Proceedings of The Institute of Acoustics

USE OF AN EJECTOR SILENCER FOR STEAM VENT SILENCING

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Abstract

The silencing of steam vents sufficiently to satisfy good environmental standards is often both expensive and difficult to implement. To overcome these difficulties a lined ejector silencer with its advantages of design simplicity and uncritical response can be used. Some results are examined here for an ejector configuration of jet area ratio varying from 2 to 6 and length to jet diameter ratios up to 16. The results are compared with established jet noise prediction methods and the ejector models of Middleton (1) and Dyer (2). In addition, the use of an ejector with other jet terminations is discussed.

Introduction

Changes in operational pattern and other factors have made necessary the recent installation of a considerable number of steam vent silencers particularly on plant pre-dating the modern 500 MW units. The ejector design is often capable of meeting the noise reduction specification and is economic in manufacture.

Description of Rig

The silencers were tested on a modified superheat safety valve fitted with a critical flow orifice downstream of the safety valve for flow measurement. Sound level measurements were recorded from a six channel microphone array set in a circular arc at a distance of 5m from the vent. On the assumptions of spherical symmetry and no extreme directivity sound power levels could therefore be calculated.

The Steam Jet

Measurements taken at specific angles to the jet were compared with the SAE predictive method (3) which is based on accepted scaling laws and detailed experimental results. The agreement at the narrower angles to the jet, say less than 50° was considered acceptable for an experiment of this type. At wider angles to the jet an increasing 'excess' noise becomes apparent particularly at mid-frequencies. By adding in line silencers to the jet exhaust the correlation could be largely re-established.

The Ejector

The principle of the ejector silencer is easily understood and is illustrated in Figure 1. The small high velocity jet is transformed into a larger slower moving jet. By using a lined ejector noise generated by the developing inner jet can be substantially removed giving a maximum possible noise reduction of

USE OF AN EJECTOR SILENCER FOR STEAM VENT SILENCING

$$PWL = 80 \log_{10} \frac{V_J}{V_E} - 10 \log_{10} \frac{A_E}{A_J}$$

The measured noise reduction would be expected to tend towards this result as the length of the ejector was increased. The measurement of the ejector velocity V_E was beyond the scope of this investigation and so comparison was made with values estimated by using data from elsewhere. Some experimental work by Middleton (1) gives values of V_E for similar conditions using a model air jet. A theoretical approach by Dyer et al (2) gives an analytical solution for V_E for an unconstrained jet exhausting into an identical fluid. Although to be treated cautiously comparisons are made in Figure 2 for an ejector with an expansion ratio $A_E/A_J = 4$. It can be seen that there is a steep increase in insertion loss as the ejector length is increased and it would clearly have been interesting to have proceeded further, until the limiting point. This maximum measured insertion loss coincides with that calculated by Dyer for an unconstrained jet of similar velocity and temperature, but this is in exception to the experimental work quoted by the same author. The sound power reduction calculated from Middleton's data underestimates that measured particularly if an excess velocity term is included. The excess velocity term is empirical and allows for the peaked velocity profile at the ejector efflux. The correction is given by

$$PWL^* = 40 \log_{10} \frac{V_{PE}}{V_E}$$

Where V_{PE} is the peak velocity in the ejector efflux.

The lack of a clear relationship between the results of these experiments and the quoted work may have several minor contributory causes but there is a qualitative explanation in the known presence of a large 'excess' noise component in the vent radiated noise. The efficacy of the silencer would thus be controlled by the rate at which excess noise is attenuated until the noise floor set by the reduced jet noise level is reached.

The point is not of great contention but as most subsonic blow off vents and similar discharges will contain a degree of 'excess' noise it follows that estimates of noise reduction for a lined ejector design using data based on pure jet noise are likely to be conservative. The use of such a silencer should not therefore be rejected on that basis particularly as it can have considerable economic and mechanical advantages over other designs.

Ejectors of different area ratio $A_E/A_J = 2.0$ and 6.0 were also tested and the results are shown in Figure 3. Although the calculations using Dyer's equations show fair agreement, in view of the known excess noise content this may be misleading. The main practical point is the lack of variation of insertion loss with area ratio. In situations where the steam flow rate and conditions can be predicted only within, say $\pm$ 50%, this insensitivity is very useful.

USE OF AN EJECTOR SILENCER FOR STEAM VENT SILENCING

Use of Diffusers

Where a silencing capability greater than 15 to 20 dB is required a diffuser may be used in conjunction with the surrounding lined ejector. For some diffusers such as (a) or (b) in Figure 4 the ejector action is lost whilst for type (c) this action remains but a lower insertion loss results. Combinations of these diffusers with outer silencing elements up to the lengths used for the ejector silencers will give insertion losses in the range 20 to 40 decibels.

Conclusions

A lined ejector silencer has been used successfully on subsonic steam discharge vents and has proved an economic and uncritical design. Insertion loss measurements are in reasonable agreement with calculations for an unconstrained jet but the presence of jet excess noise confuses this result. In conjunction with a diffuser a different type of silencer results capable of an insertion loss up to 40 decibels.

References

(1) D. MIDDLETON. JSV Vol. 11, No.4, 1970, Pags. 447-473. Theoretical and experimental investigations into the acoustic output from ejector flows.

(2) J. DYER; P.A. FRANKEN and P.J. WESTERVELT. JASA Vol.30, No.8, Aug. 1958, Pags. 761-764. Jet Noise Reduction by Induced Flow.

(3) SAE Document ARP 876. Gas Turbine Jet Exhaust Noise Prediction.

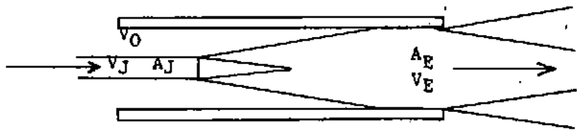

Figure 1. Showing the jet structure within an ejector.

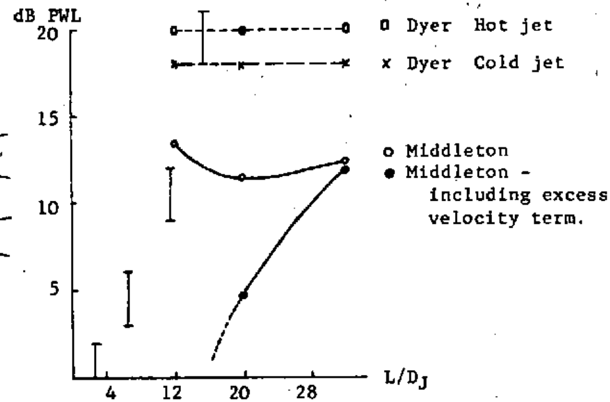

Figure 2. Ejector silencer. A_E/A_J = 4.0 Theory and experiment.

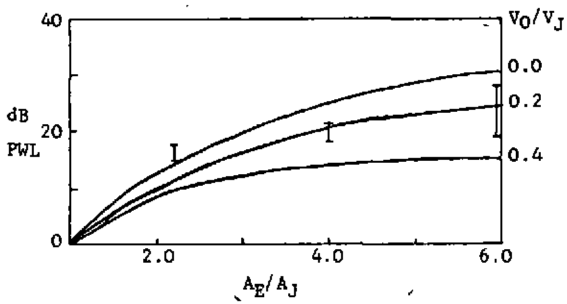

Figure 3. Comparison with Dyer's Equation L/D_J = 16; T_J/T_O = 2.

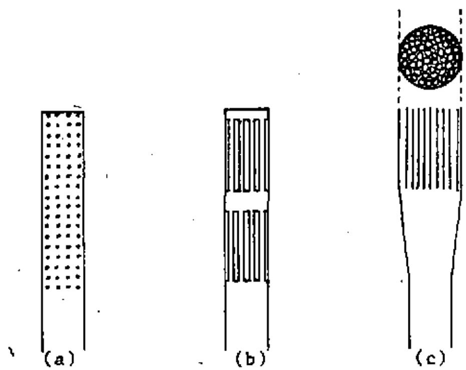

Figure 4. Diffuser Types, (a) Perforated, (b) Slotted, (c) Multitube.