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Use of Computers for Analysing noise in Mechanical Services systems

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Introduction

The calculation of the amount of noise reduction necessary to meet a given noise criterion in a low velocity ventilation duct system is a laborious process. The presence of noise generated by high air velocity, and breakout from ducts in modern systems present additional problems which, hitherto, have been beyond the scope of the practising engineer.

This paper describes the application of digital computers to such problems. By the use of simple computer programs, not only can conventional low-velocity systems calculations be speeded up, but the complex effect of velocity-generated noise and breakout noise on silencing requirements can be analysed. The space advantages of using high velocity systems are quite significant, and thus high velocity systems will continue to be increasingly used in modern developments.

At the present time, unfortunately there is no comprehensive or easy method for designing such systems. To begin with estimation of velocity generated noise of a component is rather difficult in itself. It depends on a number of different factors, and most correlations describe velocity generated noise as functions of the Strouhal Number. Added to this, there were until recently very few correlations in existance anyway.

By the very nature of this noise generation, silencing applied just downstream of the fan in the conventional manner, would be completely ineffective since the problem noise would be that generated in the system downstream of the silencer.

The first reaction therefore might be to put the silencing treatment not after the fan but at each duct termination. The complication then, however, would be the presence of noise transmitted to the ceiling void or conditioned space through the duct walls (breakout noise). This breakout noise is largely dependent upon the sound power level existing in the duct, the duct dimensions and material of which it is fabricated. Although breakout noise can be minimised by lagging the exterior of the duct, the most economical way to deal with the problem is to reduce the in-duct sound power level. This, unfortunately, cannot be achieved if all the attenuation is placed at the duct system termination. Clearly, the need is to evaluate the influence of all the noise sources simultaneously in order to optimise the amount and location of attenuation. Using manual methods, such a comprehensive analysis is beyond the scope of a practising engineer and hence an aid such as the digital computer becomes necessary.

The solution

In order to provide a complete analysis of the problem, it is necessary to consider the transfer of velocity-generated noise in both directions from the source, i.e. both upstream and downstream. The implications of this are far-reaching. To evaluate a standard duct system, one has to consider, first, the duct-borne noise of the fan and, second, the velocity-generated noise from each duct component - travelling both upstream and downstream of that component - and then to evaluate the combined effort of the velocity-generated noise and the fan noise at each individual location along the duct system. It is, similarly, necessary to consider duct break-out noise as a combination of both fan and velocity-generated noise.

With all these sources being considered simultaneously it is essential that a form of optimisation of attenuator selection and location is used to achieve the most effective and economic solution for the system under consideration. On page 4 is shown the logic sequence of the particular technique which is dealt with in this paper and which works in the following manner.

The basic principle is that, in general, it is more satisfactory - both economically and technically - to place the major sound attenaution as close to the fan as possible, rather than to use terminal attenuator units. Initially the computer program calculates the main attenuation required (F) by a standard calculation procedure rather similar to the 'Woods' Guide. The second stage of the program investigates the duct work layout, evaluates noise generated by air velocity, and computes the terminal attenuation requirements (T). This, of course, may result in the total attenuation for the system, (i.e. primary fan silencing and terminal silencing - F. & T.) being larger than is required for purely fan noise itself (F). The program then investigates breakout noise due to the fan noise and, thus, attenuation at the primary fan silencer may then be increased or decreased in order to cope with localised breakout problems.

In practice two complementary computer programs (HVAA and LVAA) are used to calculate the optimum silencing requirements. Referring to Fig. 3, HVAA includes steps 1-12, and LVAA, steps 13-17. Steps 18 onwards are completed by examination, following interaction between the user and the programs, since they require decisions, rather than tedious calculations. The reason for using two separate programs, rather than one combined, is that initially the velocity-related noise levels are calculated for the whole system and are displayed. From the results it is possible to select critical branches or areas and to input these into a standard low-velocity system program and to optimise the results for both dynamic and 'static' analyses.

Conclusion

Whilst, theoretically, it is not impossible for these calculations to be performed by hand the consistency and speed with which they can be carried out using a computer means that it is fairly straightforward for a general mechanical services engineer to analyse the noise generated in a duct work system and it is possible to be sure that this analysis will, in fact, be carried out. Many of the problems which have occurred, and which we are sure will continue to occur, due to excessive velocities, may not have been investigated during the design stage of the project purely because of the amount of work which is necessary when using a manual method.

The technique and programs outlined in this paper have now been proven in practice and have recently been used to establish optimum silencing for a modern building complex at Liverpool which has a gross floor area of 49,000 m^2. The office accommodation is fully air-conditioned, and the complexity of the system meant that the computer programs described in this note were the only practicable means of assessment.

The efficiency with which an analysis can be performed using a computer enables the design to be investigated for potential noise problems at fairly early stages of a project, when it is not too expensive to make design changes, and enables acoustic treatment to be minimised. In addition, several designs may be considered and the acoustic repercussions evaluated, at little additional cost.

References:

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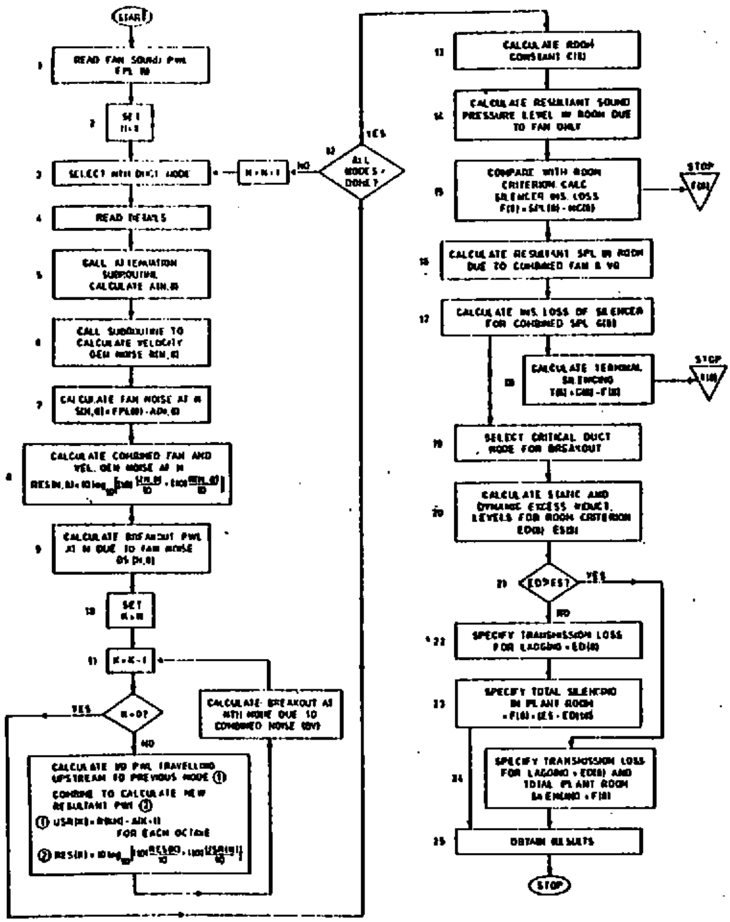

Steps in the calculation process. Note: all are arrays of eight elements each element being an octave band value.

FPL (8) Fan power level spectrum
A (8) Attenuation spectrum of duct fittings
R (8) Velocity-generated noise spectrum
USR (8) Upstream travelling component of R (8)
S (8) Static power level spectrum at one point
RES (8) Combined power level spectrum (fan and vel. gen. noise)
BS (8) Duct breakout PWL spectrum due to static induct PWL
BV (8) Duct breakout spectrum due to combined PWL
C (8) Room constant
NC (8) Noise criteria spectrum
SPL E Resultant sound pressure level spectrum due to static source
SPL C Resultant sound pressure level spectrum due to velocity and fan noise
SIL (8) Silencer insertion loss spectrum (Static)
DIL (8) Silencer insertion loss required for velocity and fan noise
ED (8) (Dynamic) Excess induct level due to velocity generated noise and fan
F Total silencing for fan noise (all in plant room)
T Total silencing at duct termination