A White Paper from the Experts
in Business-Critical Continuity

Acoustics Management and Noise Mitigation in the OSP Environment

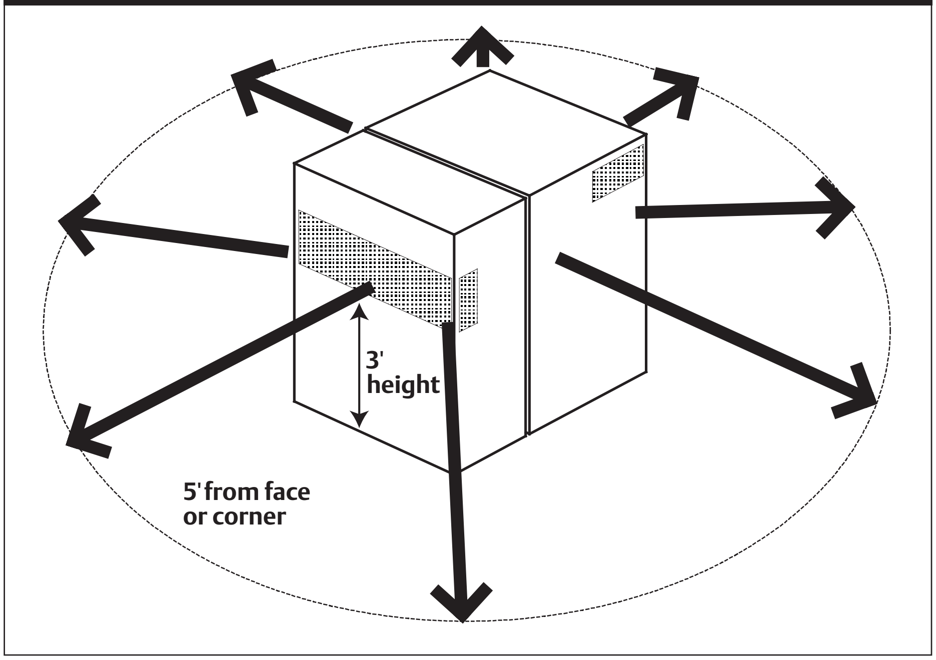
Emerson Network Power

Welcome to the neighborhood

As carriers are asking subscribers to sign on for additional and faster video, data, TV and voice services, they are deploying new, noise-generating, active electronics cabinets deeper into residential neighborhoods–annoying the very subscribers they woo. It has fallen upon the site planner to meet the challenges of coping with additional noise and satisfying the demands of local neighborhoods for unobtrusive installations.

Though the primary responsibility for noise mitigation lies with the site planner, carriers have begun to acknowledge the value of sharing that responsibility with cabinet suppliers who are skilled in acoustical management as well as thermal management.

Figure 1: GR-487 Issue 2 Measurement Points



Today's noise standards are anything but standard

The need to regulate noise emission has long been recognized by Telcordia, OSHA and nearly every municipality in the land. Each has set forth standards, and governments have written regulations and passed laws directing their enforcement. Questions arise about which of these standards are applicable to the OSP environment and how they apply.

Telcordia's GR-487 Issue 2 – R3-196 is the primary standard that governs noise emissions by today's OSP cabinets. It specifies that sound pressure* measurement be taken at eight points around the cabinet, at a distance of 5' from the cabinet and 3' off the ground. All readings shall be less than 65 dBA. If a permanent backup generator is included in the installation, the allowable level is increased to less than 75 dBA (Figure 1).

* Sound *pressure* is the measure of sound emission taken at a single point. Sound power (L_{wad}) is the integrated sound pressure (dBA) over the total surface area of the emission source. A small amount of sound power, if concentrated on a specific target, can be very disturbing. However, if this power is distributed in all directions from the source, the human ear will not even notice it.

Though Telcordia defines the standard at a 3-ft. height, many municipalities and other organizations such as ANSI (American National Standards Institute) specify performance at five feet above the ground, acknowledging that the ears of most standing humans are closer to five feet from the ground and reduce the effect of 'ground bounce'. When 'ground bounce' and sound dispersion patterns (excluding near-field effects) are taken into consideration, 3' measurements will often be louder than those taken a 5'.

65 dBA is clearly noticeable in a quiet residential area at five feet from the source, but its impact is reduced as we move farther away. Standing 12 feet away, the sound pressure is reduce to 60 dBA (still noticeable); at 16 feet, to 55 dBA (less noticeable); at 28 feet, to 50 dBA (quiet); and at 50 feet, to 45 dBA (you have to listen for it).

GR-63 Issue 2 – R4-74 is another standard that has been published by Telcordia. However, it is *not* applicable to the OSP. It deals with equipment in enclosed environments and specifies that dBA measurements be taken at four points 23.6" away and 59.1" above the floor. Under this standard, frame sound pressure emissions must be less than 60 dBA, maintenance and control equipment less than 65 dBA, power room equipment less than 83 dBA, and all other equipment less than 75 dBA. Its recent successor is GR-63 Issue 3 – R4-96.

GR-63 Issue 3 – R4-96 has migrated from sound *pressure* to sound *power* levels at 27C. While it makes sense to measure and report sound power in an enclosed environment where you are trying to model the impact of bringing an additional device into a room, this standard is *not* applicable to OSP cabinets in the open outside world. In any event, the human ear detects sound pressure, not power.

Unfortunately, most telecom equipment is designed to these standards, which is not supportive of moving towards a quieter OSP solution.

OSHA 1910.95 is another widely recognized noise emission standard that is *not* applicable to the OSP in the neighborhood. It applies to employees exposed to a particular sound level for a specified period of time; and its minimum level (90 dBA) is already much higher than what Telcordia and the municipalities are requiring (Table 1).

Table 1: OSHA 1910.95 Acceptable Workplace Noise Exposure

PERMISSIBLE NOISE EXPOSURES (1)	
Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4 or less	115

Municipal Standards are the requirements site planners must accommodate. While Telcordia, ANSI, OSHA and others have set forth guidelines, the municipalities are really ‘setting the bar.’ Their expectations exceed industry standards and every municipality is different.

Not only do they differ in values, but often measurement points (boundaries) are ambiguous. The “boundary” is usually the easement that surrounds the location. Others may define the boundary as a neighboring house or other landmark.

In some cases, it may be necessary to send an acoustics engineer to the site to assess the requirements.

Take Glendale, California’s 8.36.040 Presumed Noise Standard for example (Table 2).

Table 2: Glendale CA Presumed Noise Standard

ZONE	DECIBELS	TIME
Cemetery and residential (single family and duplex)	45 dBA	Nighttime
Cemetery and residential (single family and duplex)	55 dBA	Daytime
Residential (multifamily, hotels, motels and transient lodgings)	60 dBA	Anytime
Central business district and commercial	65 dBA	Anytime
Industrial	70 dBA	Anytime

As the tolerance for noise by municipalities diminishes, the cabinet site or the cabinet must get quieter, or the distance from the source to the boundary must expand (requiring a greater easement, which is often not an option) (Table 3).

If you have a 65 dBA noise source and the municipal standard is 45 dBA at the boundary, the boundary of the site must be 50 feet away (Table 3). How many times can you draw a 50' circle around the cabinet without encompassing somebody’s bedroom window? Better to quiet the cabinet.

Table 3: Sound Pressure Diminishment Table

Noise at 5' (dBA)	Distance (ft) to achive the following noise level (dBA)						
	65	60	55	50	45	40	35
65	5	9	16	29	50	89	159
60		5	9	16	29	50	89
55			5	9	16	29	50
50				5	9	29	29
45					5	29	16
40						29	9
35							5

What is the right measurement?

The neighborhood and the municipalities are interested in sound pressure, and the defacto standard for environmental noise measurements are in dBA. The regulations are traditionally written to dBA and the dBA scale is associated with normal conditions and hearing. While dBA may have some shortcomings, it is an appropriate scale for the OSP cabinet noise measurements.

What about the other dB(x) scales? dB(x) scales are intended to correlate the way the human ear reacts to sounds at varying frequencies at various energy levels. The dBB, dBC or dBD scales are associated with loud noise sources (Figure 2).

One of the dBA shortcomings is its failure to account for general sound (non-tonal) in the higher frequencies. The A curve was created from measurements made to pure tonal response. Examination of the dBA scale shows a nice, “soft,” peak around 6 Hz, which has been disputed.

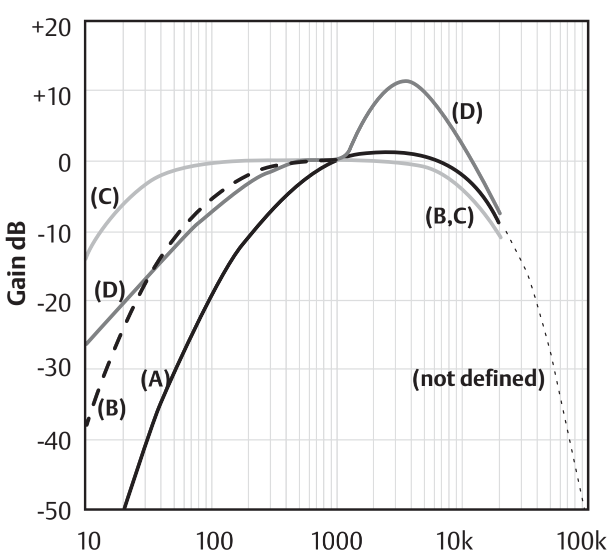
The recording industry often uses the ITU-R 468 curve because it acknowledges that the ear’s performance at higher frequencies is better than what was originally conceived in the dBA scale. The ISO community has published models (ISO 226-2003) that are closer to the dBA, but not as flat above 1000 Hz (Figure 3).

All of this discussion is further compromised by the fact that frequency response is different for different individuals; and as we get older, just as our eyesight ‘changes,’ our ability to respond to sound pressure and upper frequencies deadens.

Fortunately, for a well-designed and built OSP cabinet, the noise emissions we are dealing with are often in the 200 to 1000 Hz range and the debate about the higher frequencies is not really an issue. Bottom line: Use the dBA curve.

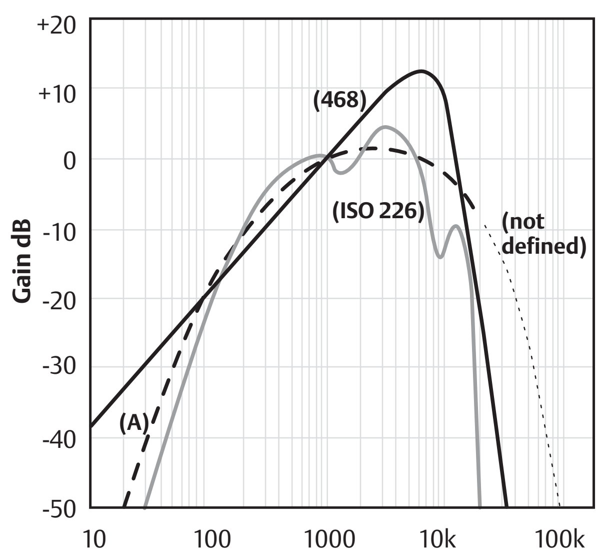
But what value? Since there are no national standards out there, it is hard to say “this is the value” we should design for. Therefore, the cabinet supplier and the site planner alike should be prepared to adapt as different sites, different equipment and different municipalities are encountered. It is important that the cabinet supplier be able to provide site planners with the acoustical information needed to work with their local communities.

Figure 2: dB(x) Curves



A–weighting (solid black), B (dashed black) C (light gray), D-weighting (dark gray)

Figure 3: Comparative Noise Curves ITU-R 468, ISO 226 and dBA



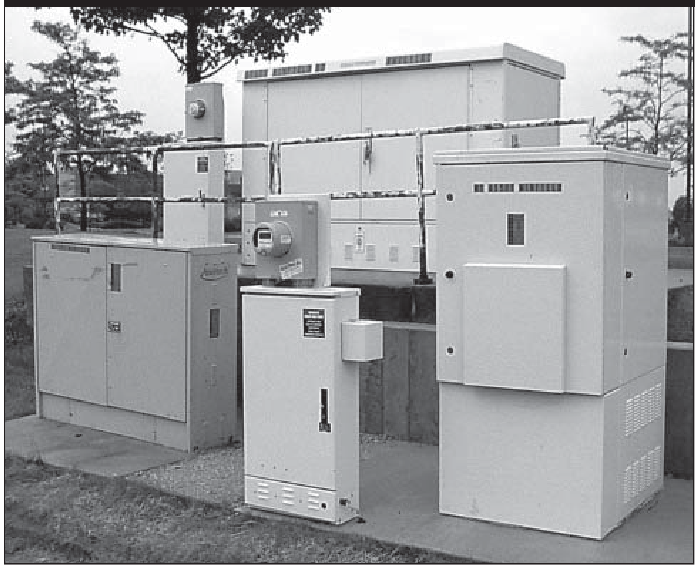
ITU-R 468 (solid black), A-weighting (dashed black), and inverse ISO 226 (2003) (solid gray)

Traditional mitigation strategies: Less than ideal

Traditionally, cabinet suppliers have made cabinets to meet GR-487 Issue 2, 65 dBA. When, as has been noted, the municipality demands a quieter installation, the carrier and local installation team have resorted to additive strategies that ultimately compromise site cost, performance and potentially safety. The problem is greatly complicated where there are multiple cabinets on one site (Figure 4).

Landscaping, including the addition of trees, shrubs, walls and fences has been a common–if not popular–strategy. This effectively increases the square footage requirements, the deployment costs and the cost of maintenance. And, in fact, grass, trees and walls do not dampen the noise, but rather shift, diffuse and redirect it (Figure 5).

Figure 4: Multiple cabinets complicate noise mitigation.



Facing the street is another approach often used to satisfy local requirements. When the cabinet has all of its cooling and heating concentrated on one side (i.e.: the heat exchanger is in the door, as illustrated in Figure 6), you point this "loud side" into the street. While this directs the sound away from nearby houses, it requires that service technicians stand in or very near to the street when accessing the cabinet, placing them in a potentially unsafe situation. Also, if you have a cabinet that is emitting 65 dBA at 5', the street or boulevard it now faces will have to be 50' wide to get the sound pressure down to 45 dBA.

Acoustic hoods and other "warts" may be added onto existing cabinets when the carrier is pressured by the municipality to "do better, sound-wise." (Figure 7) This after-the-fact strategy is another time and cost adder and can require acoustic consultants to visit the installation and experiment with hood designs to see what will be effective. Another downside: By making these changes after the fact, the carrier often compromises the integrity of the cabinet and its thermal performance, and potentially violates GR-487 compliances with salt-fog resistance, chemical resistance, brush fire specifications, etc.

The proactive approach: A quieter cabinet

Rather than casting about for costly post-manufacturing fixes to overcome noisy cabinet designs, why not invest in a quieter cabinet at the start!

A total approach is the secret to a quieter cabinet. Instead of considering the cooling system (the source of most noise) as a standalone entity, it must be viewed as part of the total entity encompassing the thermal, vibration and acoustical performance during the design phase (Figure 8).

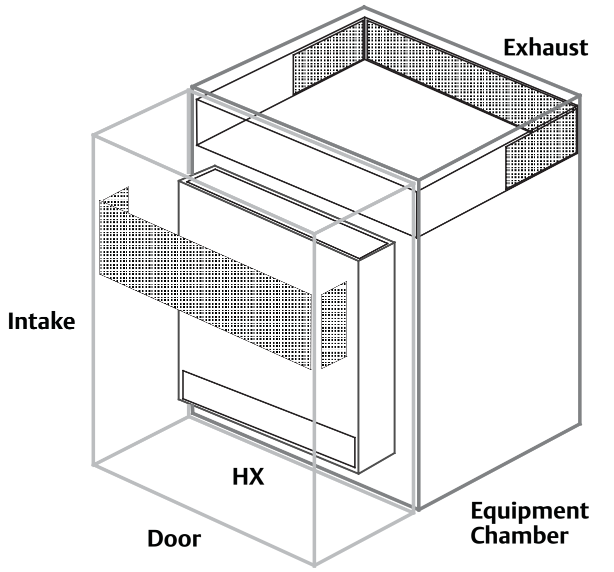
Also, since these inter-dependent elements are critical and conflicting, it is necessary to validate the models under real conditions during a "test and tune" phase (See "Test and Tune" below). In the "test and tune" phase, the solution is validated and revised, if necessary. During this phase, it is verified that no 'unknowns' have crept into the product.

Figure 5: Landscaping and fences redirect sound but do not dampen it.

Figure 6: Orienting door-mounted heat exchanger toward street directs sound away from neighbors.

Figure 7: Acoustic hoods redirect sound, but may compromise GR-487 compliance.

Figure 8: The System



The first step is the application of "sound" engineering practices to the cabinet which include:

- Isolation of any mechanical vibration within the cabinet, i.e. the use of rubber gaskets, seals, pads and grommets, to assure that any externally perceived noise is airborne, not structural
- Sealing of the equipment chamber to provide another level of isolation and enable the use of a closed-loop heat exchanger. (The following discussion is focused on OSP cabinets using closed loop heat exchangers.)

Distribution of sound energy will reduce sound pressure. While an inexpensive way to cool a cabinet is through the use of a door-mounted heat exchanger, this arrangement delivers the air into and out of the door. As a result, all the sound energy is directed to the area immediately in front of the door.

If the same sound energy is dispersed around the cabinet, the sound pressure at any given point will be less and any sensing device, including our ear, will give a lower reading (Figure 9).

A further benefit of designing the cabinet so that sound energy is directed to all sides, is that it eliminates the need for the installation planner to consider the noise profile of the unit when positioning the cabinet (and it can save the service technician from having to stand in or near the street).

An indirect intake/exhaust or sinuous path for the air, coupled with the use of acoustic absorption material, produces a "muffler" effect to further reduce noise emission. (However, this also increases system impedance and requires slightly greater fan power to drive the air.) The cabinet designer must be careful to provide sufficient space in the intake and exhaust to properly accommodate absorption material (Figure 10).

Intelligent fan controllers with strategically placed thermoresistors can monitor internal thermal conditions (heat generated by electronics and sun) and external thermal conditions (sun, ambient air temperatures) to independently set the internal and external fan speeds and provide "just enough" cooling at the lowest possible noise levels (saving energy in the process).

With an intelligent controller, fans in each loop (internal and external), can be synchronized to minimize the potential for "beating".

Figure 9: Distribute the Energy

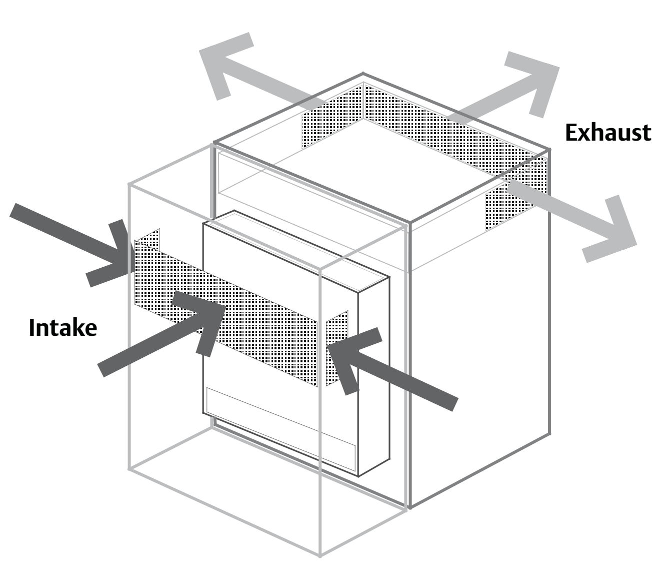
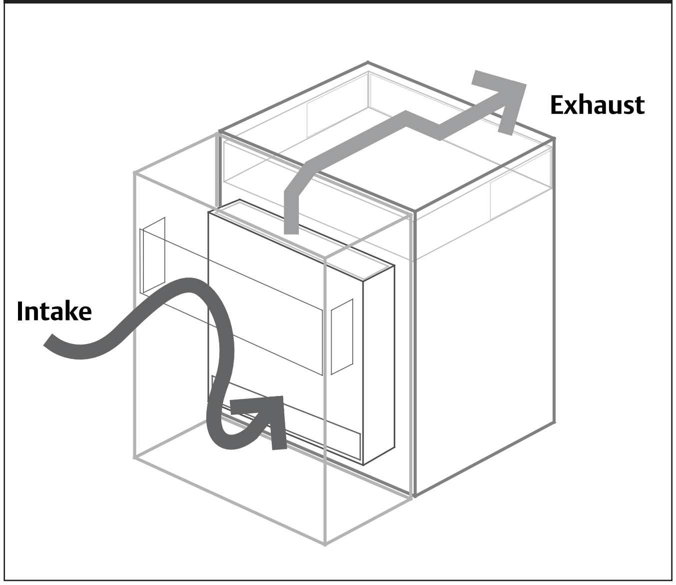


Figure 10: Indirect Intake and Exhaust



Equally important is that an intelligent fan controller provides the ability to manually set and change fan speeds as the system is tested and tuned. This allows the manufacturer to accurately validate how the system performs and simulate the conditions to collect and report on the data needed by site planners.

While intelligent controllers and other quiet cabinet design features naturally add cost to the cabinet, the ability to adapt that cabinet–in a world where there are no universal design standards–is invaluable.

Matching fans to the correct acoustic materials is another secret to a quieter cabinet. However, not all acoustic material used within sinuous pathways to dampen sound in the air channels performs equally (or is GR-487 compliant). The cabinet manufacturer cannot pick a material at random. It is necessary to understand how the fan(s) behave–emitting power and frequency–so that the proper material (matched frequencies), thickness and application can be selected.

Also, one needs to consider how a fan's frequency will shift. Slowing down a fan drops the air pressure; therefore, it is quieter. However, as the fan slows down, the frequency it emits drops, and the acoustic absorption performance of most material diminishes as frequency drops. To further complicate matters, changes in material behavior as frequencies shift are not linear.

While use of absorption material is clearly beneficial, correct application is not an obvious process, but something that must be well understood by the cabinet designer as a sound-critical solution is developed for the neighborhood.

The following chart presents an overview of the acoustic absorption of several acoustic dampening materials from different suppliers (A, B, C) and the noise frequency emissions of various OSP cabinet system elements (fans). The chart also factors in expected frequency ranges under different ambient temperature conditions (Table 4).

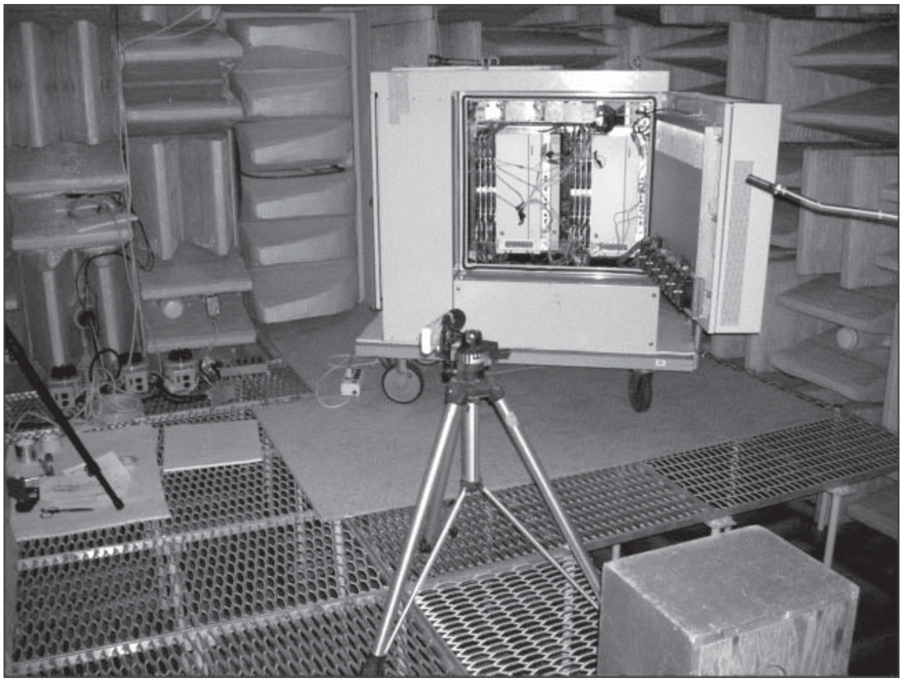
By comparing the performance of the different materials, different thicknesses and different absorption capabilities, it is possible to make a proper material selection that will result in an effective OSP cabinet solution.

Table 4: Acoustic Material Comparative Review

Comparative Review of Acoustic Material
Absorpation Behaviour by Frequency

Supplier	A		B			C			Equipment 1, 550-800 HZ	Equipment 2, 400-650 Hz	Rectifier Fans, 500-850 Hz	HX Internal Loop, 240-600 Hz	HX External Loop, 240-600 Hz
Identifier	A1	A2	B			C							
Thickness	0.25	0.5	0.5	1.0	2.0	0.5	1.0	2.0					
f (Hz)													
125	0.028	0.031	**0.1**	**0.30**	**0.48**	0.05	0.04	0.18					
200	0.035	0.051		**0.43**	**0.69**	0.05	0.15	0.40					
250	0.038	0.041	**0.3**	**0.51**	**0.83**	0.07	0.21	0.56				240	240
315	0.049	0.056		**0.58**	**0.92**	0.08	0.28	0.70					
400	0.049	0.057		**0.67**	**1.03**	0.12	0.45	0.88		400			
500	0.064	0.076	**0.5**	**0.77**	**1.16**	0.16	0.64	1.00	550		495		
630	0.072	0.091		0.81	**1.16**	0.21	**0.86**	1.06		650		600	600
800	0.081	0.108		0.87	**1.16**	0.29	**1.02**	1.08	800		843		
1000	0.192	0.274	**0.8**	0.94	**1.16**	0.41	**1.04**	1.04					

	Equipment 1	Equipment 2	Rectifier Fans	HX Internal Loop	HX External Loop
Expected frequency at 26C nightime conditions	<800	<650	<843	330	390
Expected frequency at 36C daytime conditions	800	650	<843	450	450
Expected frequency at 46C daytime conditions	800	650	843	550	550



Acoustic quiet room

Test and tune

While knowledgeable design and computer simulation can speed up OSP cabinet modeling, an effective solution will not result if thermals are treated independently of acoustic performance. After the models are complete and prototypes constructed, they must be tested and tuned to quantify the relationship between thermals and noise to assure that they behave as expected.

This is also the time to collect local sound emission requirements and other the information needed by site planners.

This requires an acoustic chamber and an intelligent fan controller to isolate, quantify and coordinate noise sources; and a thermal chamber to verify thermal performance at different fan speeds. At the same time, the test team must be able to search for any unexpected noise (such as a heat exchanger that develops a resonant frequency, fans not mechanically isolated or a previously undetected leak).

A willingness to invest in thermal chambers that support GR-487, an acoustic quiet room (<30 dBA), independent fan control (hardware/software) and a skilled test team is critical to the development of OSP cabinet solutions that satisfy environmental requirements and meet the total cost objectives of the carrier.

Supporting the site planner

Traditionally, the site planner has approached an OSP cabinet deployment with a minimum of information about cabinet performance. By implication, the cabinet complies with GR-487 and thus is quieter than 65 dBA at any of the 8 points around the cabinet. But the burden placed on the planner differs by municipal boundaries, and, within the boundary, may differ by time of day and location. To be effective, a planner needs to understand how the system performs, day, night, close in, far out, around the cabinet, at 3' and at 5'.

And it is up to the cabinet supplier to know how the equipment performs and to share this information with the planner (Table 5).

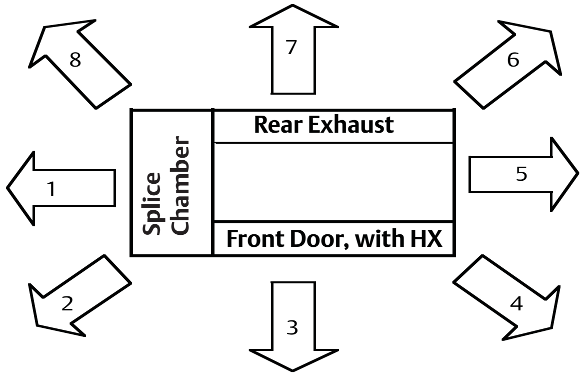
More than a container, more than a supplier

In light of contemporary technology and the environmental concerns that surround OSP deployments, today's active OSP cabinet has become a system instead of a steel box. And the manufacturer of the cabinet has become a solution provider and an active partner with the site planner.

To meet the demands put upon it by the community, the cabinet must distribute sound power evenly, provide for indirect air paths to muffle sound, contain absorption material that works in conjunction with the fans, and utilize an environmental controller that manages both sound emissions and thermal performance.

To meet the demands put upon it by the carrier, the manufacturer must be technically qualified and equipped to test and tune the cabinet to perform as required and be willing to technically support the site planner in any way possible.

Table 5: Planner's Noise Table



Acoustic noise profile (dBA)

Condition	Distance (ft)	Orientation							
		1 (Splice)	2	3 (Front)	4	5 (Side)	6	7 (Rear)	8
		Acoustic Measurement							
Nighttime	5	40	42	45	45	45	45	45	43
	10	34	36	39	39	39	39	39	37
	20	28	30	33	33	33	33	33	31
	30	25	27	30	30	30	30	30	28
	40	22	24	27	27	27	27	27	25
	50	20	22	25	25	25	25	25	23
Daytime	5	47	47	54	53	52	52	54	50
	10	41	41	48	47	46	46	48	44
	20	35	35	42	41	40	40	42	38
	30	32	32	39	38	37	37	39	35
	40	29	29	36	35	34	34	36	32
	50	27	27	34	33	32	32	34	30

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