PREDICTION OF HEAT RECOVERY STEAM GENERATOR (HRSG) NOISE ATTENUATION USING SCALE MODEL TESTING

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1 INTRODUCTION

The sound attenuation provided by the gas flow path of the Heat Recovery Steam Generators (HRSGs) has been a matter of much interest to both the acousticians and the HRSG manufacturers. Although there is some measured data available, it is difficult to generalise these numbers for all HRSG configurations.

In general, there are four mechanisms of HRSG noise attenuation:

- membrane absorption at the interior surfaces
- reactive attenuation in the gas flow path
- attenuation due to diffusion and scattering of sound
- propagation loss due to the flow resistivity of the tube bundles (viscous loss)

This study examines whether scale modelling is effective for the second, third and fourth of the mechanisms listed above. Recent developments in Acoustic Scale model testing have been used to investigate the effects of tube bundle spacing and the quantity of tube rows, on the noise attenuation properties of HRSGs. This paper outlines the systems used to conduct this research and some initial results of the scale model testing. The ultimate goal of this research will be a computer algorithm to predict the acoustic performance of an HRSG, based on the various design parameters.

At this stage, the effect of membrane absorption is assumed to be minor compared to the reactive effect, and will be added mathematically to the modelling results if it is found that this effect is significant.

At the outset of the project, it was postulated that the noise reduction in the mid to high frequency range would be a function of the flow resistivity. Also of interest is whether low frequency modes in the model are sufficiently excited by the model noise source so that the reactive effects are modelled adequately. If the method is found to be effective, a large number of

HRSG configurations could be tested at very little cost, and an accurate prediction methodology developed for HRSG attenuation.

2 THE MIDAS SYSTEM

Scale model testing has traditionally been used for the modelling of concert halls and other acoustically sensitive spaces. In the past the modelling techniques have required large models, in the order of 10:1 scale in order to achieve adequate high frequency response. At smaller scales than this, the scaled frequencies are subject to high levels of air absorption and humidity effects.

MIDAS is a state of the art measurement system which allows models as small as 1:50 to be built and tested. A typical mid frequency band of 500 Hz is scaled to 25,000 Hz. At this frequency, the impulse response of the scale model must be measured with a system capable of a very high sampling rate. A microphone capable of ultrasonic measurements must also be used. The MIDAS system uses a national Instruments NB-A2000 board capable of sampling frequencies as high as 1 MHz. The microphones used are 1/8" in diameter with frequency response up to 160 kHz. The exaggerated sound absorption of the air at these high frequencies is numerically compensated by MIDAS (1).

The system requires that a noise source capable of both high frequency sonic, and ultra sonic sound be used to generate an impulse signal. The noise source for the purposes of this modelling was supplied by a high voltage spark source.

3 SCALE MODEL

In order to test the effectiveness of the proposed method, a model of an HRSG was constructed based on actual design drawings for a project currently under construction. The model, shown in Figure 1, was constructed of core board for the outer shell, and a PVC pipe was used for the stack.

The tube bundles were built in banks with a geometry almost identical to the actual HRSG. The tubes were modelled with 18 gauge wire, and over a kilometre of wire was required for the model. The wires are held at the top and the bottom using perforated sheet metal matched as closely as possible to the geometry of the tube bundle pattern.

The noise source was placed at the bottom, towards the beginning of the transition duct. Sound level measurements were performed at 4 locations along the HRSG, and at one location in the stack above the breech. Figure 1 below shows a photograph of the model, seen with the microphone at one of the data acquisition points. The data acquisition system runs on a Macintosh computer system which can be seen in the background.

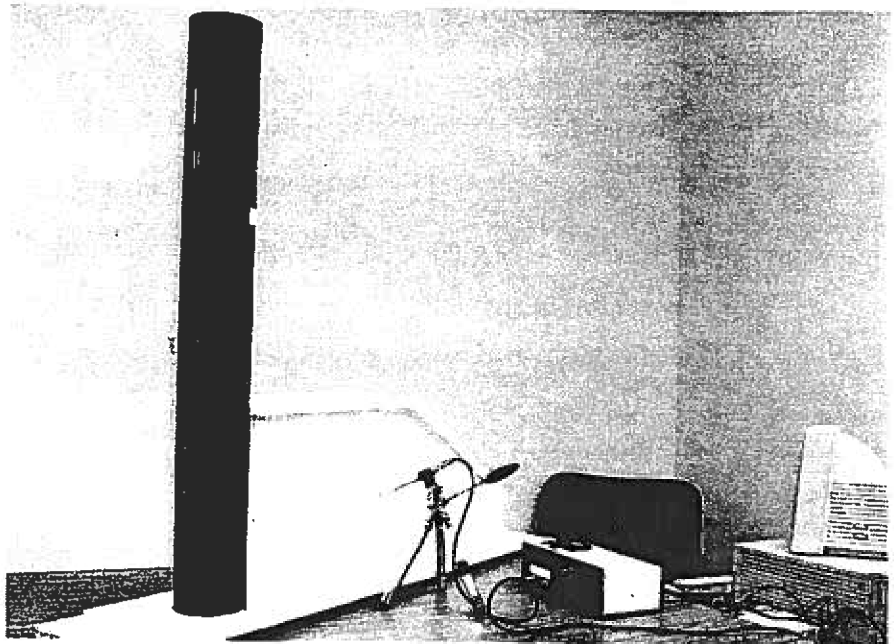

Figure 1: HRSG Model and Data Acquisition System

4 BACKGROUND THEORY

The possibility of performing predictions of the sound attenuation through HRSGs using a mathematical model to determine the flow resistivity, has also been investigated. The behaviour of sound waves in a porous medium depends on the relation of the wavelength of the sound to the thickness of the material. In the case of tube bundles, the behaviour will be controlled mainly by viscous effects.

In order to determine the expected magnitude of the viscous effects, calculations were performed to determine the expected flow resistivity of the tube bundle in the HRSG modelled, and to calculate the theoretical sound attenuation due to viscous effects.

The viscous attenuation through the heat exchanger tubes was predicted using a typical pressure drop through the HRSG of approximately 10" WG, and a gas velocity of approximately 8 m/s. The flow resistivity with these numbers is estimated to be 311 mks rayls, which would correspond to a total attenuation in the order of 6 to 7 dB at 4000 Hz. Since the attenuation through the boiler at this frequency is expected to be 40 dB or more, it is evident that the dominant mechanisms of higher frequency attenuation are the reactive effect, and the diffusion & scattering of sound.

Predictions of the expected reactive effects for the HRSG without tube bundles have been carried out using reactive modelling techniques (2). This modelling was done to evaluate the results of the calibration tests of the scale model without tube bundles installed. It is difficult however to theoretically model the diffusion and scattering effects of the tube bundles, and the influence of the tube bundles on the reactive effect of the HRSG. This is where scale modelling techniques are superior to computerised methods such as ray tracing or finite element. Due to the complexity of the sound attenuation mechanisms in an HRSG, none of these theoretical methods would provide accurate results.

5 PRELIMINARY MEASUREMENT RESULTS

Preliminary measurements were performed to determine the acoustic response of the HRSG with none of the tube bundles installed. Under the simplest of measurement conditions, these can be used to assess the limitations of the modelling technique, and to perform system calibration.

One of the main objectives of the preliminary measurements was to determine if it would be possible to model the reactive effect of the HRSG using these modelling techniques. These preliminary results indicate that the attenuation measured without the tube bundles in place is very close to what would be expected with an unlined plenum using end-in side-out theory (2). This result is significant, in that if additional testing confirms this observation, the reactive effect of any HRSG could be modelled relatively simply, for a model cost of only several hundred dollars.

6 FUTURE MEASUREMENT PROGRAM

At the time of printing, Aercoustics is in the process of additional testing, and the compilation of a data base to develop a prediction methodology for the estimation of HRSG attenuation. Measurements will be done for a variety of tube bundle configurations to determine the sound propagation characteristics through bundles with varying depths and pitches. Other HRSG geometries which will be tested include the 'once through' design, which is considerably different from a conventional HRSG design. Modelling results will be compared to in-situ measurements of HRSG attenuation performed with the loudspeaker systems.

8 CONCLUSIONS

Aercoustics has constructed an accurate scale model of a Heat Recovery Steam Generator (HRSG) for acoustic modelling purposes. The model will be tested with the MIDAS Package for small model acoustic testing. Preliminary measurements have indicated that it will be possible to model reactive effect, viscous loss and diffusion & scattering.

9 REFERENCES

1. Polack, J.D., Marshall, A.H, and Dodd, G., "Digital Evaluation of the Acoustics of Small Models: The MIDAS Package", J. Acoustic Soc. Am.,85, 185 (1989).
2. Ih, J.G., and Lee, J.S., "Low Frequency Characteristics of Unlined End-in/Side-out Rectangular Plenum Chambers", Journal of Noise Control Engineering, (2) vol. 40, 1993.