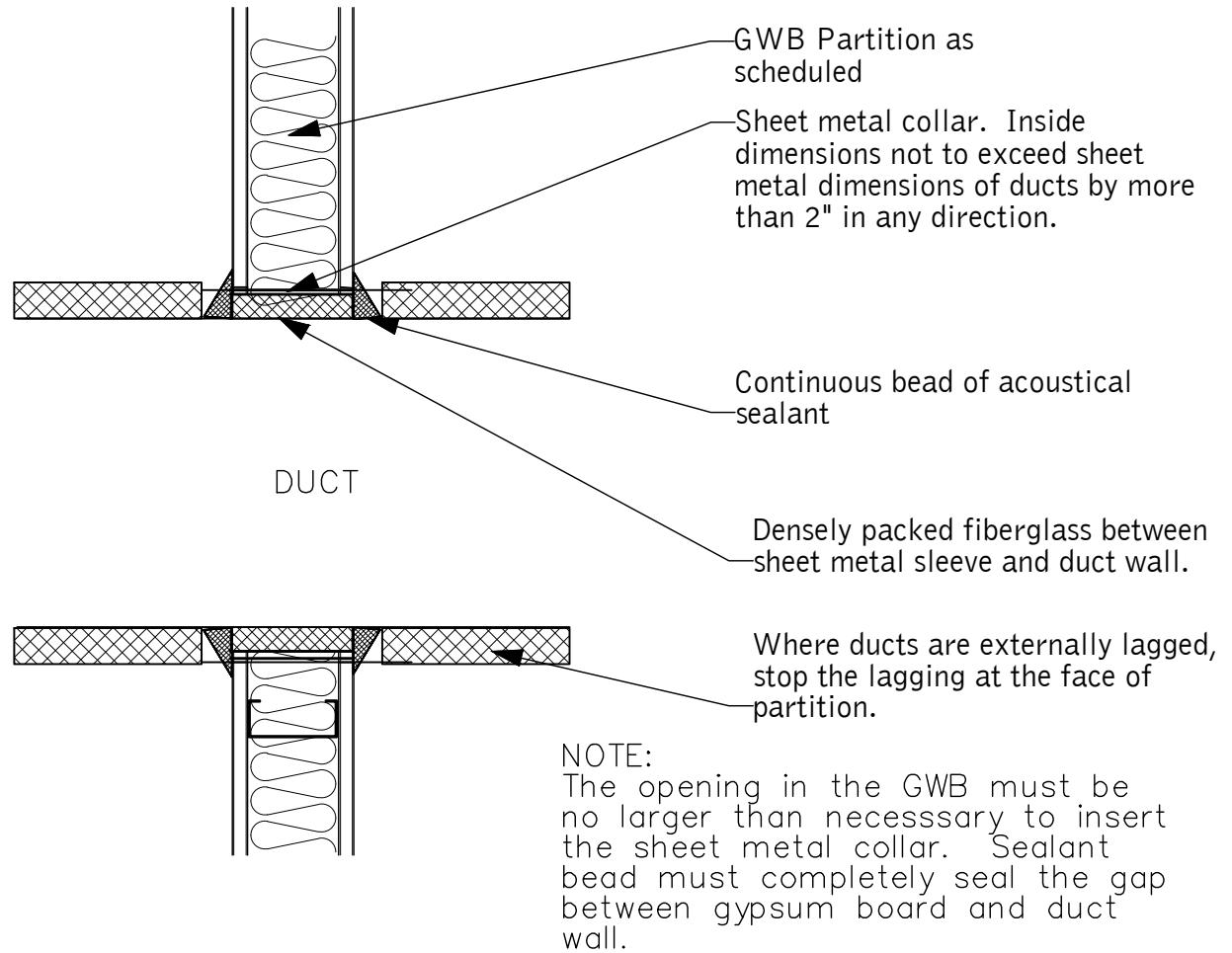
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LOS ANGELES, CA 90025

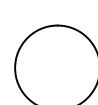
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FAX: (310)231-7816

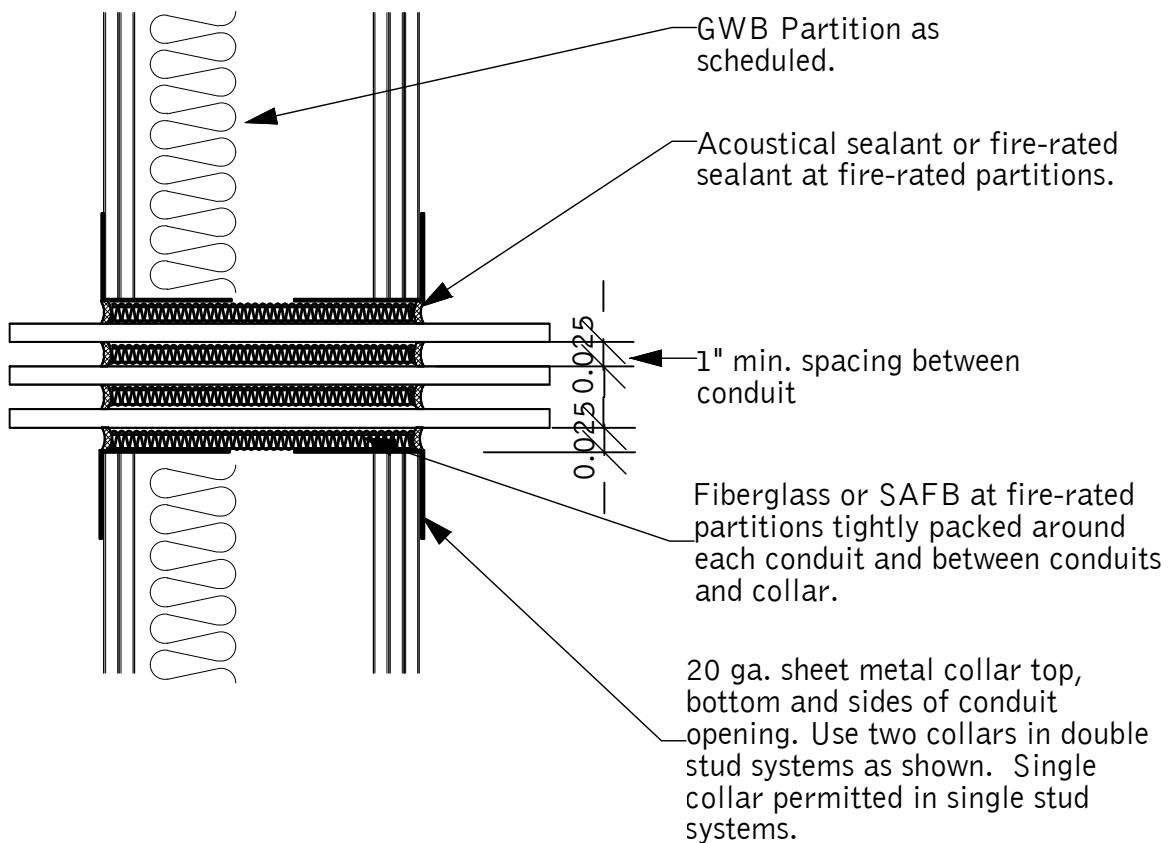


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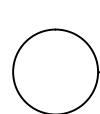


Penetration Detail GWB/Duct

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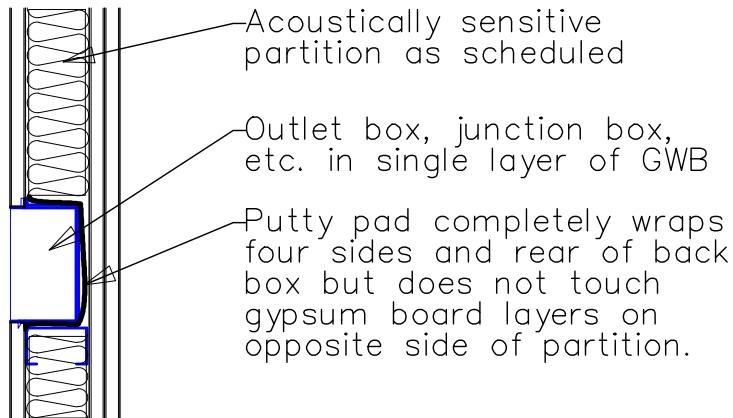


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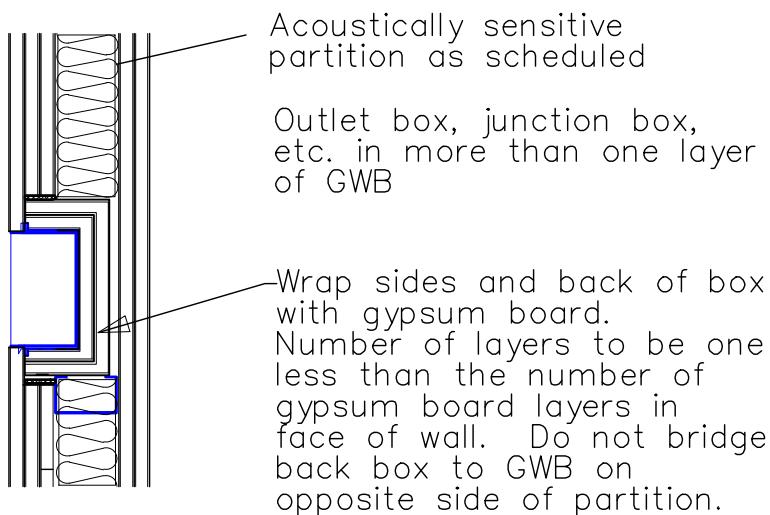


Penetration Detail GWB/Multiple Conduit

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1 Electrical Box In Single Layer GWB
 Scale: 1:10

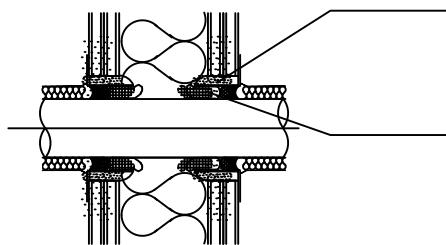


2 Electrical Box In Multiple Layers of GWB
 Scale: 1:10

Not To Scale

Penetration Detail
GWB/Electrical Junction
Boxes

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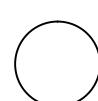


FILL WITH GYP. BD.
COMPOUND AND TAPE OR
PLASTER ALL AROUND TO
FORM COMPLETE AND
SOLID SEAL AGAINST
METAL SLEEVE.

ANNULAR JOINT 1/2" TO 1"
WIDE BETWEEN METAL
SLEEVE AND PENETRATING
ELEMENT PACKED WITH
GLASS FIBER AND CAULKED
A MIN. 1" DEEP WITH
ACOUSTICAL SEALANT AS
SHOWN ON BOTH SIDES.

UL SYSTEM NO.
WL5028

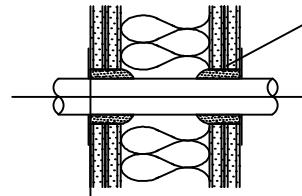
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Penetration Detail

GWB/Pipe > 2" Diameter

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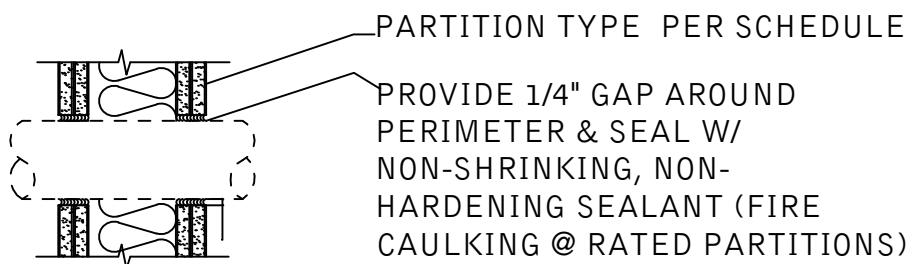


GROUT COMPLETELY,
SOLIDLY AND FULL DEPTH
ALL AROUND TO FORM A
FULL SEAL AGAINST METAL
SLEEVE.

UL SYSTEM NO.
WL1085

NOTES:

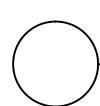
1. PROVIDE LINTELS AS REQ'D. ABOVE PENETRATIONS.
2. INTERRUPT INSULATION OUTSIDE PIPES & DUCTS AT PENETRATIONS.
3. AS FAR AS POSSIBLE, SEPARATE PIPES AND CONDUITS SO THEY CAN BE TREATED INDIVIDUALLY AS SHOWN.



PARTITION TYPE PER SCHEDULE

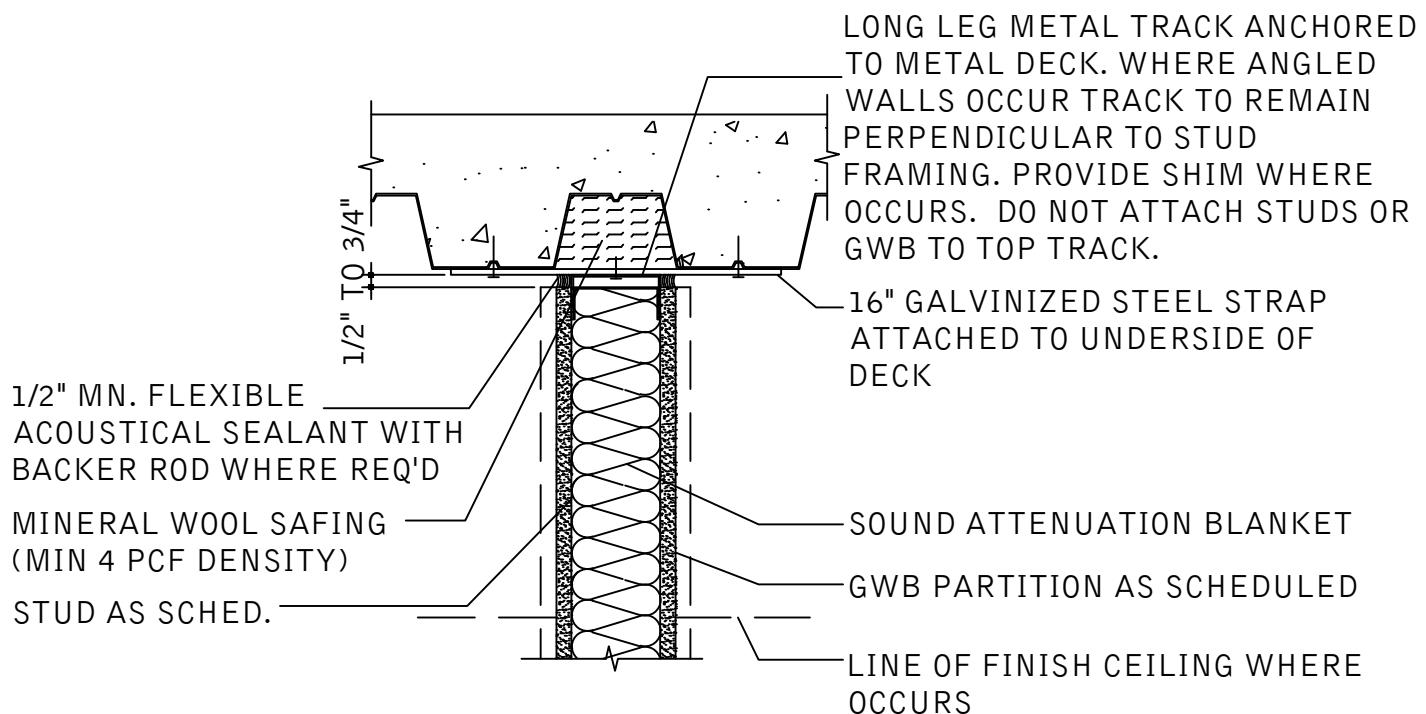
PROVIDE 1/4" GAP AROUND
PERIMETER & SEAL W/
NON-SHRINKING, NON-
HARDENING SEALANT (FIRE
CAULKING @ RATED PARTITIONS)

Not To Scale



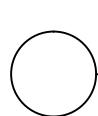
Penetration Detail
GWB/Pipe < 2" Diameter

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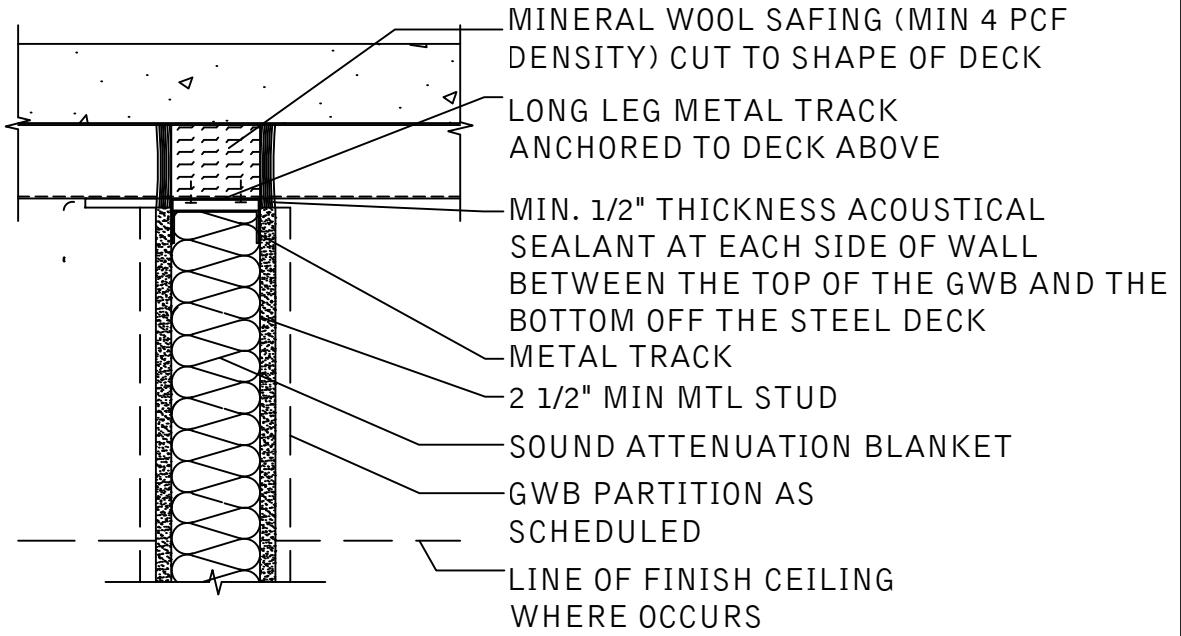
UL SYSTEM NO.
HW-D-0045

Not To Scale



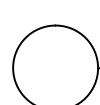
Penetration Detail GWB/Head Detail Parallel with Fluted Deck

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UL SYSTEM NO.
HW-D-0045

Not To Scale

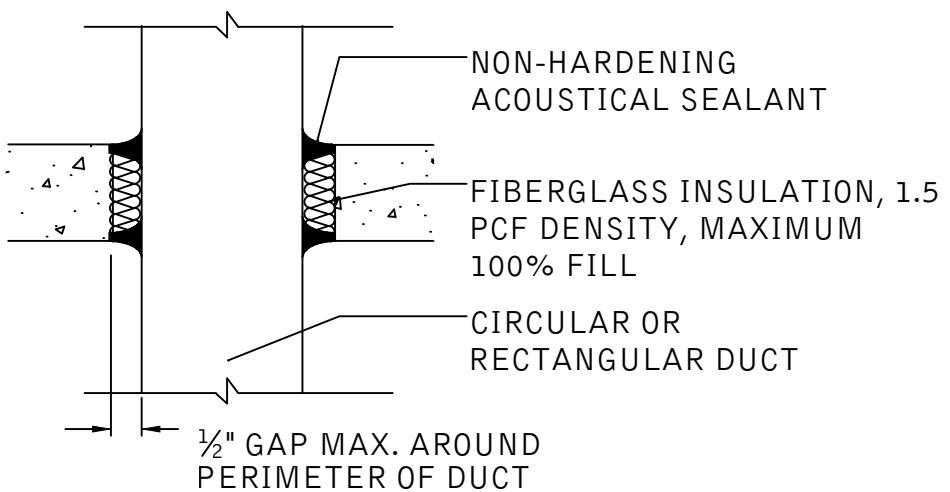


Penetration Detail

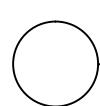
GWB/Head Detail

Perpendicular to Fluted Deck

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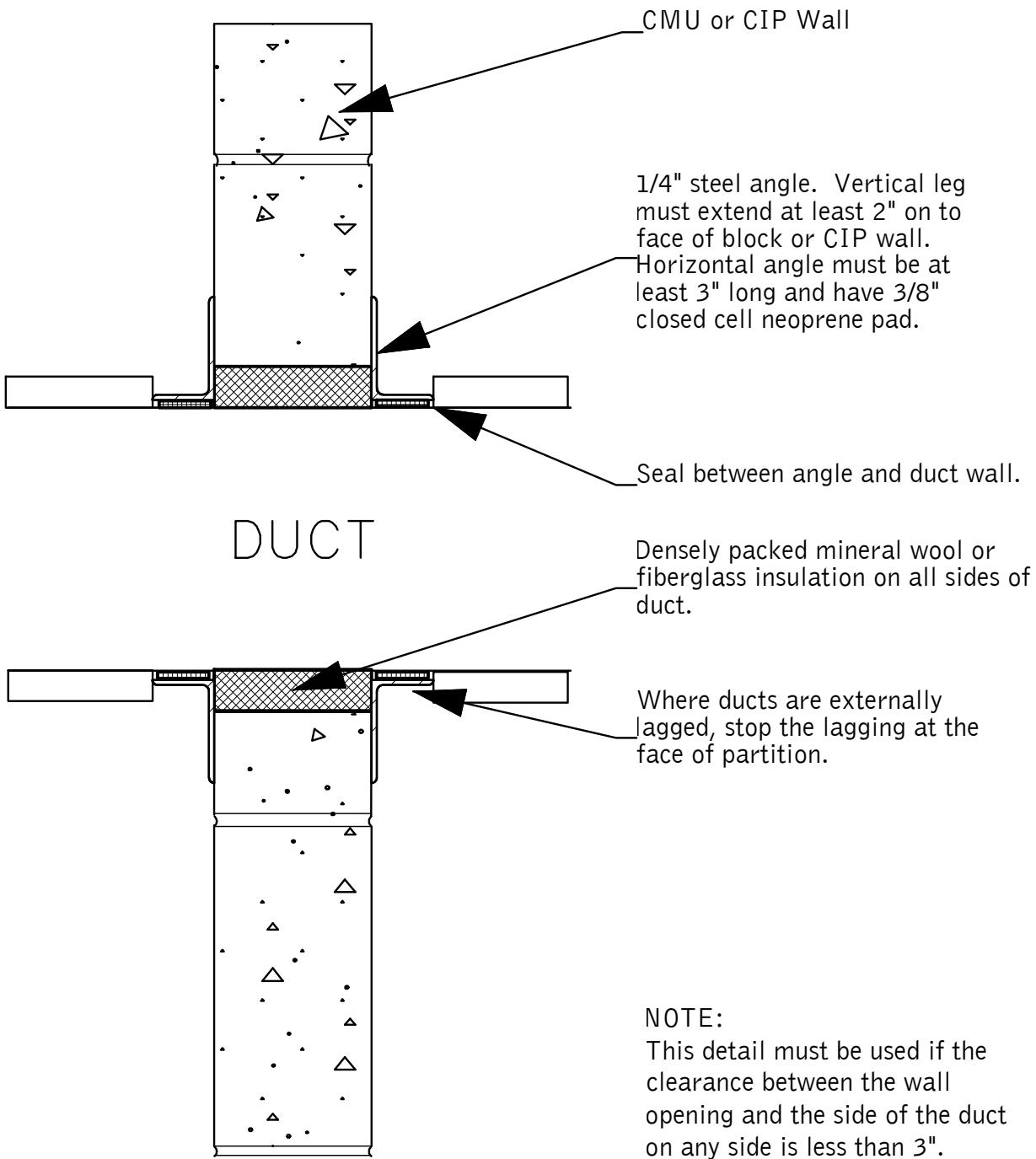
Not To Scale



Penetration Detail

Floor - Vertical Duct/Piping
Penetration

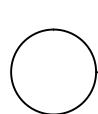
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NOTE:

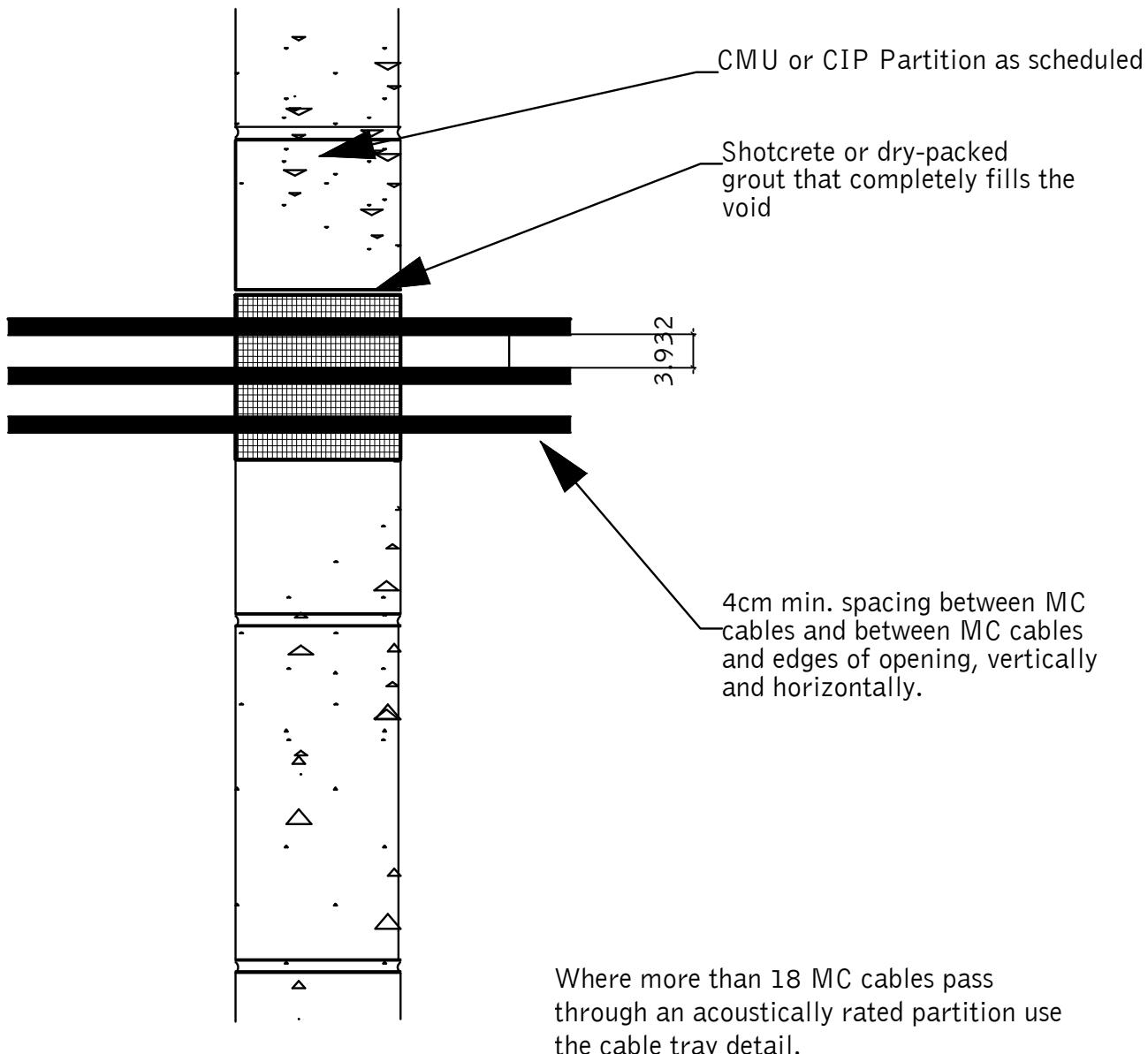
This detail must be used if the clearance between the wall opening and the side of the duct on any side is less than 3".

Not To Scale

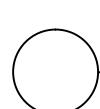


Penetration Detail CMU/Ductwork

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Not To Scale



Penetration Detail

CMU/Multiple Metal-Clad Cabling

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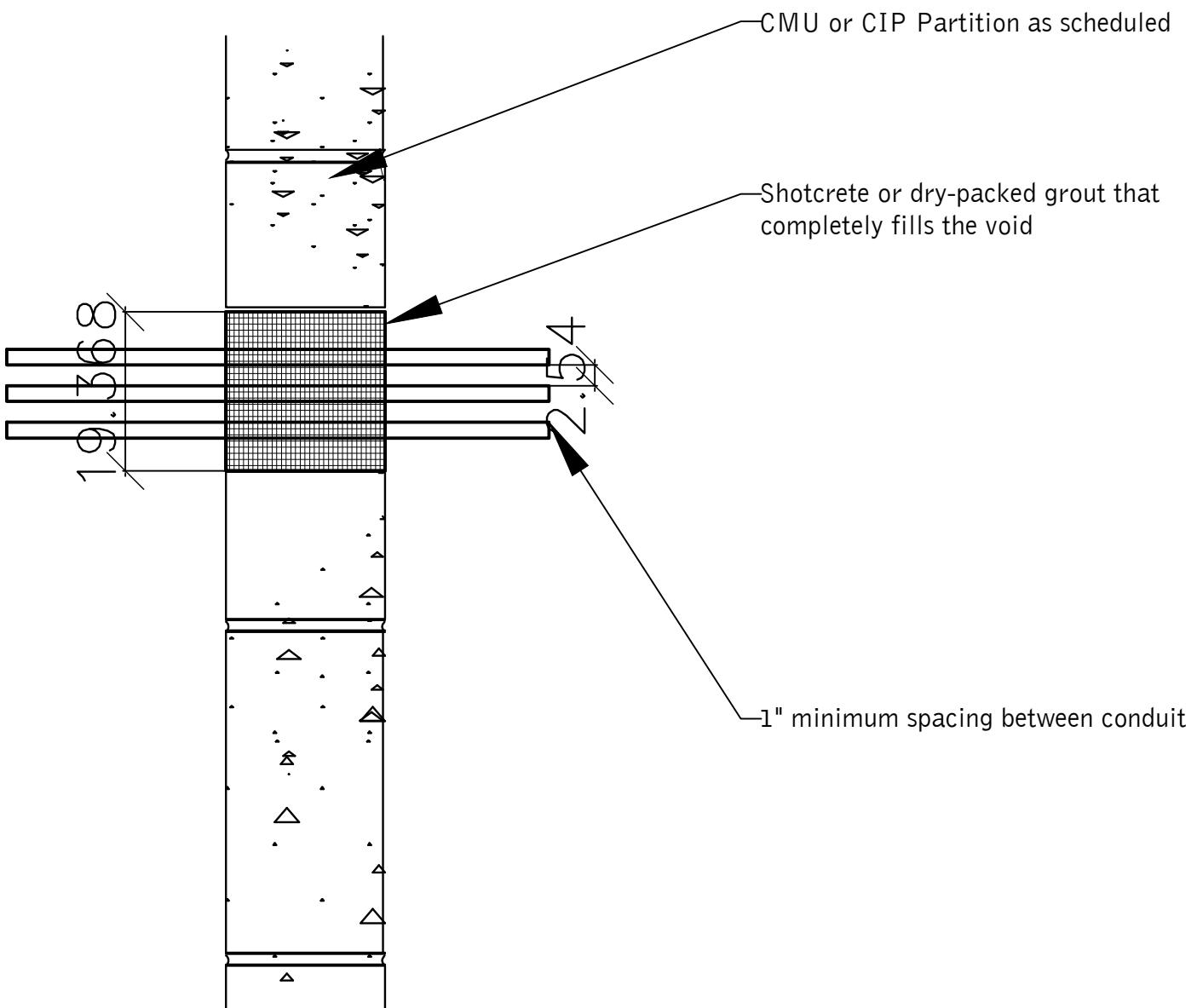
1990 S. BUNDY DR. STE. 795

LOS ANGELES, CA 90025

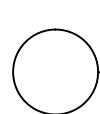
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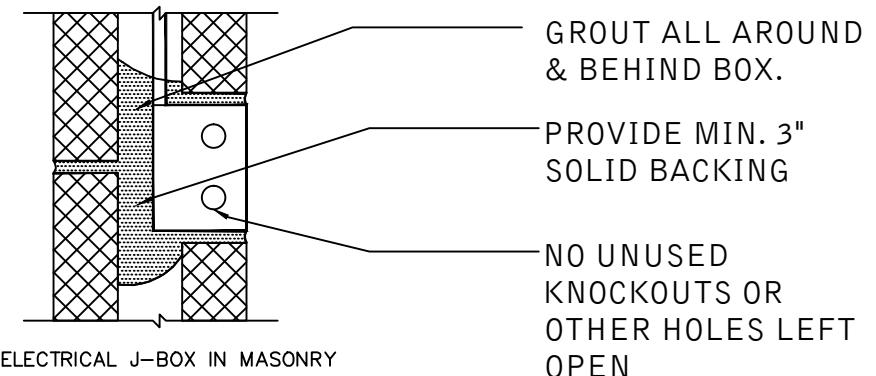


Not To Scale



Penetration Detail CMU/Multiple Conduit

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Not To Scale



Penetration Detail CMU/Electrical Junction Box

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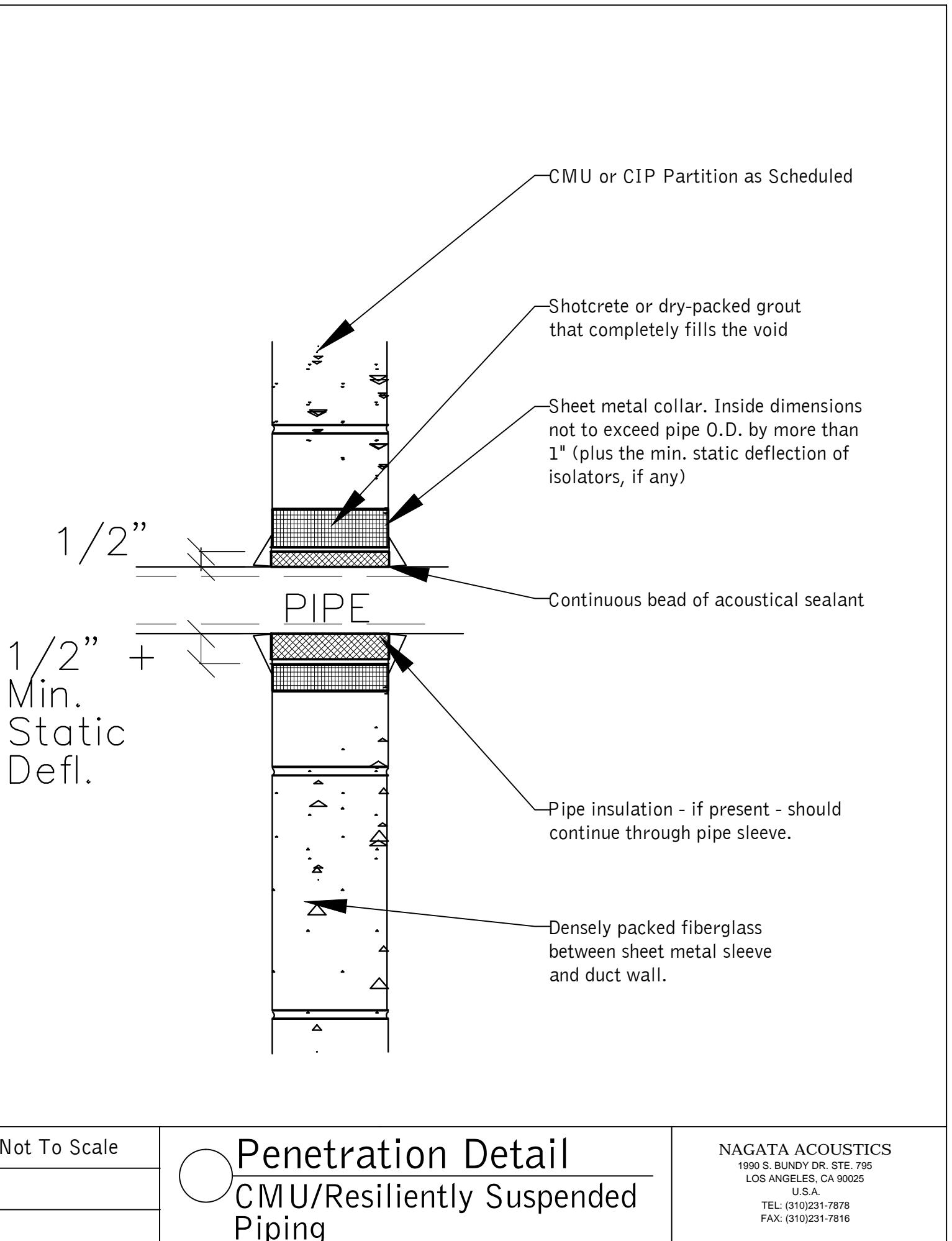
1990 S. BUNDY DR. STE. 795

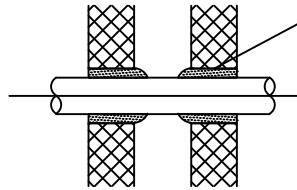
LOS ANGELES, CA 90025

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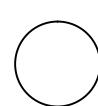


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Not To Scale



Penetration Detail

CMU/Pipe < 2" Diameter

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