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A PARAMETRIC STUDY OF THE SENSITIVITY OF COMBUSTION TURBINE INLET SILENCER INSERTION LOSS TO THE FLOW RESISTIVITY OF THE ABSORPTIVE ELEMENTS

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ABSTRACT

Silencers used in compressor inlets in industrial gas turbine based power plants typically use fabric blankets in order to retard the gradual erosion of the bulk absorptive material. The blanket ideally provides low specific flow resistance, although each silencer design involves an optimum specific flow resistance. Blankets which are heavier and thicker are more effective in retarding bulk material erosion, but if the specific flow resistance is greater than the optimum, the acoustical performance of the silencer is degraded. This parametric study quantifies the effect which a greater than optimum specific flow resistance of the blanket material has on the sound emissions from industrial gas turbine inlets, for a variety of silencer geometries.

1 - INTRODUCTION

Industrial gas turbine noise control has long employed absorptive silencers on both the inlet and exhaust gas streams. These silencers typically use glass, mineral or ceramic fiber fabrics as a blanket to enclose the less durable bulk acoustical absorptive material. This paper will address only large industrial gas turbine inlet silencers. The inlet silencers evaluated shall be of the conventional parallel splitter passive absorptive baffle type.

2 - GENERAL DISCUSSION OF THE PROBLEM

The theoretical basis for the prediction of the acoustical performance of absorptive silencers is well documented [1,2]. The typical inlet silencer for a large industrial gas turbine is constructed using a perforated steel sheet exterior surface on each silencer baffle face to enclose the bulk, acoustically absorptive, material. Practical considerations of construction assembly and operating conditions requires that the bulk absorber be separated from the inner surface of the perforated sheet. The bulk materials commonly used would otherwise tend to break down over time, due to operational mechanical and flow stresses. The bulk absorber material is typically assembled into pillows wrapped with glass fiber fabric. In special cases, enhancements such as an added layer of fine mesh screen, or a secondary layer of cloth or felted fibers beneath the fabric, may be used to separate the perforated sheet from the pillow.

The principal design parameters governing the acoustical performance of the silencer are the baffle gap width, the baffle thickness (which together define the Open Area), the acoustically effective baffle length, and the effective acoustical absorption exhibited by the combination of bulk absorbers and fabric wrap. This analysis will demonstrate the impact on far field sound level of a high specific flow resistance (SFR) for the fabric wrap.

Silencer manufacturers and designers recognize that the SFR of the wrap material must be controlled in order to minimize the adverse effects on overall silencer insertion loss performance. A trade off is necessary, however, between an optimal (usually low) SFR and the durability of the cloth wrap. If the durability is too low the purpose of the wrap is defeated. A high durability, however, for a given type of fabric, means high SFR, which directly compromises overall silencer insertion loss.

Field data from operating large gas turbines have been obtained over a broad range of SFR, in excess of a factor of 10, and for a variety of materials. With this data, it is possible to generalize on the relationship between the resistance of the wrap and the audible sound in the far field.

3 - PARAMETERS

While a variety of gas turbine silencer designs have been developed, the typical design uses the parallel absorptive baffle configuration described above. The fibrous material used as the primary acoustical bulk absorber may be mineral wool, glass fiber, ceramic wool, or basalt wool. The acoustically absorptive fill material, comprising the majority of the baffle absorptive material, will be referred to herein as the bulk absorber. The importance of the bulk absorber to this discussion is its characteristic flow resistivity given in units of mks rayls per meter (Pa*s/m^2), and determined by means of a standardized test [3]. The specific flow resistance (SFR) of a wrap material is given in units of mks rayls (Pa*s/m) and is determined similarly by means of a standardized test [3].

The flow resistivities for the bulk absorber may be in the range of 15,000 to 40,000 or more, mks rayls per meter. As in the case of the wrap material, there is an optimally effective flow resistivity for a given silencer design. This analysis will assume a fixed 35,000 mks rayls/m. Furthermore, this analysis will consider the wrap material to exhibit SFR values over a range from 250 mks rayls to values greater than 3000 mks rayls. This is intended to approximate the range of typically available and commonly applied fabrics.

A note is in order regarding the accuracy and precision with which the flow resistance of such fabrics may be defined. The recognized procedure to quantify a fabric's flow resistance is ASTM C522, the standard test method for air flow resistance of acoustical materials [3]. The Precision and Bias statement in ASTM C522 states that the reproducibility, defined as the 95% confidence interval, even for uniformly controlled samples, is expected to be 15% to 20% over the full range of expected flow resistivities (or SFR) of typical acoustical materials. Also, for any given fabric, there is an expected variability in the measured flow resistance of 15% to 30% [4] due simply to variations in the manufacturing process. Lastly, reports of interlaboratory testing of uniformly controlled samples exhibiting expected resistances in the region of interest for fabric wraps, suggests that the interlaboratory reproducibility of measurements in this range of SFR, below 3000 mks rayls, deteriorates with progressively lower SFR values [5]. Therefore, the sensitivity of silencer performance as a function of wrap SFR must be carefully considered in order to minimize risk. Such risks result from the use of materials that may exhibit, in the field, a flow resistance significantly different from the expected value, whether due to manufacturing variability, or the inherent accuracy in testing for SFR itself.

4 - STATEMENT OF THE PROBLEM

Table 1 presents the range of gas turbine silencer design parameters considered. During design it is important to know the degree to which the silencer insertion loss will be affected as a function of the wrap material SFR. More specifically, the degree to which the silencer acoustical performance, in terms of far field A-weighted sound level from the gas turbine inlet, is degraded through the use of a wrap material exhibiting a higher than optimum SFR must be understood.

PARAMETER	RANGE
Silencer Length	1800 mm – 3000 mm
Baffle Airflow Gap	75 mm – 150 mm
Baffle Thickness	75 mm – 150 mm
Open Area	33% – 50%
Ratio (Wrap SFR)/(Optimum Wrap SFR)	1 – 10
Ratio (Wrap SFR)/(Bulk Absorber Resistivity)	.007 to.0714

Table 1: Range of parameters considered.

Table 2 presents a hypothetical, normalized, sound power spectrum intended to represent the family of currently available large industrial gas turbines.

	Octave Band Center Frequency in Hz								
	31.5	63	125	250	500	1K	2K	4K	8K
PWL	0	4	12	19	26	30	23	20	20

Table 2: Hypothetical normalized gas turbine inlet sound power spectrum.

This spectrum shape will be used to assess the influence of absorber wrap resistance on the far field A-weighted sound level from the gas turbine inlet. The example far field position to be evaluated for comparison purposes, is a standard 120 meters from the face of the hypothetical inlet filter house [6]. Only the sound propagating through the silencer gas path and out through the inlet filter will be considered. Other sound emission paths, such as the breakout noise through the gas turbine inlet duct, are not considered.

5 - RESULTS

Figures 1, 2, 3 and 4 present the parametric trends developed for a select range of silencer configurations. This parametric study shows the effects of varying SFR on the far field A-weighted sound level.
The abscissa of each figure is the ratio of the SFR of the wrap material being evaluated to the optimum SFR for a given silencer configuration. The ordinate of each figure is the increase in A-weighted sound level of the gas turbine inlet sound emission, as would be measured at a position 120 meters from the open face of the gas turbine inlet silencer.
The silencer configuration is defined by the baffle thickness, the Open Area of the silencer, and the "L/D" ratio, all noted on each figure. In this report "L/D" refers to the ratio of the airflow gap width to the total effective length of baffle. It must be noted that each figure presents the trend for three different silencer lengths, but that the analysis uses a different optimum wrap SFR for each of the three silencer lengths.
It should be emphasized that these results are generated using a proprietary analytical silencer design algorithm, but that the algorithm has been verified, and 'calibrated', using full scale tests representing the full range of parameters considered. It is expected that the same general trends would result using other algorithms for the determination of silencer insertion loss. If such trends are not indicated by a particular algorithm, a review of its efficacy may be in order.

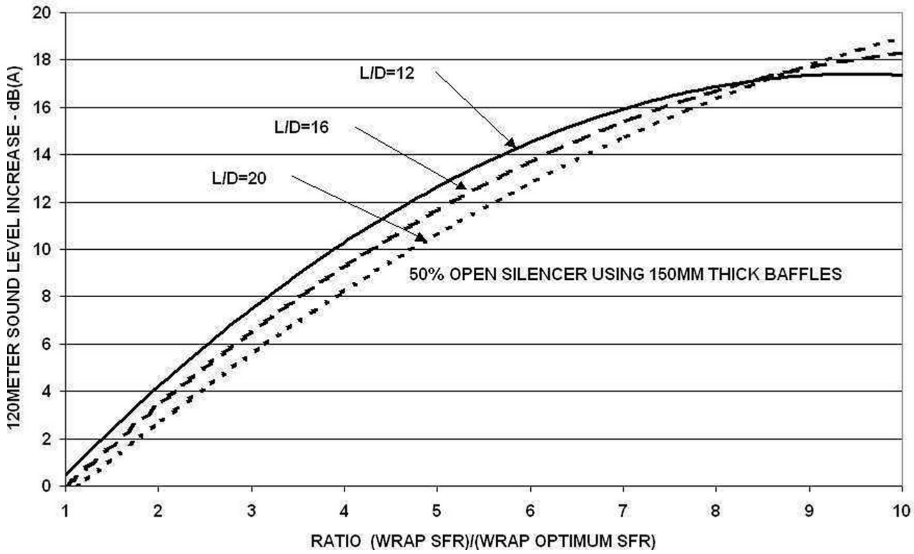

Figure 1: Parametric trends for the 120 meter far field A-weighted sound level from gas turbine inlet. 50% open, 150 mm thick baffle.

6 - CONCLUSIONS

The results of this parametric study quantify the impact on far field A-weighted sound levels from the inlet of a gas turbine, using a sound power level spectrum representative of the gas turbine industry. This data may be considered when establishing the permissible range of wrap SFR to be specified. In addition, it may be used to quantify the risk of non-compliance, in terms of A-weighted sound level, to be anticipated from SFR variations when specifying a given wrap material.

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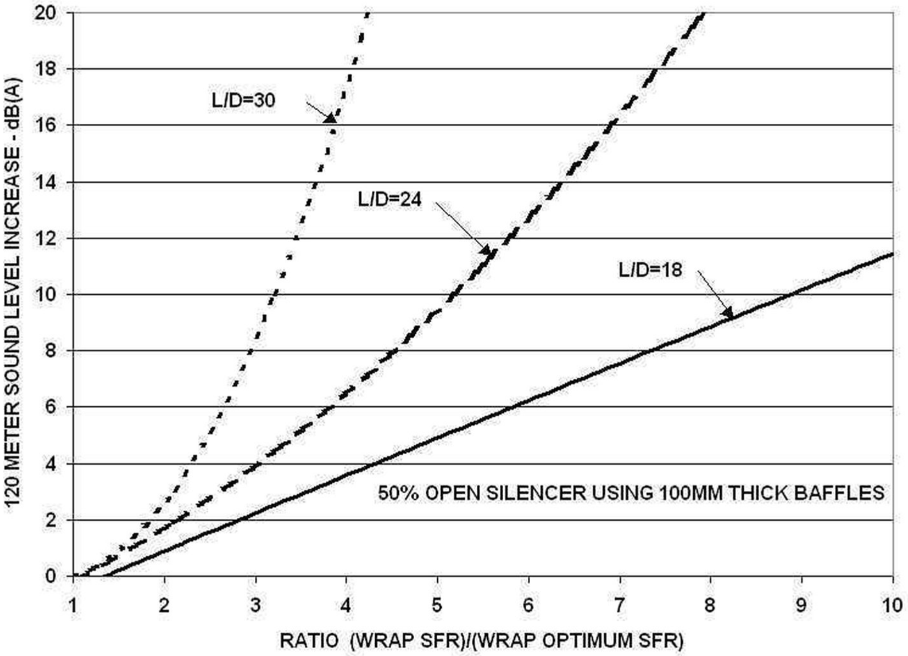

Figure 2: Parametric trends for the 120 meter far field A-weighted sound level from gas turbine inlet. 50% open, 100 mm thick baffle.

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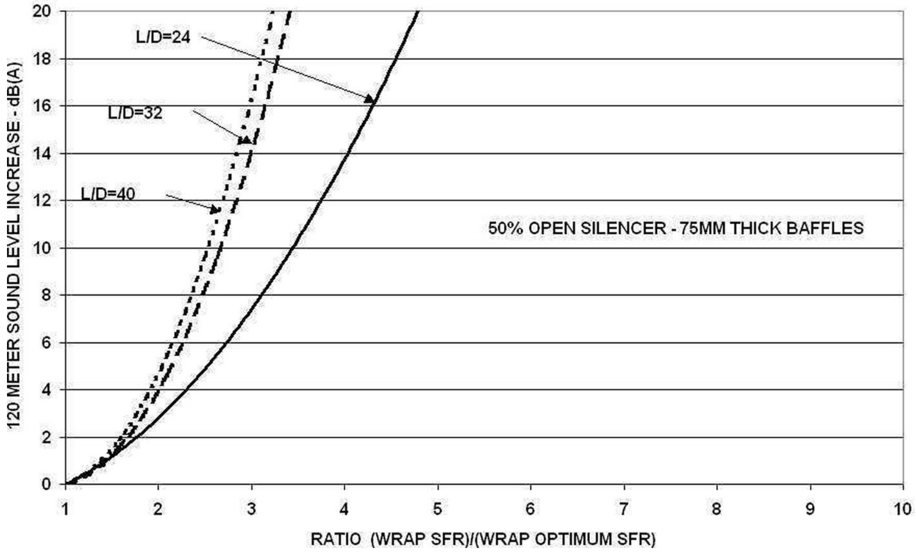

Figure 3: Parametric trends for the 120 meter far field A-weighted sound level from gas turbine inlet. 50% open, 75 mm thick baffle.

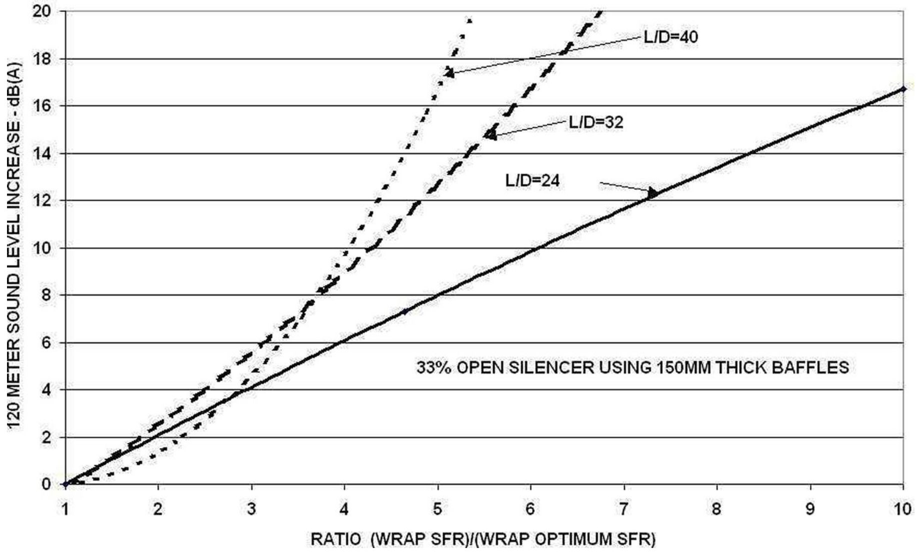

Figure 4: Parametric trends for the 120 meter far field A-weighted sound level from gas turbine inlet. 33% open, 150 mm thick baffle.