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June 28, 2016

VIA EMAIL: kristina@indowwindows.com

Kristina Damschen
Indow Windows
2267 N. Interstate Avenue
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RE: Indow Windows
Field Sound Transmission Loss Testing

Dear Kristina,

The following report was prepared as part of an Industry Research project BSCI 9750, Graduate Program in Building Science, supported by the British Columbia Institute of Technology (BCIT), Centre for Architectural Ecology. The report provides a summary of completed field sound transmission loss testing of an installed tilt-and-turn window with various insulated glass unit (IGU) configurations and an interior storm window, provided by Indow Window installed over the baseline IGUs.

The interior storm window is a secondary window that is installed on the interior side of the existing primary window. The Indow interior storm window consist of a ¼" acrylic glazing panel edge with ridged ABS plastic carrier with a hollow silicone bulb. The panel size is approximately 35.5" wide and 47" tall.

Field Sound Transmission Loss Test Methodology

Sound intensity measurements were conducted to determine the in-situ sound insulation of the window assembly plus the interior storm window. All sound transmission measurements were made in accordance with ISO 15186-2 "Acoustics – Measurement of Sound Insulation in Buildings and of Building Elements Using Sound Intensity – Part 2" Field Measurements". Measurements were made between 100 to 5000 Hz at one-third octave bands. The data within the 100 Hz band should be treated with caution because this band is out of the working frequency ranges of the 25mm spacer size used as part of the intensity probe.

To study the potential acoustic benefits of the interior storm window, baseline measurements of the installed window with various IGU configurations were conducted. The thicknesses of the double and triple glazing used in the tests are as follow: 4(22)6L, 4(16)4 and 6L(11)5(11)6L. The value between parentheses denote the depth of air-filled glazing space and the thickness of the glass panes, in mm. The type of glass used in the tests is clear float glass unless noted otherwise. The letter "L" is used to represent laminated safety glass. To further simplify and distinguish between the two double-pane IGUs in the study, the term "*double pane-acoustic*" is used to represent the IGU configuration of dissimilar glass thickness of 4(22)6L, and the term "*double pane*" is associated with the IGU configuration of even glass thickness of 4(16)4.

The instrumentation used during the study included: SINUS Soundbook noise monitoring system type Samurai (S/N: #7047), SINUS Type 1 intensity probe (S/N: #55684), Type 1 GRAS microphone type 40AI (S/N: #80459), pink noise source, omnidirectional speaker, Larson Davis type 831 (S/N: #0003129) and microphone type 377B20 (S/N: #LW131539), as well as Larson Davis calibrator type 200(S/N: #11875). The omnidirectional speaker was position in the northeast corner of the testing facility and sound intensity measurements were conducted at the exterior side of the panel. Correct calibration of the acoustic instrumentation was verified using the Bruel and Kjaer acoustic calibrator.

Description of Spaces

The testing was completed using a field testing facility set-up at the Centre for Architectural Ecology located on the BCIT's Burnaby Campus. The volume of the interior space of the testing facility is 155 m^3. Floor and elevation plans of the testing facility are included in Appendix A.

A base tilt-and-turn window with unplasticised Polyvinyl Chloride (uPVC) frame was mounted in a high-mass wood-framed wall panel inserted into an existing double swing door located at the south façade of the testing facility. The wall panel was acoustically sealed to the metal door frame. The window was installed as per a typical residential window installation with culked joints around the window perimeters. The high-mass wall panel was 82" high and 70" width. The window rough opening was 48" high, 36" wide and 7" deep. The window sill was at a height of 20" above the floor of the testing facility. Appendix B includes a series of photos of the construction of the wall panel.

Test Results

A total of seven field sound transmission loss tests were conducted, including three baseline IGU window tests and two tests with the interior storm window installed at two distances from the interior face of glazing. The sound transmission loss results are summarized in Figures 1 and 2 below.

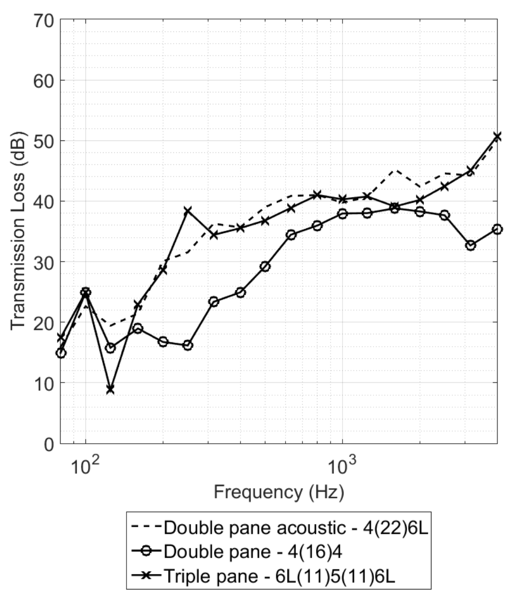
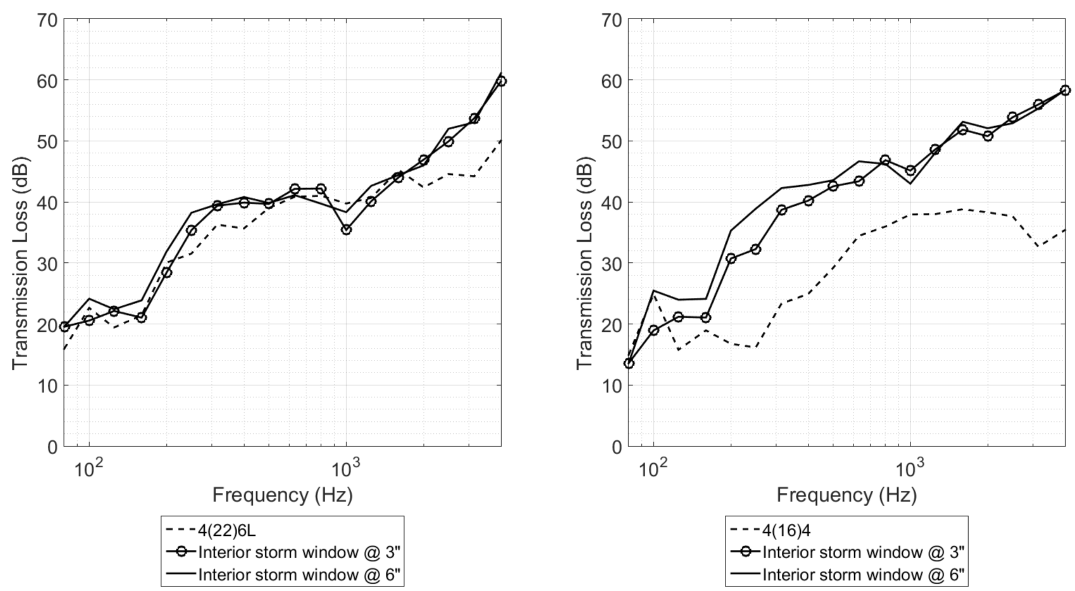


Figure 1: Sound transmission loss data for various IGU configurations: double pane – acoustic, 4(22)6L, (Dotted Line), double pane, 4(16)4, (Symbol "o" + Line), and triple pane, 6L(11)5(11)6L, (Symbol "x" + Line)

The test results are consistent with trends from published transmission loss data. As expected, when comparing between the two double-pane IGUs, the *double pane-acoustic* exhibits consistently higher transmission loss across all frequencies. This can be attributed to the combined effect of increased glazing thickness of one of the panes, increased air space between the IGU, as well as the different glass composition, an upgrade laminated for the thicker pane. The triple glazed IGU has acoustic advantages over the *double pane* above 160 Hz. However, the triple pane has almost identical transmission loss data to the *double pane- acoustic*, only showing marginal benefits around 200 to 315 Hz and above 3.15 kHz. Thus, the interior storm window was studied only on the two double-paned IGU configurations.

The acoustic performance of the interior storm window was tested at two different distances, with enclosed air spaces depth of 3" and 6". Figure 2 illustrates the measured sound transmission loss values of the interior storm window on the two double IGU window variations at the two distances.



(a) Sound transmission loss data for interior storm window installed at various distances against double pane - acoustic, 4(22)6L

(b) Sound transmission loss data for interior storm window installed at various distances against double pane, 4(16)4

Figure 2: Sound transmission loss data with interior storm window at 3" (Symbol "o" + Line) and 6" (Solid Line) depth against double pane – acoustic and double pane IGU configurations

When used with the higher performance *double pane – acoustic* window, the interior storm window has minor increase sound transmission loss at mid and high frequencies. The introduction of deeper enclosed airspace has much the same effect on the acoustic performance as the one with the shallower airspace.

When used with the *double pane* window, the deeper airspace between the interior storm window and primary window can contribute to additional sound transmission loss in the low to mid frequencies. At higher frequencies, the larger air space provides minimal advantage over the shallower airspace. Regardless of the installation placement distance from the primary window, the interior storm window provides appreciable noise reduction when it is installed over the *double pane* window, and significantly improved the overall sound insulation of the base window. At both 3" and 6" depth, the average sound insulation improvement, across frequency bands between 125 to 4k Hz, is approximately 14 dB.

In addition to sound transmission loss, the STC and OITC ratings are calculated in accordance to ASTM E413 "Classification for Rating Sound Insulation" and ASTM E1332, respectively. The results are summarized in Table 1 below. The change in transmission loss, STC, and OITC ratings between the interior storm window and the baseline IGUs are presented in Table 2. The STC reference contour is aligned with the transmission loss data for all baseline windows and the addition of the interior storm window at two distances and can be found in Appendix C.

Table 1: Sound transmission loss data, STC and OITC ratings for various IGU configurations and interior storm window at two distances

	WINDOW UNIT INCLUDING INTERIOR STORM WINDOW	COMBINED STC	COMBINED OITC*	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
				FREQUENCY (Hz) — COMBINED SOUND TRANSMISSION LOSS (dB)																
I	4mm Clear / 22mm Air /6mm Laminated	40	30	22.6	19.4	21.4	30.1	31.5	36.3	35.7	39.0	40.8	41.0	39.7	40.7	45.2	42.4	44.6	44.2	50.0
a	Interior Storm Window @ 3"	40	31	20.6	22.1	21.0	28.4	35.4	39.4	39.9	39.7	42.1	42.2	35.4	40.1	44.0	46.9	49.9	53.7	59.8
b	Interior Storm Window @ 6"	42	32	24.1	22.4	23.9	31.9	38.2	39.6	40.8	39.8	41.1	39.7	38.3	42.6	44.4	46.0	52.0	53.0	61.1
II	4mm Clear / 16mm Air / 4mm Clear	31	24	24.9	15.8	19.0	16.7	16.2	23.4	24.9	29.2	34.4	36.0	38.0	38.0	38.8	38.3	37.7	32.7	35.4
a	Interior Storm Window @ 3"	42	29	18.9	21.2	21.1	30.7	32.3	38.7	40.2	42.6	43.4	46.8	45.1	48.6	51.8	50.8	53.9	56.0	58.3
b	Interior Storm Window @ 6"	45	31	25.5	24.0	24.1	35.3	38.9	42.3	42.8	43.6	46.7	46.2	43.0	48.1	53.1	52.1	52.9	55.3	58.3

Table 2: Delta transmission loss data, STC and OITC ratings between various IGU configurations and interior storm window at two distances

	WINDOW UNIT INCLUDING INTERIOR STORM WINDOW	△ STC	△ OITC*	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
				FREQUENCY (Hz) — △ SOUND TRANSMISSION LOSS (dB)																
I	4mm Clear / 22mm Air /6mm Laminated																			
a	Interior Storm Window @ 3"	0	1	-2.1	2.7	-0.4	-1.7	3.8	3.1	4.2	0.7	1.3	1.2	-4.3	-0.6	-1.2	4.5	5.3	9.5	9.7
b	Interior Storm Window @ 6"	2	3	1.5	3.0	2.4	1.8	6.7	3.3	5.1	0.8	0.3	-1.3	-1.4	2.0	-0.8	3.6	7.4	8.8	11.1
II	4mm Clear / 16mm Air / 4mm Clear																			
a	Interior Storm Window @ 3"	11	5	-5.9	5.4	2.1	14.0	16.1	15.4	15.3	13.4	8.9	10.9	7.2	10.6	13.0	12.5	16.2	23.3	22.9
b	Interior Storm Window @ 6"	14	7	0.6	8.2	5.2	18.5	22.7	18.9	17.9	14.4	12.2	10.2	5.0	10.1	14.3	13.8	15.2	22.6	22.9

This report was prepared by the Centre for Architectural Ecology/Building Science Graduate Program at BCIT for Indow Window. Any use that a third party makes of this report, or any reliance or decisions made based on it, are the sole responsibility of such third parties.

We thank you for the opportunity to provide this information, and we trust that this information is helpful and sufficient for your purposes. If you have any questions or concerns, please do not hesitate to contact the undersigned.

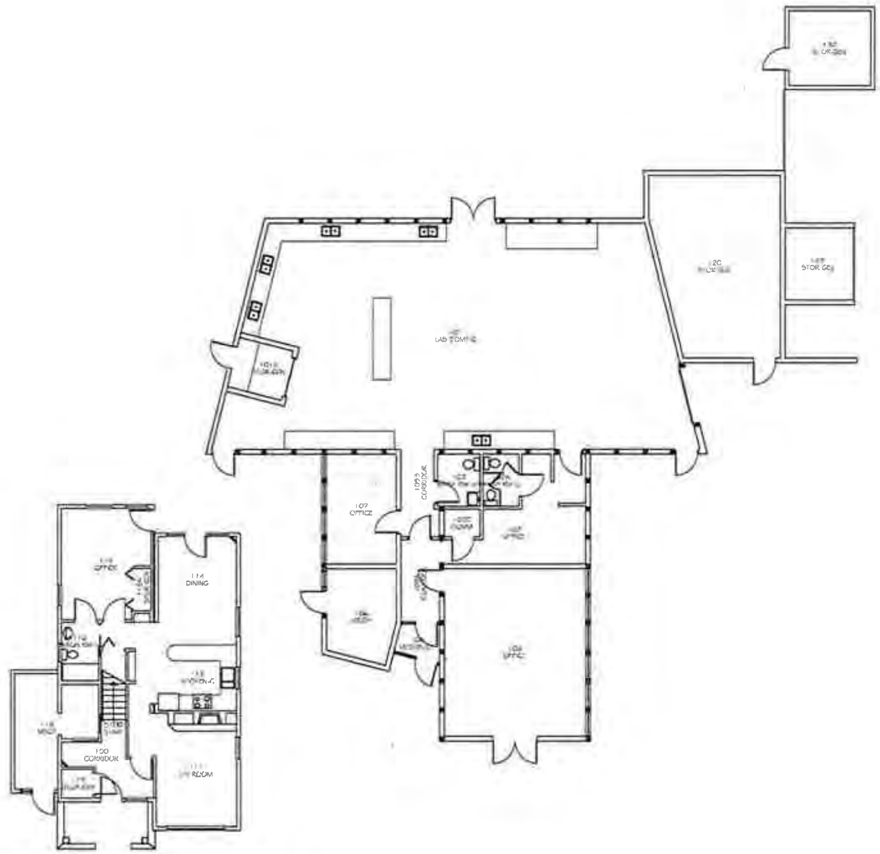
Your truly,

Joyce Mak, MEng, EIT
Building Science Graduate Program
British Columbia Institute of Technology

Dr. Maureen Connelly, PhD
Director, Faculty, Centre for Architectural Ecology
Faculty, Building Science Graduate Programs

Enc: Appendix A – Floor and elevation plans of the testing facility
Appendix B – Photo pages
Appendix C – STC results for baseline IGU windows and interior storm window

APPENDIX A: FLOOR PLANS AND ELEVATIONS OF TESTING FACILITY



NE03, FIRST FLOOR

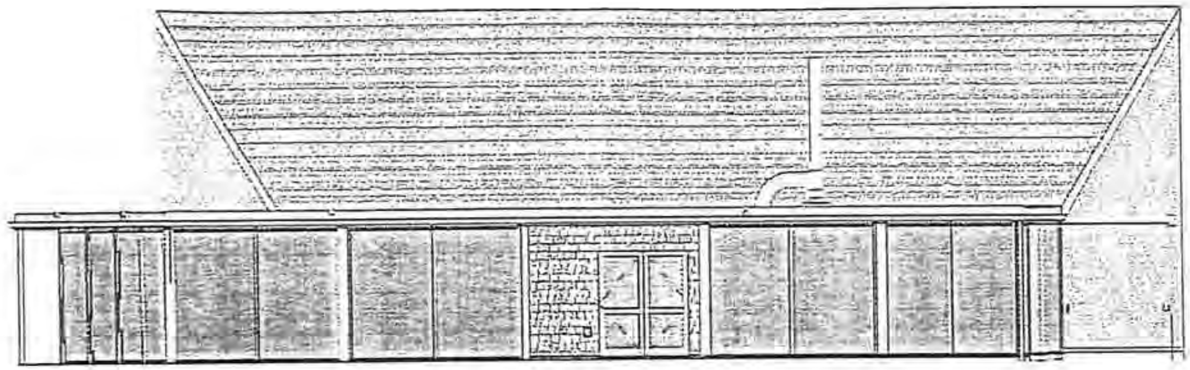
SCALE: 1:200

BRITISH COLUMBIA
INSTITUTE OF TECHNOLOGY
campus planning

LAST UPDATED: SEPTEMBER 9, 2008

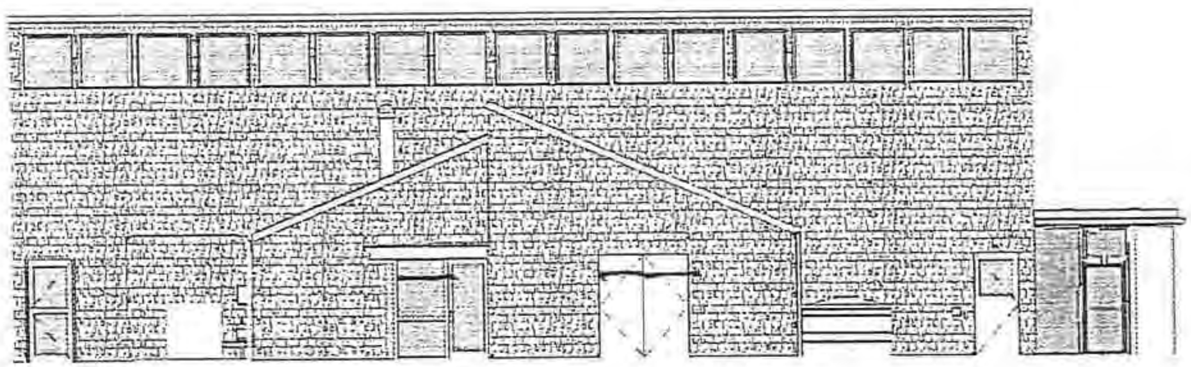
EAST ELEVATION

1 : 150



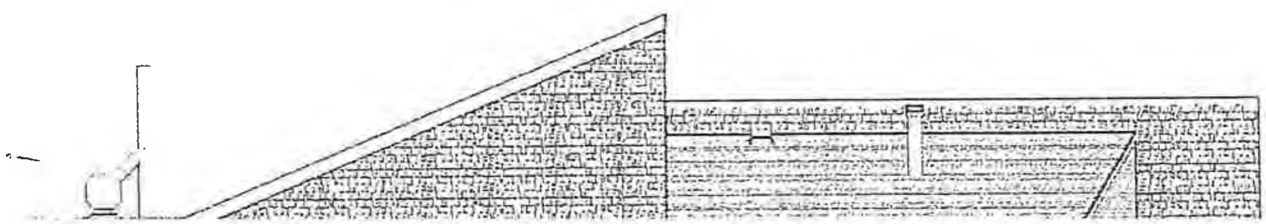
NORTH ELEVATION

1 : 150



SOUTH ELEVATION

1 : 150



APPENDIX B: PHOTO PAGES

PHOTO 1: Existing Double Door

PHOTO 2: Wood Framing for Insert Test Panel

PHOTO 3: Exterior Plywood Installed on Frame

PHOTO 4: 1st Layer of GWB on Plywood

PHOTO 5: 2nd Layer of GWB on Plywood

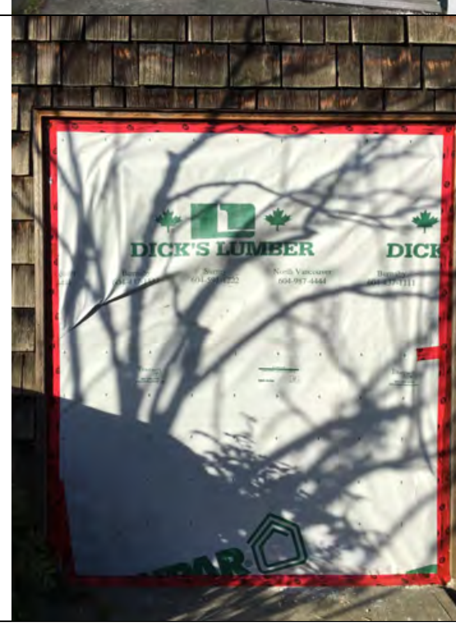


PHOTO 6: Tyvek over GWB & Plywood on Frame

APPENDIX C: PHOTO PAGES

PHOTO 7: Batt Insulation in Wood Frame Cavity

PHOTO 8: Polyethylene Sheet & Resilient Channels

PHOTO 9: Interior GWB on Resilient Channels

PHOTO 10: Window Installation

PHOTO 11: Window Rough Opening

PHOTO 12: Installed Window at Insert Test Panel

APPENDIX C: PHOTO PAGES

PHOTO 13: Horizontally Lapped Siding on Test Panel

PHOTO 14: Tilt & Turn Operation Mechanism

PHOTO 15: Drywall Return at Window Opening

PHOTO 16 :Painted Interior Side of Test Panel

PHOTO 17: Interior Storm Window (Silicone Edge Seal)

PHOTO 18: Installed Interior Storm Window

PHOTO 19: Installed Interior Storm Window, Close-up

PHOTO 20: Installed Interior Storm Window at Corners

PHOTO 21: Tripe Pane IGU, 6L(11)5(11)6L

PHOTO 22: Tripe Pane IGU, 6L(11)5(11)6L

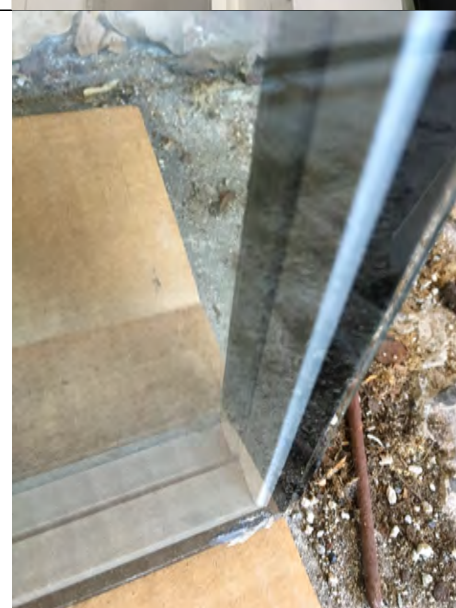


PHOTO 23: Double Pane IGU, 4(22)6L

PHOTO 24: Double Pane IGU, 4(22)6L

APPENDIX C: STC RESULTS FOR BASELINE IGU WINDOWS & INTERIOR STORM WINDOW

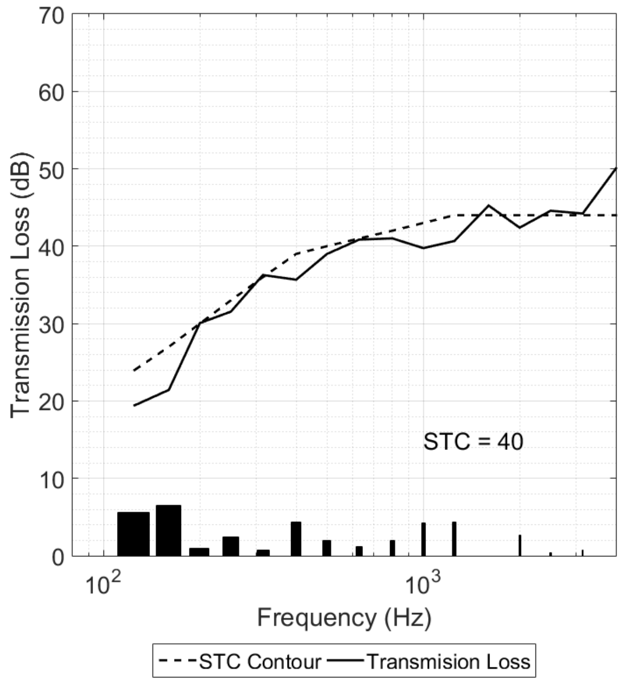


Figure 1: STC Reference Contour (Dotted Line) Fitted to Sound Transmission Loss data of Double Pane – Acoustic window*, 4(22)6L (Solid Line)*

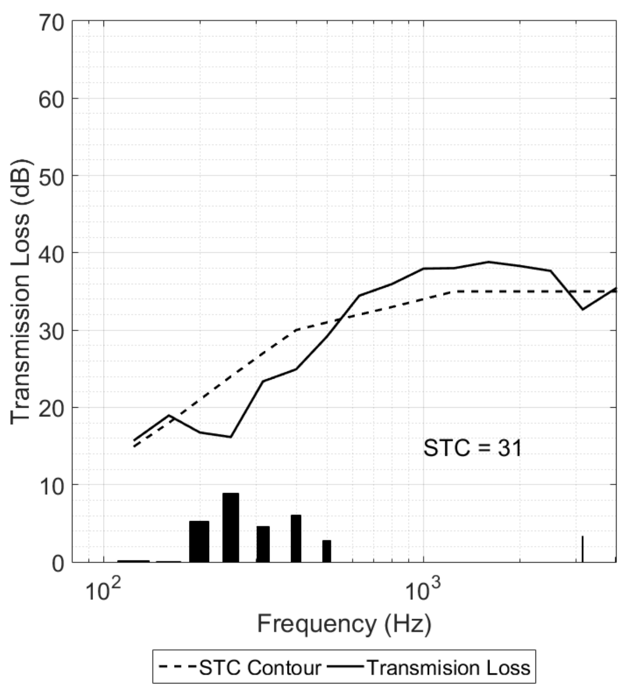


Figure 2: STC Reference Contour (Dotted Line) Fitted to Sound Transmission Loss data of Double Pane window*, 4(16)4 (Solid Line)*

Note: The deficiencies are shown as bars at the bottom of the chart. The 8-dB limitation is not invoked.

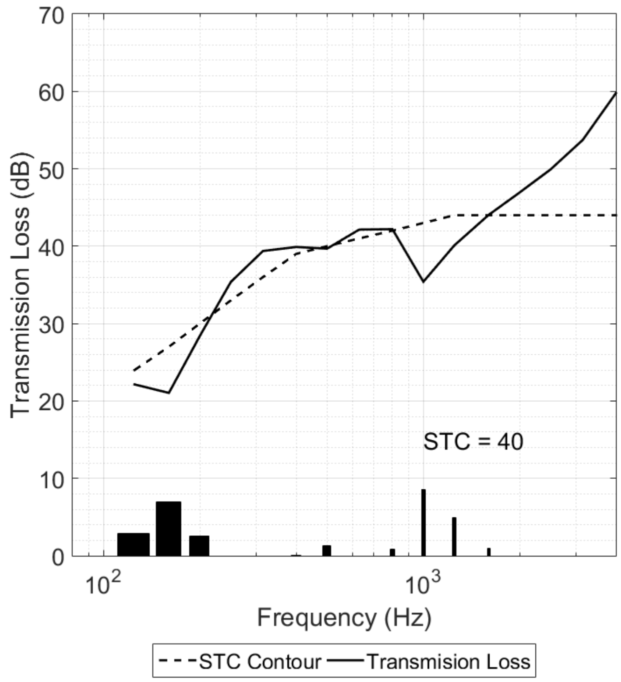


Figure 3: STC Reference Contour (Dotted Line) Fitted to Sound Transmission Loss data of Interior Storm Window @ 3" on Double Pane – Acoustic window*, 4(22)6L (Solid Line)*

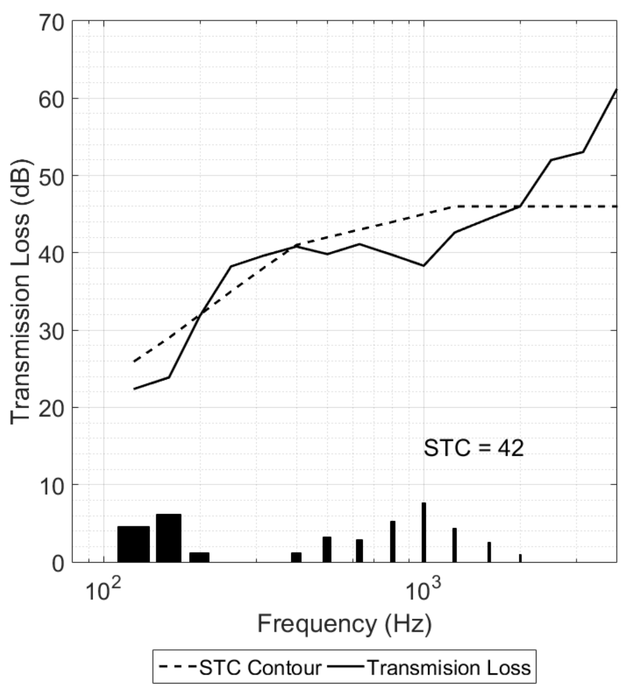


Figure 4: STC Reference Contour (Dotted Line) Fitted to Sound Transmission Loss data of Interior Storm Window @ 6" on Double Pane – Acoustic window*, 4(22)6L (Solid Line)*

Note: The deficiencies are shown as bars at the bottom of the chart. The 8-dB limitation is not invoked.

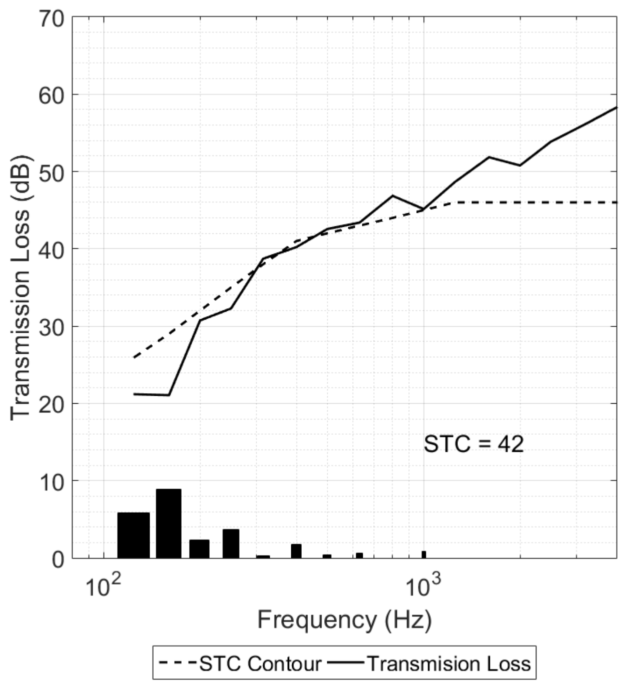


Figure 5: STC Reference Contour (Dotted Line) Fitted to Sound Transmission Loss data of Interior Storm Window @ 3" on Double Pane window, *4(16)4 (Solid Line)*

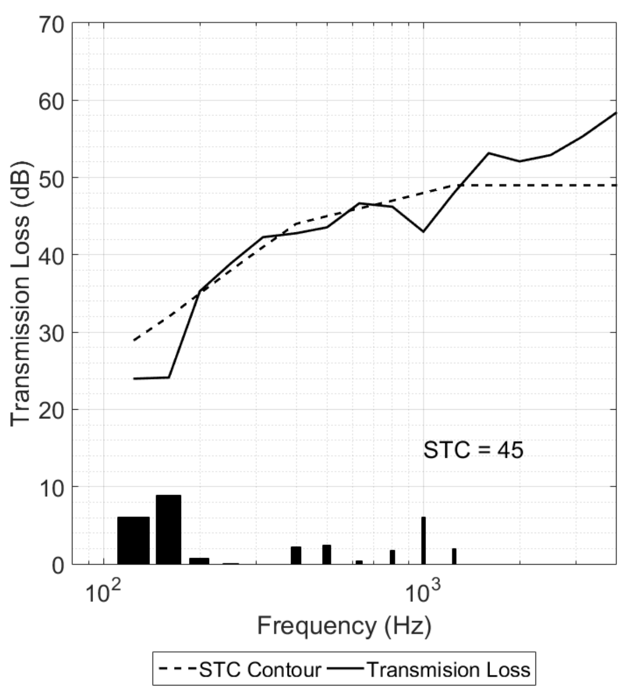


Figure 6: STC Reference Contour (Dotted Line) Fitted to Sound Transmission Loss data of Interior Storm Window @ 6" on Double Pane window, *4(16)4 (Solid Line)*

Note: The deficiencies are shown as bars at the bottom of the chart. The 8-dB limitation is not invoked.