HUSHCORE® Noise Reduction Systems for Air Cooled Chillers and Condensing Units



Source Applied Unit Mounted Equipment-"centric" Systems

Path Applied Free Standing Barriers and Enclosure Systems



Chiller Noise Transmission Paths



Screw Compressor Noise

Screw chillers have become the specified design of choice for most new construction projects because of their low first cost, high efficiency, and low maintenance expenses. Screw compressors generate moderate to loud overall noise levels and discrete tones that are extremely intrusive and annoying. Most screw models generate their fundamental tone at nominal 300 Hz frequency with strong harmonic frequencies at 600 Hz and 900 Hz.



Scroll Compressor Noise

Scroll compressors and their connected piping circuits radiate comparable overall sound pressure levels but are less tonal compared to screw machines.



Condenser Fan Exhaust Noise

Condenser fan exhaust noise is often a secondary contributing source except where receiver locations are elevated or in some cases directly above the chiller equipment. The condenser fan exhaust noise tone is around 63 Hz and below the human hearing range which drives dBA overall levels. Acoustical exhaust treatments must consider the negative impact on operational efficiency and unit power consumption.



Condenser Air Intake Noise

Condenser air intakes are the open sides and ends of the chiller where compressor radiated sound (lower region) and condenser fan sound (upper regions where condenser coils are located) flank horizontally outward from the unit. While this intake path is usually a lower priority contributing source, it can not be overlooked especially when noise reduction goals approach or exceed 8 dBA. Pressure drop is again a critical design consideration as most chillers can tolerate no more than total 0.15" to 0.25" w.g. pressure loss including system effects.



Building Reflection Noise

Published chiller equipment sound power levels are based on free field 360° spherical sound propagation. Considering no chillers can radiate spherically, there will always be contribution to overall receiver sound pressure levels from nearby reflective surfaces. Sound reflections from the roof or grade when combined with an adjacent vertical wall plane can add 3-5 dBA to the modeled or measured level at a receiver location. The closer the reflecting plane is to the source the greater the sound contribution will be.



Structure-Borne Noise

Any building structure that vibrates radiates airborne sound energy inside the space. Structure-borne unit vibration generated from chiller compressors and condenser fans can excite roof steel, metal decking and gypsum board partitions.

From Problem Definition... to Problem Solved.

Learn more at www.hushcore.net or call 610-863-6300

Acoustic Model for Air Cooled Chillers & Condensing Units



Multi-Path System Problems Require Comprehensive System Solutions

BRD HUSHCORE[®] Systems have been helping keep Business, Education, Healthcare and Entertainment facilities quiet, inside and outside, since 1975.

HUSHCORE[®] Source Applied Solutions Offer Targeted Solutions for Quieting Compressor Circuits, Condenser Fan Exhaust & Air Intakes



Standard-SC System™





Unitary-SM System™

Summit System™

HUSHCORE [®] System	System Models	Stew Stew Stew Stew HUSH COVERS™ for Compressor Circuits Circuits	HUSHCORE® Condenser Fan Exhaust Stack	HUSH DUCT TM Silencer for Air Intakes	Pressure Drop in Inches w.g.	Typical dBA Noise Reduction	See Notes Below
Standard™	SC, SL, CO & SCE	\checkmark			0.0"	3 to 5	1,2,4,5
Unitary™	SM, SM-SB, IM, IM-SB		\checkmark		0.07" to 0.15"	3 to 5	1,2,4,5
Louver™	HD, HD-IM			\checkmark	0.05" to 0.12"	4 to 6	1,2,4,5
Summit™	HDG, HDE	\checkmark	\checkmark	\checkmark	0.12" to 0.27"	9 to 12	3,4,5

Notes:

- 1. Stated Noise Reductions are not cumulative when combining systems
- 2. Stated Pressure Drops are cumulative when combining systems
- 3. Stated Noise Reductions and Pressure Drop are net of all combined system elements
- 4. Typical Noise Reductions are based on receiver grade equal to the equipment grade
- 5. Octave band performance values are available on a project need basis

HUSHCORE® Source Applied Solutions:

Equipment-centric Treatments





HUSHCORE[®] Standard[™] SCE System Treatment of 500-ton AC Chiller Compressor circuits by an average of 6.8 dBA or 30% greater than the 5 dBA performance target

Data Center - Case Study





OUTCOME:

BRD Noise & Vibration Control, Inc. manufactured and installed HUSHCORE® Standard™ SCE Systems on a quantity of (24) 500-ton Air Cooled Chillers that were identified as contributing unwanted noise levels to the surrounding community. The work was commissioned by a third-party Acoustical Consultant. The HUSHCORE® removable HUSH COVER™ acoustical jackets for the compressor circuits exceeded the minimum overall performance guarantee of a 5 dBA reduction with an average reduction around the chiller measured at 6.8 dBA.

PROBLEM: The data center owner received complaints from the nearby community having to do with the air cooled chiller overall noise and prominent discrete tones.

RESULTS: Prototyping of one unit was done to confirm the HUSHCORE[®] Standard[™] SCE treatment would meet the target performance numbers. Prototype testing by the Acoustical Consultant confirmed that the HUSH COVERS[™] provided an average reduction around the perimeter of the test chiller of 6.8 dBA. Results are shown in the below table which shows the baseline levels without treatment and then with the HUSH COVERS[™].

Cooperio	Overall	1/3 Octave (dBA) in Hz											
Scenario	Overall	250	315	400	0 500 630 800 1K 1.25K 1.6K 2K					2K	2.5K	3.15K	
Untreated chiller	43.8	18.9	24.8	22.6	23.9	34.0	38.9	38.4	33.5	34.0	28.0	20.9	13.6
Chiller with Standard™ SCE	36.3	18.8	21.7	22.5	22.8	28.9	29.8	28.3	26.4	25.9	22.9	15.8	9.5
Standard™ SCE System Reduction	7.5	0.1	3.1	0.1	1.1	5.1	9.1	10.1	7.1	8.1	5.1	5.1	4.1

Table 1: Difference in noise level (dBA) without and with HUSHCORE[®] Standard[™] SCE System

Note: Values highlighted in blue demonstrate the amount of noise reduction at the most problematic frequencies for the chiller.

CHALLENGES & SOLUTIONS: Factory OEM options could not provide the minimum attenuation recommended by the Acoustical Consultant. The cost of a third-party acoustical barrier wall solution was evaluated but determined to be cost prohibitive. There were also operational concerns that treatments might have an adverse operational impact on capacity or power consumption. Based of previous laboratory and field testing, BRD submitted a proposal within budget to meet the performance need with source applied materials having zero operational impact. BRD was also able to offer a turnkey solution that included installation of all the materials.

IMPACT: The results have allowed the Data Center to continue their good standing in the community and by doing so they assured local authorities would not have reason to oppose future expansion project noise. The HUSHCORE[®] Standard[™] SCE System of HUSH COVER[™] sound blankets have become the standard for several new projects to treat an additional (48) 500 ton units. BRD will be installing future new orders at the OEM Chiller Plant to eliminate the need for the owner to install the materials post startup.

HUSHCORE® Source Applied Solutions:

Equipment-centric Treatments





HUSHCORE[®] Summit[™] System Comprehensive Source Applied Solution for a Typical Roof Mounted Air Cooled Chiller



HUSH GUARD™ Components	HUSH DUCT™ Components
 Air discharge plenums mirror the chiller deck footprint and are segregated from the intake air. 	 HUSH DUCT[™] lengths and baffle passage widths are selected per project.
Lab test procedure for HUSH GUARD [™] enclosure panels is ASTM-E90. Ratings are reported as Transmission Loss (TL).	Intake silencer banks typically match the chiller intake areas and are sized to optimize attenuation and airflow velocity. Target velocity is 300-500 FPM.
■ The Summit [™] system minimizes the chiller overall footprint increase compared to other enclosure	Exhaust silencer banks usually align with the fan deck footprint. Target velocity is 500 to 600 FPM.
designs. Typically ~2-3 ft around chiller.	Lab ASTM-E477 ratings are reported as Dynamic Insertion Loss (DIL) for HUSH DUCT [™] silencers.
	 Clearance above condenser fans to underside of exhaust HUSH DUCTS 24" to 30".

HUSHCORE[®] Premium[™] & Supreme[™] Path Applied Systems:

The science of freestanding acoustical barrier wall performance as modeled using Just Right Acoustics[®] software.

Acoustical modeling in the Just Right Acoustics[®] software program considers several different design parameters. The direct transmitted path through the barrier is much easier to attenuate than the spillover path of sound diffracting about the top edge of the barrier wall. Over attenuation of the direct path through a barrier with a very modest Sound Transmission Class (STC) rating will quickly be limited by the "spillover" path. Effective barrier walls such as the Premium™ and Supreme™ Systems provide enough mass to attenuate the direct sound and they also have a sound absorbing inside surface to assure the reflected noise from the source side does not reverberate off nearby building walls. Spillover sound tends to travel a longer distance up to the top of the barrier and again a longer distance back down to the receiver grade while the process of sound wave diffraction over the top edge contributes to the overall performance. Higher frequency sound has a short wavelength that travels more straight line while low frequency sound can bend downward. This explains why barrier insertion loss (IL) performance drops off significantly in the low frequency octave bands. Barrier walls are usually designed to be at least 3' to 4' taller than the chiller equipment when



Source path receiver diagram

positioned about 6' from the unit. The further away from the unit that the barrier is positioned, the taller it must be to maintain comparable performance. Non-acoustical yet very important design parameters include wind and seismic restraint per code, Chiller/Equipment operational derating unit, power consumption, and the grade/ roof steel interface to accommodate the barrier static and dynamic loads.

Below is a snippet of the Just Right Acoustics[®] modeling a typical Supreme[™] System barrier insertion loss for a 12' high wall 6' from a 250 ton 8' high chiller at a distance of 127' from the property line designed to achieve ≤ 55 dBA.

Property Line overall dBA calculation										
Userdefi	Userdefined Quantity - 1 12 Min. Height of Barrier Wall-Ft.									
Octave Band Center Frequency, Hz										
63	125	250	500	1000	2000	4000	8000	dBA		
67.3	68.3	64.3	64.3	63.3	58.3	52.3	49.3	67.1	Unit Lp (Sound Pressure) @ PL 127 ft. from Unit(s)	
-6.5	-7.8	-9.5	-11.7	-14.3	-17.0	-19.9	-20.0	Barrier V	Vall Insertion Loss	
60.7	60.5	54.7	52.5	49.0	41.2	32.4	29.3	54.1	Cumulative Mitigated Source Lp, dB	
<u>-26.2</u>	<u>-16.1</u>	<u>-8.6</u>	<u>-3.2</u>	<u>0.0</u>	<u>+1.2</u>	<u>+1.0</u>	<u>-1.1</u>	(A-Weighting Scale Constants)		
34.5	44.4	46.1	49.3	49.0	42.4	33.4	28.2	(Cummulative LP, dBA)		
45 51		5	0 34							
52				5	0					
54			Overall N	/litigated S	ource Lp @	₯ PL, 127 f	t, dBA			

HUSHCORE® Path Applied Solutions:

Freestanding Perimeter Acoustical Barriers & Enclosures



HUSHCORE[®] Premium[™] System Overview:

Comparison Table for Models SW and OF

	HISHCOPE® Premium™ SW System	HUSHCOPE® Premium™ OF System
Product Eamily &	HUSH OLIU T ^M Exterior Grade OAP 200 DD	HISHELEXT exterior grade EPAC 111D D
Model	1.5" thick is nominal 47" width to maximum 25' length	1" thick is nominal 54" width to maximum 12' length
Product Description	2" thick absorber only quilted fiberglass blankets with exterior grade coated polyester facing both sides	Composite acoustical curtain panels with 1" faced quilted absorber bonded to a flexible reinforced mass loaded vinyl.
Application Guideline	HUSH QUILT™ is anchored to inside surface of a cinder block, concrete, or other Solid Wall "SW" chiller enclosure wall (by other trades)	HUSH FLEX™ panels are fastened to inside surface of a chain link or other louvered Open Fence "OF" enclosure
Fastening Method	Tap Con anchors are the preferred method for block/concrete walls Fender washers needed so anchor heads do not pull through panels	Exterior grade (not nylon) wire ties through panel grommets and around fence framing
Acoustical Performance	Modeled per block enclosure height and position (as per page 10).	Modeled per fence height and position (see page 10)
	Typical reductions as high as 15 dBA	Typical reductions are 10 to 12 dBA as fence
	Block wall height calculations can be optimized in Just Right Acoustics®	stability/integrity can limit the enclosure height capability
Wall Construction	Is usually an engineered wall and footers with PE stamp	Fence is usually not PE stamped
Wall Coverage	Panel seams are butted flush but overlap	100% coverage is the goal
	100% coverage not required to achieve stated performance but 70% with continuous across top	Panels have 2" overlapping exterior grade (not nylon) Velcro™ barrier edge seals
Access Gates	Should be covered with EBAC-111R-P instead of QAB-200-PP	Should be covered with EBAC-111R-P

Premium™ System barriers can be combined with source applied treatments to enhance acoustical performance.

HUSHCORE® Path Applied Solutions:

Freestanding Perimeter Acoustical Barriers & Enclosures



HUSHCORE[®] Supreme[™] Systems address the four primary sound paths from Air Cooled chillers using an open top free standing barrier enclosure







	Supreme™ System Design Considerations
Acoustical	On page 9 we have described in detail how the acoustical barriers geometric relationship to the enclosed equipment, the noise sensitive receiver location, and the relative elevation of these elements determines overall performance. Barriers tall enough to take away line of sight to the condenser fans can often reduce chiller noise by 15 to 20 dBA. For reductions greater than 20 dBA please see the Ultimate™ System.
Aerodynamic	To maximize acoustical performance, acoustical barriers like the Supreme [™] System must exceed in height the elevation of the condenser fans. What many wall manufacturers fail to understand or consider is the operational impact for restricting condenser cooling airflow. A 4-sided barrier exceeding the height of the chiller is a "pit condition". As an example, an 11' barrier spaced with a 6' clearance of an 8' high chiller will cause a 1.5% capacity reduction. A 12' height would be a 2.75% hit. The % power increase is 3% and 4.2% respectively for a 11' and 12' heights for this example.
Structural	The barrier wall structural framework must be able to comply with IBC or other building codes for wind and seismic. For most areas of the US, wind is the most stringent of the two, but both must be considered. Supreme [™] System barriers are designed to meet structural codes and are routinely "stamped" by a PE from the state where the building is located. The barrier structural design however must consider static and dynamic loads (moments) from the wind sail effect that are transferred to the roof or grade support foundation. Many times, it is less costly overall to design a Center of Momentum frame (COM Frame) also called a zero-momentum frame (or Zero Moment Frame) with extra diagonal crisscross and knee bracing because of the roof steel savings simplified by virtual elimination of the movement forces at tie-in.
Environmental Compatibility	Structural steel framing should always be hot dipped galvanized, powder coat painted, or both, especially in ocean coastal communities. The standard galvanized steel panel construction is acceptable for inland project locations but will not hold up well in coastal areas. Stainless steel panels are costly, and aluminum is a soft metal that is difficult to spot weld. HUSHCORE® offers a variety of materials for salt and other corrosive environments.
Integration & Coordination	Integration of the Supreme [™] System column supports with a roof steel host beam or a grade foundation or series of footers in the design phase is essential to avoid contractor cost adders and lost time. HUSHCORE [®] project managers are well trained to coordinate electrical piping, control panels, and more during construction but foundation integration at design phase is a must.

Supreme[™] HG System Wall Sections for Internal vs. External Panel Mounting Designs



Cantilevered Steel Designs can tie into chiller supports thus eliminating additional roof stub ups and penetration



HUSHCORE® Unit Enclosures

Remedial vs. New Construction - which is better?

While new construction presents the advantage of easier coordination with the building steel, not all jobs have this luxury. For remedial work and depending on the performance needed, a Summit[™] System may be a potential solution that can be integrated to the equipment to avoid building penetrations.



Concerns about creating a chiller pit?

Air-Flow and pressure drop recommendations with regard to unit spacing can be of concern with full enclosures. However, this can be mitigated and addressed through integration of our Hush Duct[™] Silencer/Louvers for your chiller intakes (see image on left). This will allow for acoustic performance while balancing unit airflow to minimize unit performance losses.

Concerns about fan-discharge air-recirculation or unit short-circuiting as a result?

Additional system features can be utilized to remediate air-recirculation discharging from the condensing fans while also providing additional attenuation. Our HUSHCORE[®] Unitary[™] system designs can be mounted to the unit directly or independently supported to aid fan discharge air (see images below).



Concerns about unit clearances and OEM spacing recommendations?

In general equipment manufacturers recommend barriers not exceed the height of the equipment for a given recommended clearance. When this is not feasible, manufacturers provide performance data to help understand the impact of barrier height and unit clearance on unit power draw and efficiency. BRD modeling and designs incorporate this data to understand and minimize these impacts while maximizing the acoustic performance.

HUSHCORE[®] Ultimate[™] System "Breathable" All Custom Enclosures Provide "Omnidirectional" Noise Reductions of 20 to 28 dBA



HUSH GUARD™ Components	HUSH DUCT [™] Components
 PE Stamped enclosure shall meet project site wind	 HUSH DUCT[™] lengths and baffle passage widths are
and snow loads per building code of jurisdiction.	selected per project.
 Air discharge plenums usually mirror the chiller deck	Intake silencer banks are larger in cross sectional area
footprint with internal seals to segregate intake air and	to achieve the lowest velocity. Target velocity across
discharge/exhaust air.	all wall and roof mounted intakes is 300 to 400 FPM.
■ Lab test procedure for HUSH GUARD [™] enclosure	Exhaust silencer banks usually align with the fan deck
panels is ASTM-E90. Ratings are reported as	footprint. Target velocity is 500 to 600 FPM.
Transmission Loss (TL).	■ Lab ASTM-E477 ratings are reported as Dynamic
Clearances are usually 6' around and 8' between	Insertion Loss (DIL) for HUSH DUCT [™] silencers.
chillers.	 Clearance above condenser fans to underside of exhaust HUSH DUCTS 24" to 30".

Ultimate™ System Design Parameters

Understanding Ultimate™ System Acoustical Performance

- Lab test data for panels and silencers is not an accurate predictor of the integrated enclosure performance
- Panel (TL) and Silencer (DIL) lab test data should be comparable so that neither is a performance weak link
- Enclosure performance may be capped or limited by the overall pressure loss guidelines for the equipment manufacturer. That pressure loss tolerance may vary among manufacturers.
- An ambient sound survey is recommended at noise sensitive receptor locations in the community. Ambient levels should be ideally 10 dBA below the target level and a minimum of 5 dBA below to limit contribution.
- The Noise breakout path needs to be considered when selecting the silencer casing gauge. High TL silencer casing may be required.
- As much as 30% of the overall Ultimate[™] System acoustical performance has to do with flashing, sealing, and plugging. Without such attention to detail by the installer design performance could be compromised by 5 to 7 dBA.
- A properly sealed enclosure will pass the daylight test, i.e., no direct daylight should be visible. Passing the daylight test will mean gaps around the steel beam webs between silencer models, around access doors and pipe penetrations, etc. must be sealed.
- System performance is always predicated on accuracy of the chiller manufacturers sound power baseline frequency profile per AHRI-370.

Understanding Ultimate[™] System Aerodynamic Performance Lab test data for the air intake and condenser fan ■ Ultimate[™] System aerodynamic performance should exhaust silencers is published as per the ASTM-E477 be calculated with sharp inlet and abrupt expansion test set up using straight duct in and out of the tested plenum or as applicable to the final design. Pressure silencer modules. This is the "catalog" pressure drop drop with system effects can be 2 or more times and does not consider the system effects of how the the catalogue value routinely shown per standard silencers are installed in an Ultimate[™] System applica-ASTM-E477 tion where banks of intake and exhaust silencers are Roof intake where applicable should be 24" minimum installed with perpendicular directional airflow. shorter than the condenser fan exhausts in order to prevent short cycling. Other Ultimate[™] System Design Considerations Galvanized steel construction for steel framing panels • The structural engineer of record for the project is and silencers except in coastal areas where powder responsible for specifying adequate footers pad turn coast paint or other finish is better in saltwater downs modifications to roof steel, etc. to handle static environments. and dynamic loads imposed by the enclosure. Clearances above condenser fans and in front of coils, Other optional features to consider include sloped compressors, etc. should be determined by the chiller standing seam roof cladding for water shedding, manufacturer or design MEP as part of pre-bid design hinged and latched access hatches and door locks. discovery provided to the Ultimate[™] System design. **Ultimate™ System Specification Tips** Schedule maximum allowable octave band sourced ■ Require Ultimate[™] System bidders to provide power for the equipment with property line sound documentation of minimum (3) completed projects of pressure (dBA) performance criteria because specifycomparable scope. ing panel and silencer lab data will shift performance The enclosure design specification should list essential accountability to the MEP engineer. components required material, finalized pressure drop Make sure all listed chiller bidders can live with the including system effects an engineering services to be provided as part of the enclosure such as load calcs, enclosure pressure loss. PE stamps, ambient testing, etc. ■ Contact the Ultimate[™] System designer before a specification is cut and pasted to a new project.

HUSHCORE® Path Applied Solutions Offer Greater Acoustical Performance Using Perimeter Barrier and Enclosure Designs

Premium™ SW

Supreme™ HG

Ultimate

HUSHCORE [®] System	System Models	Description	Typical Clearance to Unit Cabinet	Typical dBA Noise Reduction	See Notes Below
Premium™	OF, SW	OF is HUSH FLEX™ panels mounted to chain link or another open fence. SW is HUSH QUILT™ mounted on block or another solid wall.	4' to 8'	8 to 10	1 thru 5
Supreme™	HG	HG is HUSH GUARD [™] panels mounted to structural steel framework.	4' to 8'	10 to 15	1,2,3, & 5
Ultimate™	Custom	Full enclosure with 4 walls, roof, and integrated silenced intake and exhaust systems to manage airflow.	6' to 10'	15 to 30	1,2,3, & 5

Notes:

- 1. Impact on unit operating efficiency and power consumption are calculated per project
- 2. Stated Noise Reductions are dependent on enclosure height and elevation of receiver location
- 3. Octave band performance values are available on a project need basis
- 4. Only use for grade mounted units
- 5. Wind load ratings are project dependent

HUSHCORE[®] Noise Reduction Systems are also available for Water-cooled Indoor Chillers

Standard[™] SC System featuring HUSH COVER[™] removable acoustic covers

Premium[™] HF System featuring HUSH FLEX[™] acoustical curtain enclosures

Ultimate[™] HG System featuring HUSH GUARD[™] metal panel enclosures

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01.2023 | .5M