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ENGINEERED SOLUTIONS TO REDUCE OCCUPATIONAL NOISE EXPOSURE AT THE NASA GLENN RESEARCH CENTER: A FIVE-YEAR PROGRESS SUMMARY (1994-1999)

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INTRODUCTION

At the NASA John H. Glenn Research Center at Lewis Field (formerly the Lewis Research Center), experimental research in aircraft and space propulsion systems is conducted in more than 100 test cells and laboratories. These facilities are supported by a central process air system that supplies high-volume, high-pressure compressed air and vacuum at various conditions that simulate altitude flight. Nearly 100,000 ft² of metalworking and specialized fabrication shops located on-site produce prototypes, models, and test hardware in support of experimental research operations. These activities, comprising numerous individual noise sources and operational scenarios, result in a varied and complex noise exposure environment, which is the responsibility of the Glenn Research Center Noise Exposure Management Program. Hearing conservation, community noise complaint response and noise control engineering services are included under the umbrella of this Program, which encompasses the Occupational Safety and Health Administration (OSHA) standard on occupational noise exposure, §29CFR 1910.95[1], as well as the more stringent NASA Health Standard on Hearing Conservation[2].

Prior to 1994, in the absence of feasible engineering controls, strong emphasis had been placed on personal hearing protection as the primary mechanism for assuring compliance with §29CFR 1910.95 as well as NASA's more conservative policy, which prohibits unprotected exposure to noise levels above 85 dB(A). Center policy and prudent engineering practice required, however, that these efforts be extended to engineered noise controls in order to bring existing work areas into compliance with §29CFR 1910.95 and NASA's own policies and to ensure compliance for new installations. Coincident with the establishment in 1995 of a NASA-

wide multi-year commitment of funding for environmental abatement projects, the Noise Exposure Management Program was established, with its focus on engineering approaches to reducing occupational and community noise exposure. The organization and mission of this Program were documented shortly after its inception[3], and individual programmatic components have been the subject of subsequent papers[4,5,6]. This paper summarizes the status and accomplishments of the *engineering* aspects of the Program from a five-year retrospective viewpoint and includes a review of retrofit noise control solution strategies, which have not been previously documented.

ENGINEERING APPROACHES TO NOISE EXPOSURE MANAGEMENT

A portfolio of engineered noise control solutions has been developed to meet the varied and specialized noise exposure reduction requirements at NASA Glenn Research Center. These solutions have typically not involved modification of the noise source mechanisms because of the unique or research-related nature of most problematic noise sources at NASA Glenn. Additionally, in research support areas that house multiple pieces of large mechanical equipment, source noise control is usually impractical. For this reason, large mechanical equipment buildings and their associated systems present the most significant noise exposure management challenges[7]. Although these constraints restrict the options for engineered noise control treatments, a limited array of successful approaches has been developed, customized to the GRC environment and standardized for consistent future implementation.

Silencers for gas flow systems. The prioritization of projects for funding and implementation considers a number of factors. Highly ranked among those considerations is the potential for sudden, unprotected employee exposure to extremely high noise levels (e.g., those that would likely exceed the OSHA limits for unprotected exposure), particularly due to sources located in outdoor areas where barricades and warning signs would be ineffective. Thus, gas flow system safety reliefs, vents and exhausts were evaluated, and their potential for causing hearing loss was estimated as a means for staging the implementation of their respective solutions. Approximately eight major outdoor silencer systems have been installed as well as two hydraulic system silencers and two equipment blowdown silencers. Small off-the-shelf pneumatic tool exhaust silencers have been distributed and are available on request as new tools are acquired.

Acoustical pipe lagging. Another noise problem associated with gas flow systems is pipe-radiated noise. Reduction in pipe-radiated noise has been accomplished with the development and implementation of a standard specification for acoustical pipe lagging that is applicable to most large diameter process air piping. A layered installation of 1 psf loaded vinyl over six inches of mineral fiber with an aluminum jacket has been used successfully in a number of high-noise areas. Variations on this standard have been developed for smaller diameter pipes and for lower-noise sources, including hydraulic fluid lines in materials research laboratories. Acoustical pipe lagging has been installed on eight separate systems, as well as two hydraulic systems.

Construction or renovation of “quiet” plant offices and control rooms. In most high-noise areas, operational requirements necessitate that employees spend some portion of their time in the field visually monitoring or maintaining equipment. However, in most experimental research and support facilities, there are ample opportunities to reduce noise exposure by providing quiet enclosures (offices, control rooms, break rooms, etc.) where employees may conduct business or seek relief from the noise when they are not required to be in the field. Construction of a new or

replacement enclosure (or a major renovation that increases the noise reduction of an existing enclosure) is often the most cost-effective approach to reducing employee noise exposure in this scenario.

Field-constructed rooms as well as manufactured (purchased) enclosures have been used with equal success. In both cases, the designs and specifications for the wall panel, window and door units are developed to provide a high degree of noise reduction. Enclosures also employ flush-mounted electrical hardware, lead-wrapped ventilation ductwork and silenced utility penetrations. Isolated floor systems have been used in areas where multiple pieces of large, rigidly mounted mechanical equipment are responsible for high levels of structureborne noise. In selected areas where audibility of the equipment signals is critical (for machine health monitoring), high-sensitivity microphones located in the high noise area provide a signal, at a reduced and controllable level, to a speaker mounted in the control room. Eleven new or replacement offices, control rooms and break rooms have been constructed, and five have undergone extensive renovations.

Architectural modifications that reduce sound transmission between existing spaces. Most often, particularly in the case of block wall enclosures, the envelope of a preexisting enclosure requires only minor modifications to achieve its full noise-attenuation potential. The space is usually evaluated to identify sound transmission paths between the quiet space (which may be outdoors) and the adjacent test cell or high-noise area. These noise leaks are then corrected with some combination of architectural modifications, including replacement acoustically-rated doors and windows, replacement acoustical door seals and repair of penetrations that have been made in the envelope of the space for the purpose of passing utility or signal cables. These architectural modifications have been made extensively around the NASA Glenn site, particularly in test cell control rooms.

A technique for temporarily sealing cable tray penetrations has been developed and widely used to abate nearly every occurrence of noise transmission through these penetrations. This technique involves permanently attaching a multiple-piece loaded vinyl "sleeve" to the block wall, around the perimeter of the cable tray. The sleeve may be laid open to pull cables, then stuffed with acoustically absorbing material and re-wrapped around the tray.

Sound-attenuating booths for protected communication in high-noise areas. In large high-noise areas such as wind tunnel support buildings and process air plants, a full-time staff of operators provides continuous monitoring and field maintenance of large mechanical equipment. The extremely high sound level hinders face-to-face communications and complicates radio communications between field operators and remotely located dispatch personnel. The requirement for safety and clarity of communications has resulted in the establishment of noise-attenuating communication stations conveniently located throughout those areas. The communication enclosures reduce noise to acceptable levels that permit direct and radio communication and also provide operators occasional relief from the noise as operations permit. The accessibility of the enclosures discourages employees from removing hearing protection in high-noise areas, thus eliminating the most severe contributions to noise exposure for the operations staff as well as for transient maintenance, construction and engineering personnel.

“BUY QUIET” APPROACH TO NEW EQUIPMENT PURCHASE SPECIFICATIONS

The implementation of retrofit engineered controls is a key element of the NASA Glenn Noise Exposure Management Program. Realization of the full value of this financial investment depends on the ability to maintain momentum toward a quieter work environment, which, in turn, depends on preserving gains that have been made with each successive project. In addition, it is desirable to shift the focus of noise control design and expenditure from relatively expensive retrofit projects to the initial design and construction stage of *all* projects, where noise reduction is most appropriately achieved. New equipment purchases continually present opportunities to further both objectives. In many work areas, multiple, complex or distributed noise sources limit opportunities for cost-effective source noise control, requiring emphasis on hearing protection and personnel enclosures as the primary means of noise exposure management. In these areas, gradual, yet cost effective, reduction in area noise levels (and employee exposures) may *only* be achievable as noisy equipment is replaced over time.

During 1996, the Noise Exposure Management Program implemented a “Buy Quiet” program with the goal of achieving long-term reduction of employee noise exposures through purchase of equipment that conforms to hearing conservation goals. Project designers and engineers who purchase equipment expected to generate noise emission levels of concern for hearing conservation (80 dB(A) and above) are required to consider noise emissions along with other performance criteria. In order to provide the means to effectively pursue this approach, a *Guide to Specifying Equipment Noise Emission Levels* was published[7]. To launch the Program and encourage pilot projects, funding was provided to offset the additional cost associated with meeting noise emission specifications for three initial equipment purchases.

Developed to support hearing conservation goals, the *Specs Guide* also addresses relevant community noise and speech communication issues, covering noise emission from a broad variety of fixed and portable equipment expected to produce noise approaching levels of 80 dB(A) and higher. Adjustments are applied to baseline noise emission criteria for various siting and operational considerations, yielding the maximum permissible sound level. Additionally, maximum permissible octave band sound power levels are specified for outdoor equipment, based on a limiting spectrum designed to prevent community noise problems. A computer spreadsheet and accompanying manual guide the purchaser through the development of noise emission requirements, and recommended language is provided for incorporation into a comprehensive equipment specification.

Consistent specification of low-noise equipment is an important component of bringing about reductions in workplace and environmental noise levels, reduction of administrative and operational noise controls, and improvement in the safety, productivity, comfort and regulatory compliance of the work environment. Gradual decreases in area sound levels are expected over time, as equipment purchases are made in accordance with the “Buy Quiet” Program.

“QUIET BY DESIGN” PROCESS FOR NEW GAS FLOW SYSTEMS

Equipment noise emission specifications developed in accordance with the “Buy Quiet” Program help ensure the purchase of low noise equipment. However, not all new systems and equipment are purchased from vendors. In particular, gas flow systems required for the operation and support of some research facilities are often designed in-house. In this case, “Buy Quiet” maximum equipment

noise emission specifications provide design goals for those systems, but the *Specs Guide* stops short of offering detailed guidance on how those goals might be achieved.

Gas flow systems are a significant contributor to the noise exposure landscape at NASA Glenn. These systems span the range of flowrates and capabilities, from small scale model research fixtures that employ supersonic flows and specialized gasses to large mechanical equipment and piping that provides high pressure processed air and altitude exhaust for wind tunnels and engine test cells across the site.

During 1998, the Noise Exposure Management Program implemented a "Quiet by Design" Program as a complement to the "Buy Quiet" Program. *A Reduced-Noise Gas Flow Design Guide*[8] serves as a companion to the *Specs Guide* and covers the noise produced by gas flows as it relates to piping, reliefs, vents, and turbomachinery. This *Design Guide* is a collection of powerful computerized design tools that may be used to estimate noise emission of a variety of equipment noise sources. These sources may then be incorporated into a complete system that also includes the effects of piping and noise-attenuating elements such as silencers and pipe lagging. A computer spreadsheet and accompanying manual guide the user through the design process, from noise emission specification through predictive equations and selection of noise control elements. The ability to predict sound levels at any point in a system greatly facilitates the development of noise control strategies for new experimental research facilities and support systems.

SUMMARY

The NASA Glenn Research Center Noise Exposure Management Program seeks to limit employee noise exposure and maintain community acceptance for critical research while aggressively pursuing engineered controls for noise generated by more than 100 research facilities and the associated services required for their operation.

Progress toward control of gas flow noise sources has been achieved with the installation of silencers for pressure reliefs, vents and exhausts. In addition, the application of acoustical lagging treatment has reduced noise radiated from high-pressure air supply and exhaust piping. Sound-attenuating personnel enclosures and communication stations facilitate safe in-plant communications and reduce employee noise exposure, while test cell modifications such as sound-attenuating doors and silenced utility penetrations reduce noise levels in adjacent control rooms and hallways. Two additional programs preserve gains from retrofit noise controls and maintain momentum toward a quieter work environment. A "Buy Quiet" program requires employees to consider noise emissions along with other performance criteria when purchasing equipment expected to generate noise emission levels of concern for hearing conservation. To complement this program, a "Quiet by Design" initiative provides guidance for new gas flow facilities, systems and equipment designed in-house rather than purchased from outside vendors.

Although personal hearing protection is still an important component of Glenn Research Center's noise exposure management strategy, emphasis has gradually shifted toward engineered noise control solutions that permanently reduce employee noise exposure. These solutions also maximize research productivity by reducing or eliminating administrative or operational controls and by improving the safety and comfort of the work environment.

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