ACOUSTIC PERFORMANCE CONSIDERATIONS FOR A 'ONCE THROUGH STEAM GENERATOR' (OTSG)

Vince Gambino and Payam Ashtiani
Aercoustics Engineering Limited 50 Ronson Drive,
Toronto, Ontario, Canada, M9W 1B3

1. Introduction

Once Through Steam Generators (OTSG) are used by electricity power plants and a host of other industrial and/or commercial centers to recover the heat from a gas turbine exhaust stream. The OTSG works by passing the hot exhaust over tube bundles. The steam can then be either fed into a steam turbine generator to obtain electricity, or used for heating and humidification in a variety of applications. Figure 1 shows the standard arrangement of an OTSG in a typical cogeneration plant. An OTSG can attenuate gas turbine exhaust noise (Lw~150 dB re 1pW). Parameters governing the acoustic performance of an OTSG under both steam generating and dry running conditions are discussed herein.

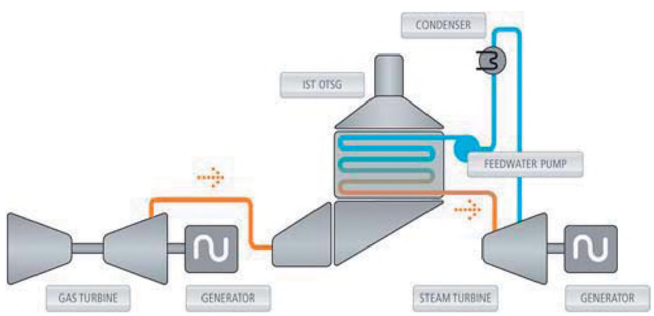

Figure 1 : OTSG in Cogeneration Plant

2. Sources of Noise in an OTSG

The OTSG is generally comprised of the following sections: The inlet from the turbine, inlet plenum (sometimes fitted with a silencer), environmental controls, tube bundles, exhaust hood and exhaust stack. The main source of noise in the OTSG originates from the aerodynamic and combustion noise. It is critical to have reliable input sound power from the gas turbine to the OTSG. The noise from the turbines exits the circuit in two ways: casing/wall radiated noise, and noise exiting from the exhaust stack. There is also some flow induced noise from the exhaust gas stream going through the various OTSG components. The interaction of this sound field with the various components inside the OTSG results in a significantly modified sound spectrum at the OTSG outlet. The acoustic performance of an OTSG cannot be determined from a simple speaker test alone that is conducted under ambient temperature and static conditions. The higher speed of sound and the regenerated noise from interactions of the gas flow with the OTSG components result in unique noise reduction characteristics that vary case by case.

3. Acoustic Environment inside an OTSG

Studies on the acoustic environment and related existing phenomena have been conducted on for HRSGs [4], and the prediction of sound attenuation using scale modelling techniques [2]. The following are areas of study that require systematic consideration when analyzing the noise control mechanisms, which dictate the acoustic performance of an OTSG.

3.1 Elevated Gas Temperature

Power systems involving Once-Through-Steam-Generators can be run in two modes: Simple or Combined cycle. Simple cycle mode involves the gas turbines running without producing any additional steam, i.e. no water is fed through the OTSG tubes and no steam is produced. In this mode, the temperature of the exhaust gas stream can reach near 650°C. In combined cycle operation the OTSG unit produces steam. In this mode OTSG inlet gas temperatures are near 815°C and approximately 95°C at the stack. This strong thermal gradient has a significant effect on affect the sound propagation through the OTSG.

3.2 Gas Flow Conditions & Flow Induced Noise

Gas flow from the exhaust stream of the gas turbine generators can reach or at times exceed flow velocities of 75 m/s at the OTSG inlet (i.e. exhaust of the GT). At these velocities, flow induced noise mechanisms such as vortex generation and other effects have the potential to become problematic in the OTSG. The insertion of environmental control stages and tube bundles inherently causes turbulence in the flow and can further augment flow induced noise and vibration, which can also give rise to fatigue damage.

4. Summary of Sensitive Parameters

4.1 Geometry

Geometry plays a major role in the acoustic performance of the OTSG. Area changes in the flow can cause acoustic reflections back upstream of the flow. The reduction due to partial sound reflection is a function of the ratios of the area change [1]. The design, however, should weigh in the benefits of the number of area change reflections with respect to the pressure drop caused by the area changes. Similarly, a change in the flow direction (for e.g. through L-Junctions) also provides attenuation at the cost of flow disturbance and increased pressure drop.

4.2 Casing construction

Casing construction is an important consideration to ensure that there are no acoustic compromises in the overall performance of an OTSG. The construction of an OTSG casing involves heavy and temperature resistant materials to ensure long term viability and to minimize heat loss. A typical construction will have an isolated internal shell, typically made of a moderate gauge steel plate, and an outer shell typically with a heavier/thicker steel construction. The two layers are usually separated by ceramic fibre or similar insulation. Low frequency noise reduction is crucial in this application, so it is important to keep the mass and stiffness of the casing wall high in order to attenuate sound in this frequency range.

4.3 Tube bundle arrangement and flow considerations

Tube banks have the ability to reduce noise due to reactive effects of cross sectional area changes as seen by the flow, as well as propagation losses due to the flow resistivity of the tube bundles (viscous loss). The location and orientation of the tube bundles must be very carefully considered in the design. There is potential for flow induced acoustical vortex shedding which can potentially give rise to significant flow related acoustic and structural integrity concerns. Several studies

[3] [5] show the potential effects of flow through different tube bundle arrangements. The analysis involves obtaining a Strouhal number, *S*, based on tube separation ratios. The vortex shedding frequency is then $f_{VS} = S \times V_{\max} / D$ (Hz). The frequency *f* is dependant on the flow velocity V_{max} and the diameter *D* of the tubes in the array. Care has to be taken to ensure that the vortex shedding frequencies do not coincide with the resonant frequencies of the tubes or other structures, or with the acoustic modes in the OTSG duct and plenum. It is also important to consider the effects of any environmental controls, plates, cavities or any other obstructions that may impede the flow.

5. Conclusion Remarks

OTSG's can be are quite effective in mitigating the noise emissions from a gas turbine exhaust. Successful designs minimize vortex generation, detune acoustic and/or structural resonances. The degree of noise reduction that can be realized is illustrated in **Figure 2**. The OTSG affords significant attenuation over the entire audible range.

6. References

[1] **Leo L. Beranek,** *Noise and Vibration Control (Revised Edition),* Ch11 (I. L. Ver, C. I. Holmer), Institute of Noise Control Engineering, 1988.

[2] **M. Bracken, M. Barman and V. Gambino,** *Prediction of Heat Recovery Steam Generator (HRSG) noise attenuation using scale model testing,* Aercoustics Engineering Limited, Proceedings of the Spring Environmental Noise Conference, Alberta EUB, 1996.

[3] **S. Joiner,** *Acoustical Analysis of Nepco-Brownsville Peaking Plant,* Innovative Steam Technologies (IST), November 1998.

[4] **G. F. Hessler,** *Issues in HRSG System Noise,* Proceedings at the 1997 NOISE-CON at Pennsylvania State University, June 1997.

[5] **F. L. Eisinger and R. E. Sullivan,** *Unusual Acoustic Vibration in Heat Exchanger and Steam Generator Tube Banks Possibly Caused by Fluid-Acoustic Instability,* Journal of Engineering for Gas Turbines and Power Vol. 115,pg 411, April 1993.

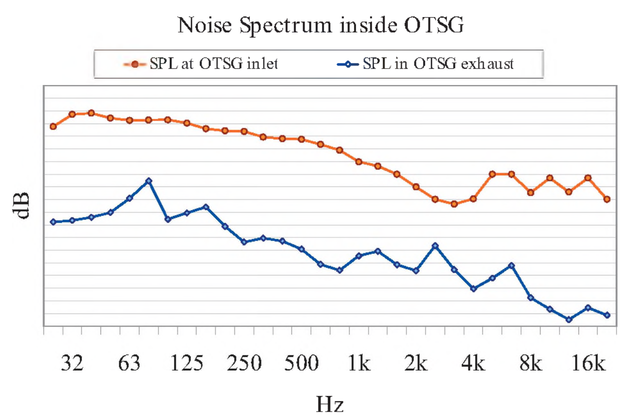

Figure 2: Sound at the inlet and discharge of an OTSG. 1/3rd octave sound level spectra were obtained using a calibrated high temperature microphone assembly with an anechoic termination.