

# ACTIVE NOISE CANCELLATION AT THE OTTAWA HEALTH SCIENCES CO GENERATION FACILITY

**Vincenzo Gambino**

**Antonio Gambino**

**Robert Rimrott**

Aercoustics Engineering Limited

50 Ronson Drive, Suite 127

Toronto, Ontario M9W 1B3

**Dr. Werner Richarz**

Aercoustics Engineering Limited

c/o Carleton University

Department of Mechanical Aerospace

Rm. ME3135, 1125 Colonelby Drive

Ottawa, Ontario K1S 5B6

## 1 INTRODUCTION

Complaints about noise from the co-generation facility at the Ottawa Health Sciences Centre started when the unit went into operation in 1992. Owned and operated by TransAlta Energy Corporation, the non-utility power generating station supplies power and steam to the Ottawa Health Sciences Centre Complex, and is located about 400m from a quiet residential area.

Although active noise cancellation, in the past, has been applied with limited success for mitigating outdoor noise problems, Aercoustics Engineering Limited designed and installed such a system in the summer of 1994, overcoming significant engineering constraints to complete a successful execution of this technology. Active noise cancellation is well suited to mitigating low frequency pure tone noise problems where sound is used to cancel the offending noise electronically by generating a mirror image or out of phase sound signal. The combination of noise and anti-noise results in an energy efficient solution that, at less than one-fifth the cost of silencer baffles, is also cost effective.

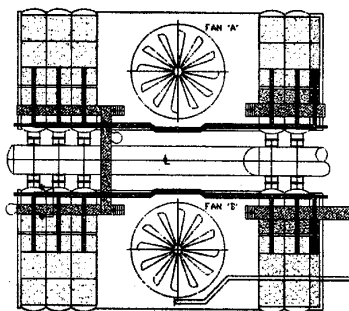


FIGURE 1: Plan View of Wet Surface Air Condensing Fans

## **2 NOISE SOURCE DESCRIPTION**

Aercoustics Engineering Limited was retained by the TransAlta Energy Corporation in 1993, to mitigate excessive low frequency noise from high speed operation of two wet surface air condensing or WetSAC, fans. As shown in Figure 1, these fans are axial, 26 ft. in diameter, have flow rates of 1,000,000 cubic feet per minute; the 15-foot exhaust stack is constructed of a stiff, lightweight quarter-inch fibreglass shroud shaped for aerodynamics.

The low frequency noise was a result of a 23.8 Hz pure tone due to the bladepass frequency of the WetSAC exhaust fan(s). The resulting 23.8 Hz pure tone is both evident in the exhaust sound spectra and in the sound radiated by the excitation of the stiff, lightweight fan shroud which radiates sound efficiently in the 24 Hz frequency range and behaves much like a loudspeaker.

## **3 LOW FREQUENCY NOISE CRITERIA**

Complaints of low frequency noise from the neighboring community at OHSC generally occurred between 7pm to 11pm under receptor downwind and temperature inversion conditions. The indoor low frequency noise level, in fact, is the same as the outdoor level. The low frequency noise is perceived as a distant rumble or vibration which causes rattling in floors, walls, and windows.<sup>2</sup> A review of research literature indicates that in general, people have an increased sensitivity to low frequency sound in the 20 Hz to 75 Hz region.<sup>3</sup> This point is significant as the human ear is very sensitive to slight increases in low frequency energy even though it is believed that human hearing is not discriminating in this range as defined by the 'A' weighting sound curve which de-emphasizes low frequency sound thereby giving more weight to mid and high frequency sound.

In co-operation with the Ontario Ministry of Environment and Energy, state of the art low frequency noise criteria was proposed for the project. The selected criteria correlates the unweighted or 'flat' sound level with the dBA sound level.<sup>4</sup> Sound measurements taken on site verified that the design target of the active noise cancellation system is to attenuate low frequency sound emissions in the 25 Hz 1/3 octave band by at least 6 dB.

## **4 NOISE CONTROL DESIGN REVIEW**

Extensive research and cost benefit analysis of several noise control measures were undertaken prior to selecting active noise cancellation which was demonstrated to be the most practical and cost effective solution. Other mitigation methods analyzed included:

A) Aerodynamic redesign of upstream fan supports which were deemed to be one of the sound propagating mechanisms causing flow disturbances by promoting flow separation and propagating pressure fluctuations. This approach revealed structural constraints and uncertainty in the performance of potential modifications.

B) Silencer baffles were also investigated, but their installation and support would have been a difficult, costly structural operation. The WetSAC fan backpressure capability was found to be insufficient to withstand the sizeable pressure drop which baffles would introduce: a drastic reduction in efficiency and premature mechanical failure would be inevitable. And long term capital costs would be well over 5 times the total cost of the active noise cancellation system; energy savings inherent in the use of the active noise cancellation system are especially significant.

C) Helmholtz resonators - several tuned chambers built around the fan shroud and vented into the fan exhaust flow were also reviewed, but this method was deemed high risk and experimental due to the susceptibility of the resonator performance to flow conditions, and the significant construction effort required.

## 5 DEMONSTRATION OF ACTIVE NOISE CONTROL SYSTEM

Aercoustics carried out an active noise control demonstration as shown schematically in Figure 2 to determine the feasibility of the active noise control method in mitigating WetSAC low frequency noise emissions. Low frequency noise in the 24 Hz frequency range was reduced by at least 6 dB with the use of a horn loaded, compressor driven electro-pneumatic transducer and signal controller. Since the demonstration system equipment proved to be costly and maintenance intensive as a permanent installation, a study into achieving the same performance from a practical and cost-effective alternative was conducted.

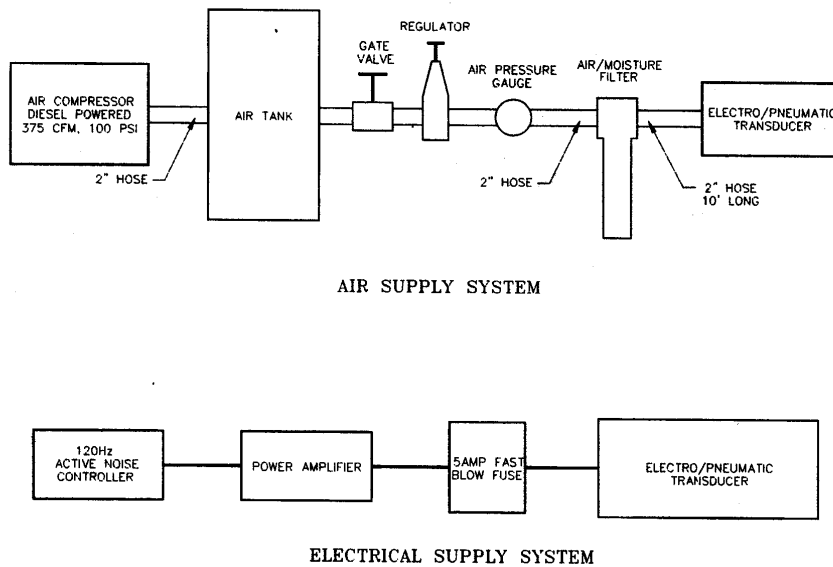


FIGURE 2: Schematic of Demonstration Noise Cancellation System

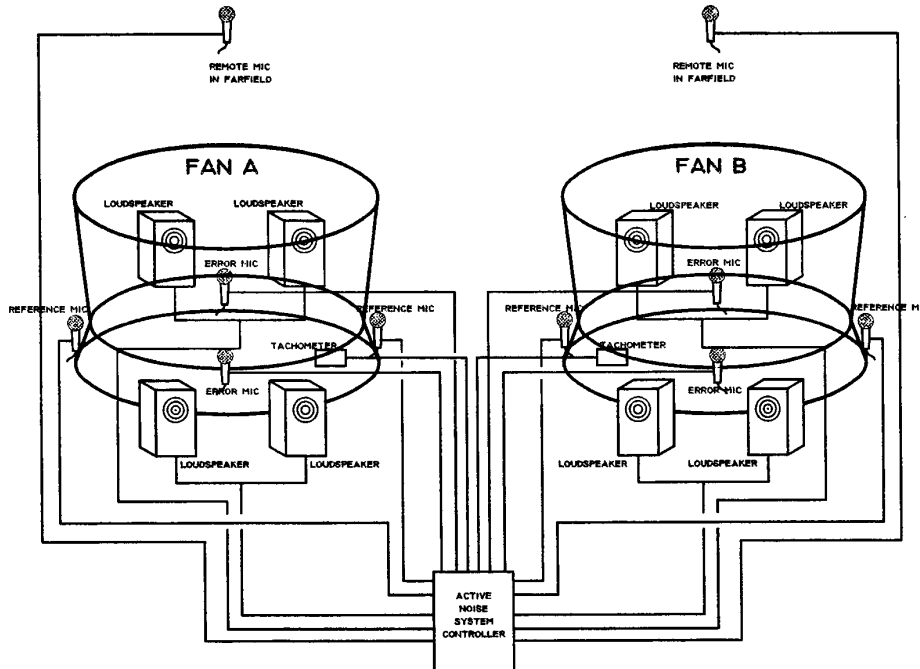


FIGURE 3: Schematic of Permanent Active Noise Cancellation System

## 6 PERMANENT SYSTEM DESIGN AND INSTALLATION

A permanent active noise control system which is shown in Figure 3 was engineered in the spring of 1994 and integrated into the overall operation at the OHSC facility that same summer. Several innovative and unique design features in the installation combine fundamental engineering principles of electrical, mechanical, acoustical and audio engineering with signal processing, instrumentation design and manufacturing quality control. These include custom designed and fabricated high precision loudspeakers and microphones as shown in Figure 4 which were manufactured in Canada, and designed to operate year round in the very humid WetSAC fan area over a temperature range of -40 to +40 degrees C. In particular, the microphone array has special built in provisions to prevent condensation and humidity problems as illustrated in Figure 5 which can severely impact transducer performance.

Kevlar diaphragm loudspeakers are housed in heated enclosures built to withstand the hostile outdoor environment. Each loudspeaker system was designed and specifically tuned to the frequency range of interest to meet a target sound level of 125 dB at 1m at 24Hz. In total, two sets of four loudspeaker enclosures housing 16 18-inch drivers were placed circumferentially around each respective WetSAC fan to optimize cancellation. In this configuration the axial acoustic centres of the source and anti-noise source are nearly identical, (within one eighth wavelength) a condition necessary to maximize noise cancellation.



FIGURE 4: Active System Transducers. Loudspeakers designed to withstand hostile environment.

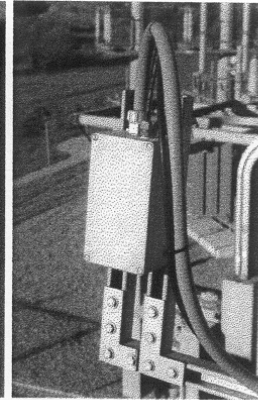


FIGURE 5: Weather Resistant Microphone

The active noise controller was designed to ensure that the offending noise source and cancellation sources would always be out of phase at the 23.8 Hz cancellation frequency. The system requires an absolute frequency reference for reliable operation. The frequency reference is supplied by a tachometer which is mounted at the fan drive shaft. There are also two reference microphones mounted on each fan shroud which provide the amplitude and phase reference of the fan noise. An error microphone mounted on each pair of loudspeakers monitors the amplitude and phase of the signal from the canceling noise source. This information is processed by the controller such that the error signal is always out of phase yet equal in amplitude with the reference signal. The loudspeaker output amplitude is modulated with up to 9000 Watts of available amplifier power to optimize cancellation of the fan low frequency noise. The sensitivity of the active noise cancellation system performance to phase and amplitude variations is illustrated in Figure 6.

Long term viability issues have also been addressed - the unit has been designed to shut down automatically if it malfunctions. In the event of problems with hardware, the system transducers all operate in pairs to ensure that a backup unit exists; microphones and loudspeakers are inspected daily and the system's performance is monitored live from the plant control room to ensure optimal cancellation.

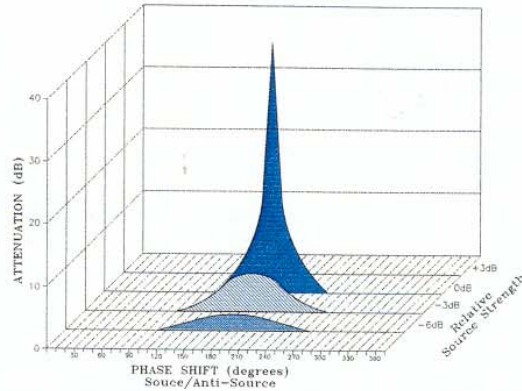


FIGURE 6: Illustration of System Performance Sensitivity to Phase and Amplitude

## 7 ACTIVE NOISE CONTROL SYSTEM PERFORMANCE

Sound measurements performed around the perimeter of the plant property typically indicate an 11 dB reduction (as high as 17 dB measured) at 23.8 Hz as shown in Figure 7 and a global cancellation pattern, since there are no regions where the anti-noise is adding to the offending noise. This is about twice the reduction possible through the traditional methods previously mentioned. Fan low frequency noise is about four times louder without the active noise cancellation system operating. This acoustic performance not only surpasses the six dB target but also confirms the expectations of high performance as a result of optimizing phase and amplitude characteristics and of aligning the acoustic centres of the anti-noise and offending noise sources. The Aercoustics active noise cancellation system has been operating reliably since August, 1994, and with the facility four times quieter than it was, there have been no noise complaints since its installation.

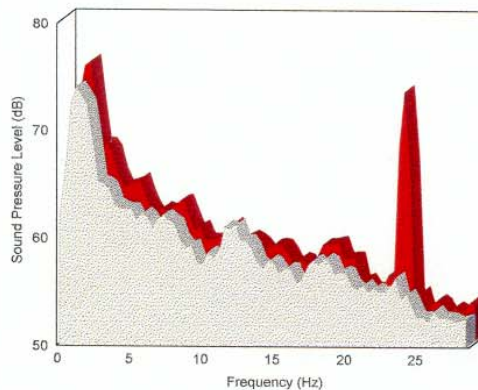


FIGURE 7: Narrowband spectra illustrating the reduction of the 23.8 Hz low frequency pure tone by up to 17 dB within the residential community.

## 8 CONCLUSIONS

AERCOUSTICS Engineering Limited has demonstrated the benefits of active noise cancellation by effectively mitigating environmental low frequency noise emissions at the Ottawa Health Science Centre Co-generation facility by 11 dB. The significance of this unique solution is supported by the long term cost savings and the superior acoustic performance of active noise cancellation over conventional noise control methods. Ideally suited for the control of low frequency pure tone noise sources such as industrial fans, transformers, wind turbines, arc furnaces, baghouses, combustion exhaust systems, active noise cancellation has many potential applications and it readily complements passive noise control techniques which are commonly used to mitigate mid and high frequency noise.

## 9 REFERENCES

1. Nelson, P.A., and Elliott, S.J., "Active Control of Sound" *Academic Press Limited*, 1993.
2. Hubbard, H.H., "Noise Induced House Vibration and Human Perception", *Noise Control Engineering Journal*, 1982.
3. Gambino, V., and Barman, M., "Discussion of Low Frequency Noise Criteria", *Aercoustics Engineering Limited*, November 4, 1994
4. Broner, N., Leventhall, H.G., "Low Frequency Noise Assessment by Low Frequency Noise Rating Curves (LFNR)" *Journal of Low Frequency Noise and Vibration*, 1983.

### NOTES:

- A. The authors would like to thank Mr. Denis Tremblay of Audion Limited, Messrs. Kimbull McAndrew, Richard Langhammer and support staff of TransAlta Energy Corporation for their valuable assistance with this project.
- B. This project was selected as a winner of the 1995 Award of Excellence by the Association of Consulting Engineers of Canada and the Canadian Consulting Engineer Magazine.