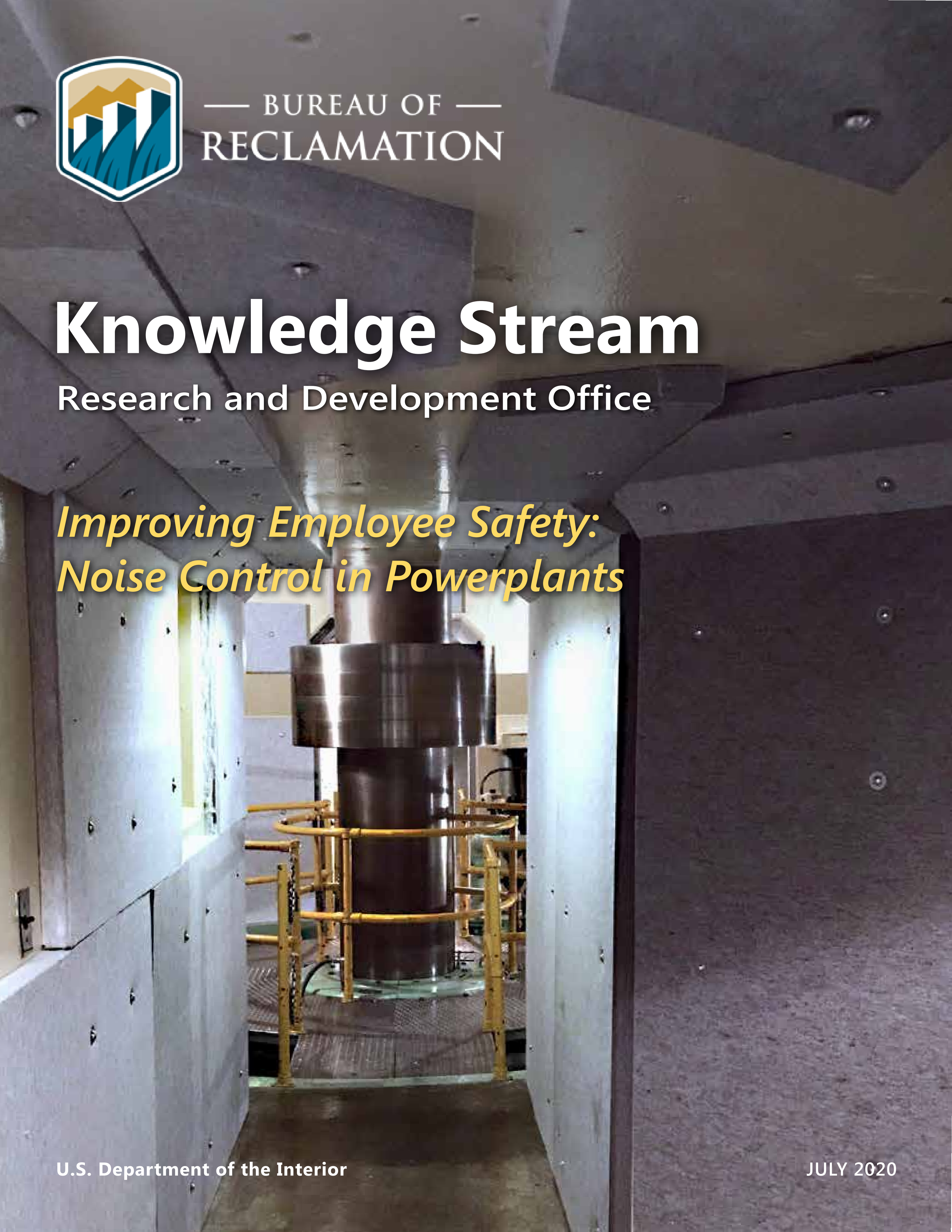

BUREAU OF RECLAMATION

Knowledge Stream

Research and Development Office

Improving Employee Safety: Noise Control in Powerplants

U.S. Department of the Interior

JULY 2020

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Message from R&D

Welcome! In this issue of the Knowledge Stream we are sharing about how we're addressing noise-related safety challenges in Reclamation's powerplants and other facilities. Reducing noise helps to protect employees from the impacts of noise-induced hearing loss, create a better working environment, and promote employee safety and health.

In this issue, we're excited to highlight collaborations involving R&D Office's Science and Technology Program, Reclamation offices and facilities, and outside organizations. These efforts involved demonstrations and facilitated adoption – an important act of transitioning maturing technologies into broader use. In this case, the adopted technologies were developed for noise assessment and control in submarines and adapted for situations at Reclamation powerplants. Highlights include:

- conducting noise assessments at Columbia-Pacific Northwest region powerplants of different sizes and configurations, subsequently using results to custom design and demonstrate different noise control strategies.
- conducting additional assessments at Upper Colorado Basin's Flaming Gorge powerplant and Wyoming Area powerplants having ages ranging from 26 to 93 years, where the latter provided a valuable collection of testing opportunities given the wide range of older to newer hydropower technologies at those facilities.
- Applying lessons learned at smaller facilities to conduct large-plant demonstrations at Grand Coulee, Hoover, Glen Canyon, and Shasta dams, each featuring complex noise emission situations.

As always, we appreciate your time and consideration in reading about innovation funded by Reclamation's R&D programs. Please enjoy this issue of the Knowledge Stream and offer us any feedback for improving our strategies to transfer solutions to users.

Levi Brekke
Program Manager

About the *Knowledge Stream*

The *Knowledge Stream*, published by the Bureau of Reclamation's Research and Development Office, is a quarterly magazine bringing mission-critical news about the agency's innovations in the following:

- Science and Technology Program
- Desalination and Water Research Purification Program
- Prize Competitions
- Technology Transfer
- Open Water Data...and more.

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Covers: FRONT: Acoustic absorption material in turbine pit and draft tube corridor at Flaming Gorge Dam. BACK: Flaming Gorge Dam was built by Reclamation as part of the Colorado River Storage project. The dam is a concrete thin arch structure with a maximum height of 502 feet and a crest length of 1,285 feet. The dam is located 43 miles north of Vernal, Utah, with installed capacity of over 150,000 kilowatts.

Community Needs

Why do we need Noise Controls?

Noise-induced hearing loss impacts not just the employee's hearing, but their mood, concentration, demeanor, reactions, and families. It is Reclamation's number one workers' compensation cost, where such costs can exceed millions per year. Reducing noise in powerplants lowers the frequency of these situations, reduces costs, and creates opportunity to apply such funds to other mission needs. More importantly, reducing powerplant noise protects Reclamation's employees from the impacts of hearing loss, creates a better working environment, and demonstrates commitment to employee safety and health.

Acoustic Array test set up at Grand Coulee G9

In the late 1990s and early 2000s, many of Reclamation's facilities attempted to reduce the noise in their plants without significant results. This was unsuccessful due to lack of understanding noise behavior in a concrete powerplant, how to detect sources of noise, and how to mitigate noise once the sources are understood. Since then, advancements have occurred in understanding how noise behaves within workspaces and in the technologies used to measure and mitigate noise sources. These advancements have enabled acoustic engineers to discern and rank the top three "primary" paths through which noise travels from the sources to the worker. The primary paths include airborne, structureborne (vibration) and a path that's a combination of both. This allows acoustic engineers to develop and install controls to mitigate the noise.

In 2011, the Reclamation's Security, Safety, and Law Enforcement Safety and Health Office along with the Research and Development (R&D) Office partnered with the Office of Naval Research (ONR) to determine if the techniques ONR uses to identify, measure, and control noise in their submarines and aircraft carriers would work in Reclamation's powerplants. Under this research partnership, and leveraging funding from the R&D Office – Science and Technology Program, the team conducted initial noise assessments at facilities in Reclamation's Eastern Colorado Area Office (Estes, Flat Iron, Mary's Lake), Reclamation's Columbia-Cascades Area Office (Roza, Chandler, Green Springs), and at the U.S. Army Corps of Engineers facilities in the Columbia River Basin (Bonneville, The Dalles, and Chief Joseph Hydropower

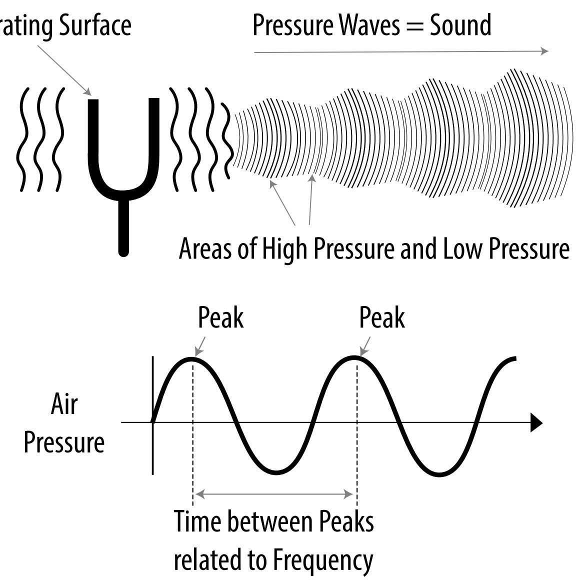
Damping Treatment Application - Catapult Underside on USS Dwight D. Eisenhower

Facilities). The Green Springs, Roza, and Chandler Powerplants were chosen as the first sites to demonstrate advanced measurement technology and implement noise controls, which produced positive results.

These first demonstration facilities proved the ability to reduce noise levels by up to 16 decibels, or more than 85%. The R&D Office received enthusiastic feedback from plant personnel and management. As a result, the R&D Office committed to partner with the field offices to support at least one demonstration in each region. Additionally, the R&D Office partnered with the Power Resources Office (PRO) to extend these noise survey and control strategies to Reclamation's largest powerplants. The challenge with a large facility is the potential number of noise sources, the size of the space, and the large concrete surfaces. One of the large-plant demonstrations at Shasta Dam is nearly complete, and controls installation at Hoover powerplant is ongoing. The success of the initial installations generated much interest. To date, noise surveys have been performed in 35 plants and controls have been installed in 20 plants.

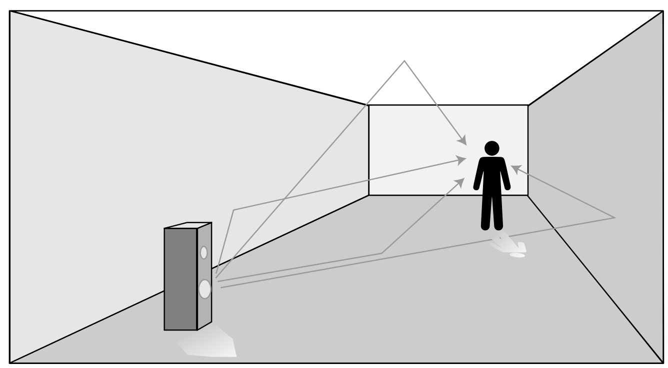
Key Perspectives

The Basics of Sound



Vibratory surface producing pressure waves in air

There are several basic concepts to understanding sound. These are amplitude, frequency, reverberation, how human's brains interpret these components, and tone. To explain these concepts let's consider a tuning fork. If a tuning fork is banged on a desk, the vibration of the fork causes sound waves whose amplitude varies with time with this amplitude being associated with the loudness or noise level. The frequency is related to the time it takes the tuning fork to go through one full cycle of vibration, which shows up as the time between sound wave peaks. The unit of sound is most commonly expressed in decibels (dB). Almost always when discussing sound related to hearing, we will refer to the A-weighted decibel value (dBA) because this more accurately represents how the ear interprets the sound level and is also more accurate when describing potential hearing damage.


Reflections from hard surfaces increases actual sound pressure levels at receiver

The human brain interprets the sound heard by the ear. These sounds are relative to each other. For example, the noise level of a jet aircraft at 150 ft away is approximately 140 dBA, a loud rock concert generates approximately 120 dBA, and a lawn mower at five feet away will measure approximately 90 dBA.

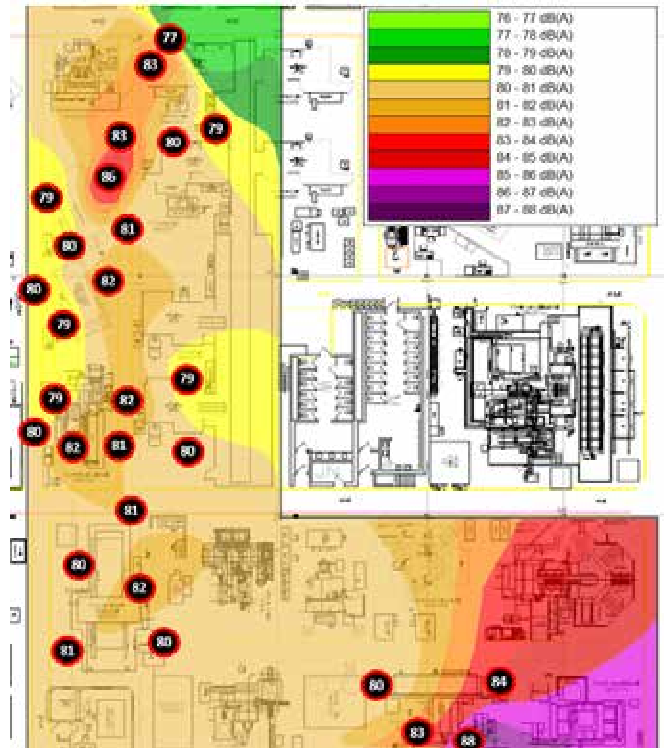
The loudness of the sound that a human hears is also dependent on the environment and is a subjective interpretation that varies by individual. If exposure to a noise source is outside in the open air, the noise level is different than exposure to the same noise source in an enclosed space. Reflections of the noise in the enclosed space will increase the amplitude or noise level. Generally, a doubling of loudness is an increase of 10 dB. However, this a subjective number because every person's brain interprets loudness differently. Regardless of the annoyance factor, exposure to high noise levels over time will result in hearing loss. Currently, the OSHA standards say that workers cannot be exposed to a noise levels greater than a time-weighted average (TWA) of 90 dBA over an 8-hour time period. However, Reclamation is following the more conservative Department of Defense standard which limits the TWA to 85 dBA. The period of maximum exposure also is cut in half for each 3-dB increase. Thus, if exposed to average levels of 88 dBA, the maximum exposure time is only 4 hours.

Tone is noise at a single frequency. A tuning fork primarily vibrates at a single frequency. To a human, noise at a specific amplitude and single frequency is more disruptive to concentration and focus than noise at the same amplitude at many frequencies, which is called broadband noise. In other words, if both are at the exact same overall noise level, broadband noise is more tolerable than noise at a single frequency.

Noise Measurement Techniques

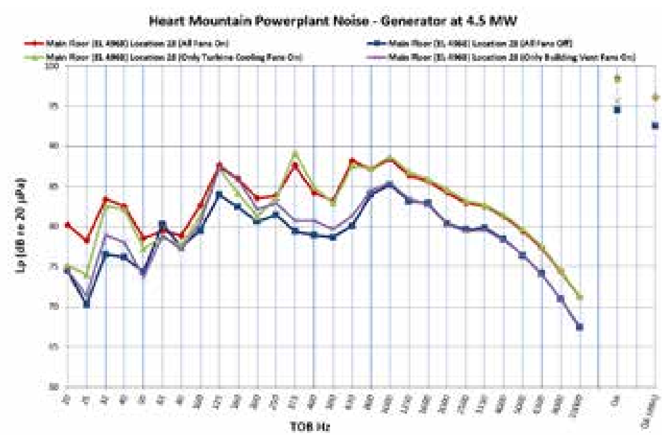
To control and mitigate noisy situations in powerplants or other confined spaces, the first step is to understand the noise environment. This understanding starts with focus on noise measurement equipment and their applications needed for noise control. Instruments used for noise measurement must meet industry standards and be calibrated by an accredited lab annually.

Typical sound level meter



Typical mapping of noise levels

Sound Level Meter: The sound level meter (SLM) is a single channel hand-held instrument with a built-in microphone and is the most fundamental piece of noise measurement equipment. Using this meter will provide a basic level of the noise environment in a facility. The microphone, much like the ear, converts changes in the air pressure caused by sound waves into an electrical voltage which is proportional to the sound pressure level (SPL) expressed in decibels. The current international standard that specifies SLM functionality and performance criteria is IEC 61672-1.



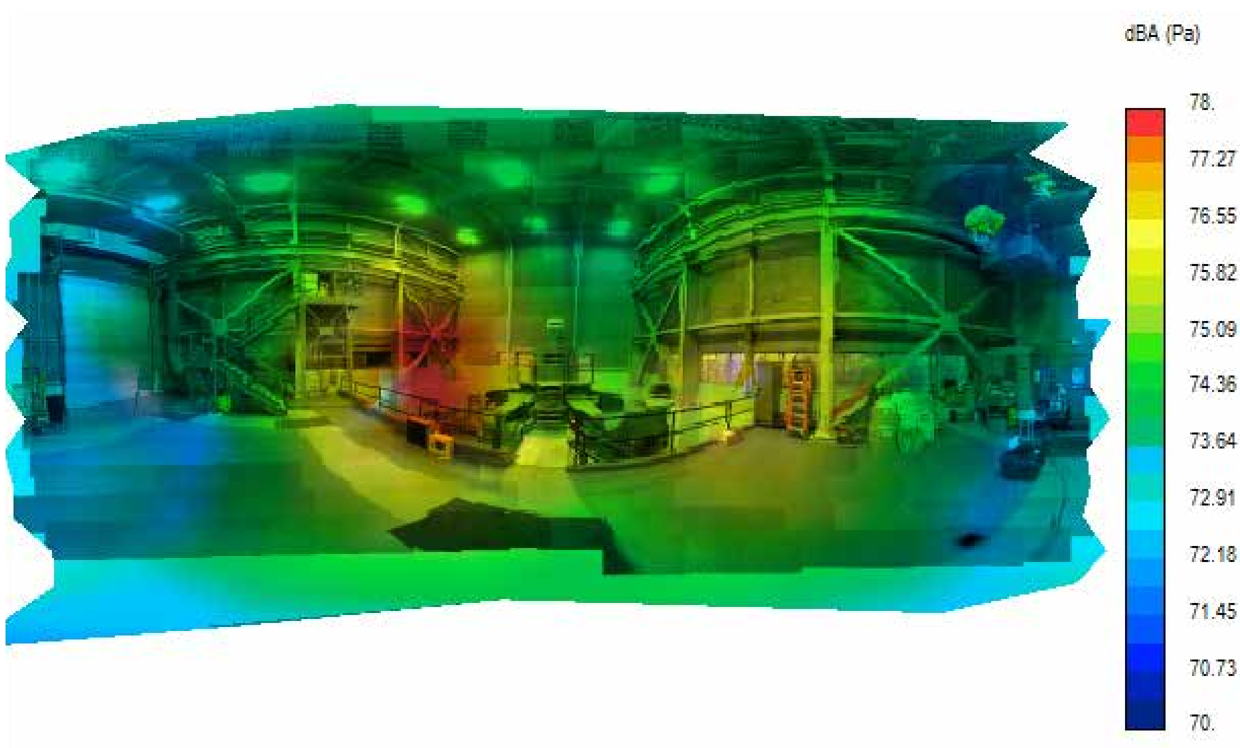
Typical frequency spectrum one-third octave plot

Frequency Analyzer: To properly design a noise control plan, it is not enough to only measure the overall noise level. Noise frequencies must also be measured. The measurement of noise frequencies is accomplished using a spectrum analyzer. Often, vibration, which is a measurement of motion rather than noise, is also measured to determine if noise is radiating from a vibrating surface. The frequencies that make up the vibration also must be measured. A typical frequency plot can be of noise and/or vibration is where the x-axis is the frequency of the individual bands and the y-axis is amplitude in dB. The logarithmic summation of all these bands will give the overall dB value (OA) which is shown on the right hand side of the plot.

The frequency content of the noise is used to determine the sources of the noise. Having this information enables design of noise mitigation controls that match the frequencies to be mitigated. An experienced acoustics engineer will also use this information to determine the noise paths which is necessary in order to design effective noise controls.

Acoustic Array: This advanced instrument is used when there are multiple noise sources and it is difficult to determine the loudest sources and the path from the noise to a person. Knowing the loudest sources, and being able to rank the sources in strength, is necessary to design effective noise controls. This array allows visualization of the acoustic "hot spots" by overlaying the measurement over a 3-D picture of the space.

Acoustic Array Instrument



Typical Acoustic Array Measurement

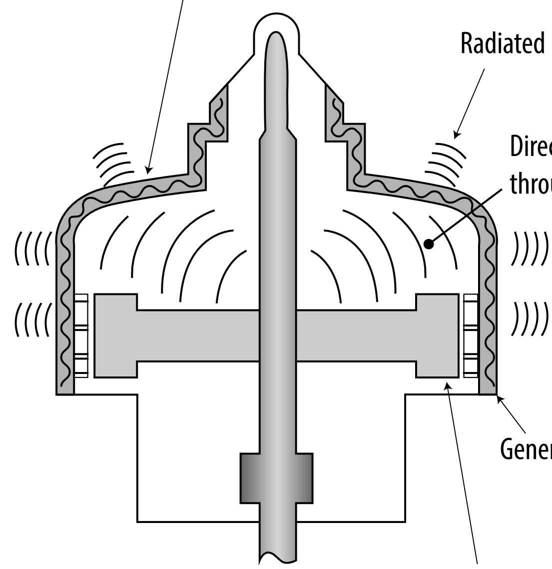
Noise Control Techniques

Depending on the types of noise sources involved, there are a variety of noise mitigation techniques available to control sound in power plants. Before reviewing these techniques, it is first necessary to understand the role of the noise source, sound path, and receiver in selecting a mitigation technique.

Noise Source, Sound Path, and Receiver

The noise source is any item of machinery or equipment which generates airborne or structureborne noise. Examples of machinery and equipment emitting noise in powerplants include the generators, scroll cases and draft tubes, turbines and penstocks. Typically flow noise is generated from the scroll cases, draft tubes, and penstocks, while turbine pit noise results from the turbine runner.

Once noise is emitted, sound may travel to a receiver location through three types of paths, each of which must be evaluated for each noise control situation.



Source-Path-Receiver Model

- Direct Airborne Path: This is acoustic energy that travels directly from a source (e.g., generator) to your ears through the air.
- Primary Structureborne: This occurs when machinery causes the structure upon which it is mounted to vibrate. An example is a pump mounted directly to a foundation without isolation. Depending on the frequency of the vibration and the radiation efficiency of the structure, this vibration will generate sound pressure waves that contribute to overall noise levels.
- Secondary Structureborne. Although this is a less common mechanism, it must be surveyed as a potential contributor when developing an appropriate noise control plan. When a very loud noise source with high acoustical energy impinges on a structure, it can cause the structure to vibrate and radiate acoustic energy. If the airborne levels inside the generator are high enough, these airborne noise levels will impinge on the generator shell causing it to vibrate and radiate acoustic energy, triggering the need for associated noise treatment.

Reducing Noise

There are three ways of reducing noise: at the source, treating the path or treating the receiver. The preferred method is to treat the source, if possible. Treating the path is the next option, which is achieved in conjunction with treating the source. The last option is to treat the receiver, which typically involves the use of personal protective devices such as ear plugs or muffs. According to OSHA, this is the last option while engineering controls to mitigate noise should always be the first option.

Treating the source, such as "buying quiet" in the initial phase or replacing old noisy equipment with quieter models, is the most effective way to reduce noise. This is possible if the project is in a design or an overhaul phase. Another method is to look for ways in which the process can be done in a quieter manner. For instance, pneumatically driven machines are often replaced with hydraulics, noisy pumps are replaced with quieter pumps, or suppressors are installed in noisy hydraulic lines. Processes are also improved such as designing a quieter sandblasting nozzle. These are all practical examples.

Another method for reducing noise at the source is vibration isolation. In this instance, machinery is hard mounted to a supporting foundation. This situation frequently results in vibrational energy from the equipment, which is then transmitted to the supporting foundation. Eventually, this vibrational energy finds a "weak link" in the form of a surface with high radiation efficiency and this surface radiates acoustic energy causing noise. An easy solution is to mount the equipment on an isolator, such as a rubber mount or a pad, which decouples the equipment from the foundation thereby preventing vibration in the supporting foundation.

Treating the path is performed using a method involving the installation of materials that absorb sound, and installation of high transmission loss barriers which block sound. If an area consists of hard surfaces that do not absorb any sound, the sound levels are higher than the source due to sound reflections from the surfaces. To lower noise levels from the reflections as well as reduce acoustical energy, walls and ceilings are treated with absorptive material. To be effective, at least 40% of wall surface area should be treated in each space. Examples of absorption controls are provided later in this issue's articles on actual plant installations This noise mitigation technique is very effective and in one installation inside a turbine pit, a reduction of 16 dB (85% reduction in noise) was achieved.

The use of high transmission loss barriers which block sound from the source to the receiver is another very effective method and is often used in combination with absorption. These barriers can range from overlapping, clear strip curtains to two-inch thick acoustic blankets. The

Example of hard mounted pump

Examples of resilient isolation mounts

Examples absorption treatment in power plants

Examples high transmission loss barriers to block noise

Custom designed acoustic silencers and louvers

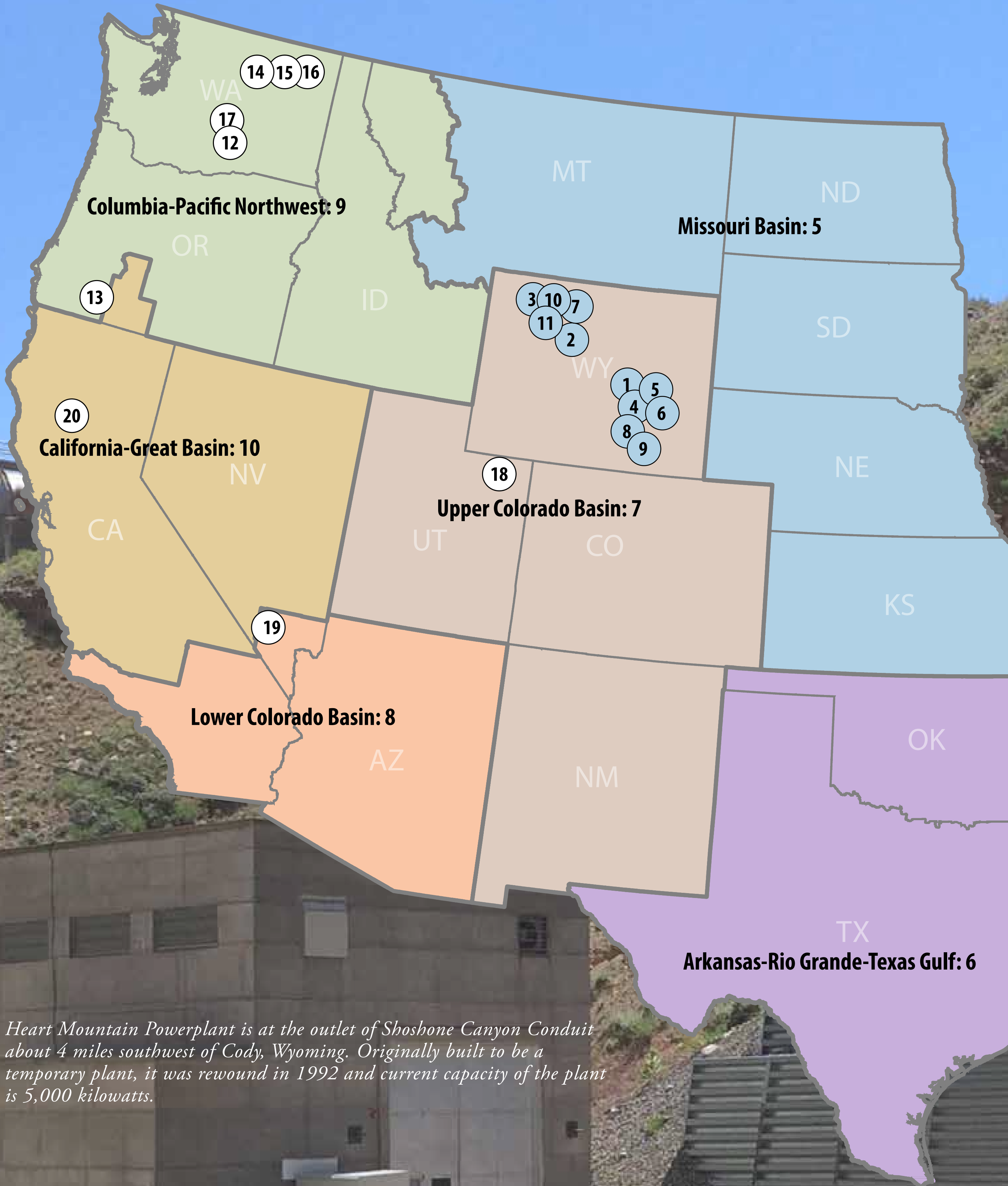
Spray-on damping material to reduce noise radiating from surface

blankets have a mass loaded vinyl layer sandwiched between an inch of fiberglass insulation on either side. In hydropower plants, these controls are used in draft tube and scroll case corridors in order to surround compressors and jet pumps as well as block off noisy areas around generators.

Vibrating surfaces will often radiate acoustic energy causing noise. When the structural vibration is caused by airflow through a duct, the noise source cannot be decoupled from the structure. Damping is applied to the vibrating surface to reduce the structural vibration. This damping is usually in the form of tiles or a spray-on treatment. Reducing the vibration of radiating surfaces reduces noise levels.

The final path treatment is silencers or louvers. When the noise source is mainly due to air flow, such as from intake or exhaust fan, or from high airflow coming from a turbine pit or the cooling slots of a generator, the use of silencers or louvers is an effective treatment. In this situation, the air flow is necessary and must not be blocked by a barrier. Silencers or louvers consist of baffles that contain sound absorbing materials that absorb acoustical energy as the air flows through these baffles. An example of custom louvers is shown above.

Summary of Noise Controls



Heart Mountain Powerplant is at the outlet of Shoshone Canyon Conduit about 4 miles southwest of Cody, Wyoming. Originally built to be a temporary plant, it was rewound in 1992 and current capacity of the plant is 5,000 kilowatts.

Facility	Largest Noise Reduction	Research Noise Control
1. Alcova	**6-8**	High Transmission Loss Firestop and Acoustic Fill Bricks
2. Boysen	**1-4**	Acoustic Barriers: Overlapping Strip Curtains
3. Buffalo Bill	**7-11**	Acoustic Barriers: Overlapping Strip Curtains
4. Fremont Canyon	**7-10**	Damping Tiles on Cabinet Panels
5. Glendo	**5-7**	Acoustic Enclosure around Compressors using Acoustic Blankets
6. Guernsey	**4-6**	Custom Louvers & Baffles (20 slots) & Install Acoustical Louvered Doors
7. Heart Mountain	**11-15**	Redesign intake airflow and develop input silencer & Custom Louvers & Baffles (20 slots)
8. Kortes	**8-10**	Silencer in each generator cooling door opening (6 total)
9. Seminoe	**8-14**	Generator Top Railing around Cooling Slots High Transmission Loss Sound Absorption Blanket
10. Shoshone	**8-10**	Acoustic louvers mounted at exhaust fan in electrical cabinet
11. Spirit Mountain	**6-15**	Openings between Scroll Case and Turbine Pit Platform High Transmission Loss Sound Absorption Blankets
12. Chandler	**4-5**	Spray-on Damping Material on Generator Cooling Ducts
13. Green Springs	**8-16**	Control Room Acoustic Material in Penetrations into Turbine Pit
14. Grand Coulee Left Powerhouse	**1-6**	Spray-on Damping Material G-9 Generator Air Housing
15. Grand Coulee Right Powerhouse	**2-6**	Turbine Pit Access Overlapping Strip Curtains
16. Grand Coulee Third Powerhouse	**No Resurvey**	Draft Tube and Scroll Case Access Acoustic Barriers: Overlapping Strip Curtains
17. Roza	**6-8**	Plant Walls 2" Acoustic Insulation with Perforated Aluminum Facing Acoustic Fan Silencers
18. Flaming Gorge	**6-14**	Bearing Cooling Water Supply Valves in Unwatering Gallery Enclosure Acoustic Blankets
19. Hoover Dam Powerhouse (AZ and NV Sides)	**No Resurvey**	Acoustic Louvers on Floor Grate Openings to Level 1 (Eductor Level) & Stairwells from Eductor Level: 2 Inch Thick Absorption Panels
20. Shasta	**8-12**	Main Plant Walls 2 Inch Thick Absorption Panels

R&D Region Summary

California Great Basin –Large Plant Demonstration at Shasta Powerplant

The R&D Office partnered with the Power Resources Office to perform noise surveys at Reclamation's large plants (Grand Coulee, Hoover, Glen Canyon, and Shasta) and demonstrate techniques to reduce noise that can be applied across the power industries' fleets, no matter the size of the facility. There are unique challenges associated with a large plant including more and larger equipment, more untested control measures, and the sheer size of the concrete space. Reverberation, or reflective energy, was especially challenging at these facilities. In order to address this challenge a large portion of the wall surface area was treated with absorption material. Reclamation learned to what degree covering more surface area led to greater noise reduction. Acoustical noise barriers were also installed throughout the plants. An unexpected lesson was that at the lower levels of the plant, noise can vary significantly the elevation difference, or head, between the headwater and tailwater. The greater the head, the louder the noise. With different heads, the primary noise source can also change. Between the pre and post-tests, the head changed, where the lower plant noise levels increased. This was not anticipated nor was this experienced in prior demonstrations. On future installations, this is a consideration when installing controls on lower levels.

Acoustic absorption material installed on Shasta plant walls

Acoustic absorption material installed on Shasta turbine pit walls

Columbia-Pacific Northwest – Challenges at Roza, Chandler, Green Springs and Grand Coulee

Roza, Chandler, and Green Springs were Reclamation's first demonstration sites for using new noise survey techniques and installing the recommended noise control solutions. The use of the acoustic array and gaining confidence in its results were proven and demonstrated. The acoustic array identified the unique challenge at Roza, which had two large cooling fans which were the primary noise sources rather than the generator. Designing, building, and installing silencers for these fans was daunting, but was proven as a worthy endeavor when the noise in Roza dropped 4-6 decibels (50%). Roza was the first site to test a spray on damping material to reduce the vibration of the generator cooling ducts, thus reducing noise radiating from the surface.

At Chandler, the generators are open air for cooling, so a direct noise path existed. Installation of acoustic blankets around the generator slots was recommended, but plant staff were concerned about overheating. Facility managers, Reclamation staff and ONR contractors decided to experiment with the situation by installing the blankets and monitoring the temperatures. This led to the positive confirmation that the acoustic blankets could be installed without causing overheating issues.

Fan silencers installed at Roza

Chandler acoustic blanket installation around generator cooling slots

Spray-on damping treatment on Roza Cooling Ducts

Green Springs is a high head (1800 ft) impulse turbine and was the noisiest of the initial three powerplants. Its noise levels required double hearing protection in some locations which was this facility's biggest research challenge. It was the first to demonstrate that high transmission loss curtains and acoustic absorption material in the wheel pit would be successful in reducing noise where the levels were 101 decibels. After noise control installations, double hearing protection was no longer required in the plant. Prior to noise control installations, operators complained that talking on the phone in the control room was very difficult and yelling was necessary.

Grand Coulee Unit G9 was rewound in 2011, which involved the design being changed from a multi-turn coil to Roebel bar. After the rewind, noise levels in the powerplant were so loud that G9 was placed in last-on/first off status. This forced the unit to be run minimally while workers were present in the plant. While performing surveys in the Left Powerhouse, it was evident that G9 was a primary noise source. It was also apparent that vibration, which likely emanated from the winding inside the generator, was causing a direct airborne emission path from the winding. This was also causing the generator air housing to vibrate significantly. Although many controls were suggested, Grand Coulee has only implemented a control involving spray-on application of damping material to the air housing. This was the first attempt at using this material on such a large surface. Noise levels were reduced up to 6 dB (50%) and generally the powerhouse noise levels remain in the 85-87 dBA range. A second phase noise control is scoped for later this year which involves installation of acoustic blankets inside the generator air housing.

Historic preservation was another unique issue encountered during the Grand Coulee' noise controls project. Sound absorption material was not installed due to historic preservation concerns. All noise controls can be removed to return a facility to its original condition, which is one way to meet historic preservation criteria. Sound absorption panels are now matched to the colors already at the plant, and the spray on damping is painted to match the other generators.

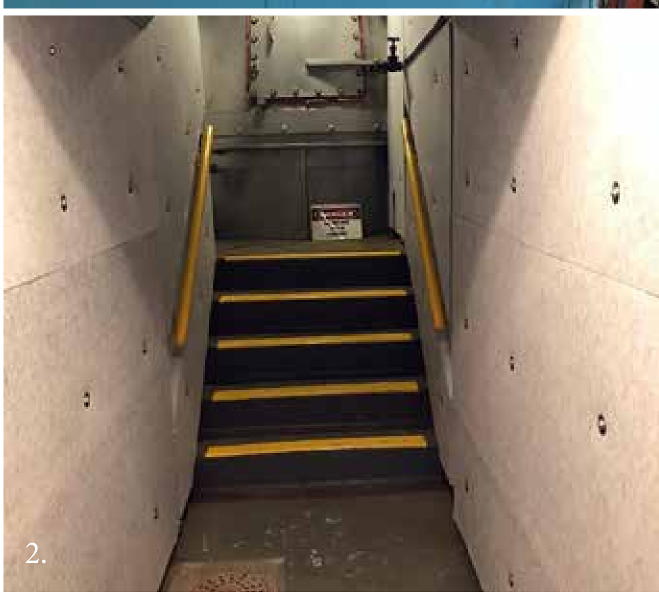
Acoustic barrier material installation in Green Springs turbine pit

Grand Coulee G9 measuring air housing vibration

Grand Coulee G9. G9 top diamond plates after installation of spray-on damping material

Upper Colorado Basin – Flaming Gorge Challenges

After hearing about this project's success, Flaming Gorge volunteered to be the test site in the Upper Colorado Basin. Noise levels were high, above 90 dBA in the wheel pits, and above the 85 dBA target set by Reclamation on the main generator floor. The main source from the generator was just below the generator thrust bearing. This was the first attempt at hanging acoustic blankets from the generator housing railing to block the noise path directly to the concrete walls and the main generator floor. Also, as in prior installations, absorption panels were installed on the plant walls. Between these two controls in the main plant area, a reduction on the main floor of up to 8 dB or a 60% noise reduction, was achieved. On the wheel pit floor, once absorption panels were used in the wheel pits, noise reductions up to 16 dB (84% reduction) were achieved. In the pipe gallery, to reduce the noise from the cooling water supply valves, the same acoustic blankets that were hung from the generator railings were used. These controls, coupled with overlapping acoustic strip curtains installed in the scroll case opening, resulted in a noise reduction of 3 dB or 29%.



1. Acoustic blankets installed on top of generator housing 2. Acoustic absorption material in turbine pit and draft tube corridor
3. Acoustic barrier around bearing cooling water supply valves

Missouri Basin – Challenges at Wyoming Area Powerplants

Wyoming Area Office powerplants are unique because their ages vary from 26 to 93 years old (Spirit Mountain-Guernsey). This means there is a large variety of hydropower generating technologies in operation. Additionally, many of these plants are small which increases the potential for high noise levels due to many noise sources. These facilities are the most challenging from an R&D perspective and have generated some of the most unique solutions.

At Alcova, acoustic blankets like those installed in Flaming Gorge were used to block noise in the turbine pits allowing workers to work on one unit while the other unit remains operational. This created a workspace below Reclamation's 85 dBA requirement. Acoustic bricks were also used to block noise emitted from piping penetrations into the turbine pits. These unique solutions reduced the noise by up to 5 dB (44%).

High transmission loss acoustic material in piping openings to turbine pit at Alcova

At Buffalo Bill, the excitation equipment fans created noise levels as high as 92 dBA. Custom silencers were designed, built, and installed for the first time on this type of electrical equipment. This solution, coupled with absorption treatment installed on the walls and areas above the generators, reduced noise up to 9 dB (65%). The same excitation equipment fan silencer was used at Shoshone since it has the same excitation cabinet setup.

Before and after pictures of excitation equipment cabinets showing custom silencer at Buffalo Bill

Guernsey encountered two problems where two unique solutions were attempted at the acoustic louver doors at the wheel pit, and custom-designed generator cooling slot baffles. These louver doors were designed to allow air flow as well as attenuate the noise. The generator cooling slot baffles were new and installed in this plant rather than the acoustic transmission loss blankets. This new solution was necessary because there was no means to mount blankets and provide enough airflow to the generators. This led to noise reduction of up to 9 dB (65%) achieving Reclamation's target of 85 dBA.

Heart Mountain was the most challenging facility. The acoustic environment was extremely complex due to the highly reverberant surfaces and as many as three primary noise sources not including the reverberation. This facility required the most rigorous testing with scenarios involving noise sources in operation. Using the acoustic array to rank the noise sources was extremely challenging. Noise levels were as high as 97 dBA in several locations. A complete redesign of the ductwork surrounding the cooling fans (the primary noise source) was required, and silencers were designed for the cooling fan intakes. Cooling slot baffles like those used in Guernsey were also utilized. The results were excellent with up to a 15 dB (82%) reduction, and the whole main plant was now under the 85 dBA target.

During testing at Kortes, only two of the generators were operating. However, with all three generators operational, noise was expected to be 90 dBA or greater. The main noise came from the generator cooling door openings. There were two doors per generator where custom acoustic silencers were designed and installed. This resulted in a noise reduction up to 8 dB (60%).

Close-up view of generator cooling slot baffles at Guernsey

Acoustic silencers in generator cooling door openings at Kortes

Lower Colorado Basin – Large Plant Demonstration at Hoover Dam Powerplant

Hoover Dam powerplant is unique in that it has two nearly identical powerhouses. While the noise survey was only conducted on the Arizona side, results from that survey informed design and installation of controls on both Arizona and Nevada sides. This is because the physical configurations of the two sides are roughly the same. The eductor gallery proved to be the loudest location in the powerhouse with noise levels as high as 106 dB. Such noise levels require exposed workers and visitors to wear double hearing protection. Noise at this level also permeates from the 1st floor to the 2nd floor.

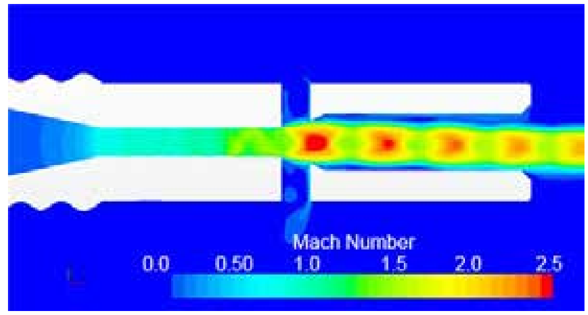
Noise control efforts are ongoing. A series of sound absorption louvers were installed on vents in the floor of the 2nd floor to mitigate a direct sound path from the eductor gallery. Absorption panels were also installed in all the stairwells leading from the 1st floor to the 2nd floor to further reduce noise from the educator galleries. Additional reduction of noise on the 2nd floor will also be addressed by installing and utilizing electric pumps instead of eductors for unit cooling water. Acoustic strip curtains will be installed between the educator bays to reduce noise in the areas outside the bays. The post-control noise survey will occur as soon as practical.

Absorption Panel in Stairwell from Eductor Gallery (Floor 1) to Piping Gallery (Floor 2)

Silencers on Floor Grates leading from Pipe Gallery (Floor 2) to Eductor Gallery (Floor 1)

R&D Research Case History

Sandblasting Research to Reduce Noise and Increase Efficiency



Numerical model showing flow inside nozzle

The sandblasting process is an extremely high noise procedure. Noise levels as high as 123 dBA were measured during sandblasting operations at Grand Coulee. Continued exposure to noise levels of this magnitude, even with double hearing protection, presents a major risk to one's hearing.

Reclamation invested research dollars to tackle the very difficult problem of designing a quieter, more efficient sandblast nozzle. A unique measurement technique was made using a head with ear canals to measure noise levels under a sandblasting hood while measuring noise levels outside of the hood. The purpose of this test was to quantify actual in-ear noise levels in order to set noise reduction targets. Advanced fluid dynamics models were then generated to model the flow of air and blasting media inside the nozzle to understand the mechanisms generating noise. A series of tests with controlled parameters were then conducted to measure noise from standard off-the-shelf nozzles and correlate to these models. Based on this research, several prototype nozzles were manufactured and tested and compared to the baseline nozzle noise measurements. While these prototype nozzles did exhibit some promising noise reductions, it was evident that more research and another round of model-test-manufacture would be needed.

Based on promising results from these Reclamation-supported efforts, Noise Control Engineering submitted a successful proposal to the US Navy, Office of Naval Research under the Small Business Innovative Research (SBIR) program, leading to award of a Phase I contract. This follow-on work is now in Phase II and showing promise of meeting the objectives of a 20 dB noise reduction and a 20% increase in efficiency. Once nozzles are in final stages of development, Reclamation would like to test them in sandblasting operations.


Sandblasting hood where noise levels reach 123 dB

Contributors and Partners

Erin K. Foraker – Erin joined the Research and Development Office in 2012. Erin coordinates two research areas within the R&D Office's Science and Technology Program: Power and Energy, and Water Infrastructure. Both areas address improving maintenance practices and tools, improving reliability and efficiency, and improving safety on hydropower and infrastructure sites within Reclamation. Erin also develops and leads external partnerships in these areas of research.

Michael Green - Michael joined the Safety and Occupational Health Office in 2013 as a safety engineer. Michael provides technical safety expertise in support of Reclamation's comprehensive safety program. Michael coordinates and executes safety projects focused on improving safety of operations and personnel across all of Reclamation. Michael leads safety program development focusing on industrial process exposures, life safety and fire protection.

Jeffrey M. Komrower – Jeff is a Senior Engineer and project manager at Noise Control Engineering LLC. Jeff has over 40 years of experience in the acoustics and vibration field and has recently been the project manager on efforts to reduce noise on US Navy aircraft carriers, working directly with the program officer for the Navy's Noise Induced Hearing Loss program. His experience also includes working to keep the US Navy nuclear submarines quiet as well as structural testing of the Space Shuttle orbiters. He also has extensive experience in the noise reduction of industrial facilities.

Theresa A. Gallagher – CDR Gallagher is an Environmental Health Officer with the United States Public Health Service currently under detail to the Office of Research & Development, Environmental Protection Agency in Las Vegas, Nevada. She serves as the Safety, Health, and Environmental Program Manager. She served as Reclamation's principal staff advisor for public and occupational health and industrial hygienist 2009-2017. Before leaving Reclamation, CDR Gallagher's initiative was responsible for the current program to reduce Noise Induced Hearing Loss via noise levels in hydroelectric powerplants.

External Partners

- Office of Naval Research
- U.S. Army Corps of Engineers – Columbia River Basin - Bonneville, The Dalles, Chief Joseph Powerplants

Reclamation Partners

- Interior Region 5 & 6: Missouri Basin & Arkansas-Rio Grande-Texas-Gulf
  - Eastern Colorado Area Office - Estes, Flatiron, Mary's Lake Powerplants
  - Wyoming Area Office – Seminoe, Kortes, Fremont Canyon, Alcova, Glendo, Guernsey, Boysen, Shoshone, Buffalo Bill, Spirit Mountain, and Heart Mountain powerplants.
- Interior Region 7: Upper Colorado Basin
  - Upper Colorado Basin Power Office - Flaming Gorge, Glen Canyon, Upper and Lower Molina Powerplants
- Interior Region 8: Lower Colorado Basin
  - Hoover Powerplant
- Interior Region 9: Columbia-Pacific Northwest
  - Columbia Cascades Area Office - Yakima Field Division: Roza, Chandler, Green Springs powerplants
  - Grand Coulee Power Office
- Interior Region 10: California-Great Basin
  - Northern California Area Office – Shasta Powerplant
- Power Resources Office
- Programs and Policy – Safety and Emergency Management (previously the Safety & Health Office of the Reclamation's previous Safety, Security, and Law Enforcement Office)
- Research and Development Office - Science and Technology Program