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REAL LIFE ACOUSTIC INTERFERENCE PATTERNS

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INTRODUCTION

The two cases covered in this paper are not by any stretch of the imagination technically involved; in fact they are rather simple. I feel however that they are of interest, because one does not often come across such well defined "text book" cases of interference in practice. They are also of interest, because in both cases the first people to be involved completely misinterpreted the situation through not recognising what was happening.

The idea of sound from several separate noise sources adding to and subtracting from each other is one of the simpler concepts in acoustics and is indeed the basis of active sound cancellation.

The occurrence of such interference patterns in real life, other than in cases where they are deliberately produced is however rare. The reason for this is that in order to produce interference patterns the noise sources must be coherent, and this does not often happen. The writer has encountered very few noteworthy cases in over twenty year's experience. However, the two described below were met within a short time of each other in totally different circumstances, although in both cases the national grid provided the synchronisation.

In both cases everything was clear and consistent, once the mechanism was understood, but the unusual circumstances caused a great deal of initial confusion, not only to the lay people involved, but also to at least one acoustician.

THE CASE OF THE NOISY SUPERMARKET DISPLAY CABINETS

The Problem

A well known supermarket chain experienced noise problems with some of the chilled display cabinets used for displaying food in one of its newly opened branches. Although most of the cabinets were satisfactory, one or two appeared to be very noisy. So much so that customers remarked about the noise and staff filling the cabinets, complained that some of them gave them headaches. Several of the "noisy" cabinets were examined, both in situ in the store and also back at the manufacturer's works. However, in all cases no consistent differences could be found between the "noisy" cabinets and the "quiet" ones. The cabinets consisted simply of a metal box with a small electrically driven fan which circulated air over a cooling coil in the base of the unit and over the food on display.

Changing components between cabinets had no effect on the problem, nor did improving the balance of the motor and fan which apart from some solenoid valves were the only active parts in the cabinets.

The Evidence

When we were called in to investigate the problem, a number of things were immediately apparent.

The noise levels were indeed unpleasantly high, up to 67 dB(A) (86 dB linear) near some of the cabinets. The noisy cabinets appeared to be scattered in groups about the food hall in no particular pattern.

What was also very obvious was that although the noise level varied markedly from place-to-place, the sound level meter reading was absolutely rock steady, with no time variation whatsoever. Analogue meters have their advantages! It was also noted that the highest levels did not necessarily occur next to the cabinets, but in some cases were to be found in the centres of the aisles.

A frequency analysis showed, not unexpectedly, that the noise was all concentrated at 100 Hz, making magnetically induced vibration from the mains electricity supply a prime suspect. Sure enough accelerometer signals showed that panels on the chiller cabinets were indeed vibrating at 100 Hz.

It was clear that the several units that made up any one run of cabinets were not vibrating in phase with each other, because there were very wide variations in the noise level as one moved along each run. A visit to the mains distribution boards at the rear of the store soon provided an explanation for this. In order to distribute the load evenly between the three phases of the mains supply the various cabinets were connected in small groups to each of the three phases. The size of the individual groups had been chosen so that the total load of each group was the same, regardless of the sizes of cabinet involved.

The Proof

By this time an interference effect was suspected as being at the heart of the problem and responsible for the wide variations in noise level. The proof was not only easy, but also quite spectacular, even for the writer, who knew what to expect. One of the apparently silent cabinets was switched off. It immediately became noisy, because it had been almost completely cancelling out the noise from the surrounding cabinets when it was running.

The Solution

When the fan and motor from one of the units was examined, it was found that the small shaded pole motor produced very high levels of vibration along the motor axis at 100 Hz, which was ideal for causing forced vibrations in the large flat panel that supported the motor. Vibration from the solenoid valves which were attached to much more rigid parts of the structure was found to be negligible.

Fitting soft rubber vibration isolators under the motors produced an immediate cure to the noise problem without disturbing the rest of the cabinet, but because of the form of mounting and the space available, it was not possible to produce an arrangement that was at the same time sufficiently soft and acceptably stable.

However, fitting stiffening strips across the flat panels that supported the fans reduced the vibration of the panels to an acceptable level. When this was done to all of the cabinets, the "noisy" ones were eliminated. However, not only did the treatment eliminate the "noisy" cabinets, but it also eliminated the very quiet ones as well!

THE CASE OF THE MONDAY MORNING COMPRESSOR VIBRATION

The second problem was very different in scale. In this case the source of the "vibration" was known to be some 850 horse power compressors supplying part of the compressed air needs of a large car plant.

There were five compressors, two Ingersoll Vee twins and three Alley flat twins installed in a large compressor house thirty metres or so away from one of the main factory buildings which housed some relatively quiet development areas.

People working in the main factory area complained about high levels of noise and "vibration" from the compressors for short periods of time, especially first thing on some Monday mornings.

The noise, when it occurred, was worst at specific locations close to the external wall of the building and also close to some of the stanchions. Popular opinion was that the noise was "coming from the stanchions".

A previous investigation had failed to find the source of the noise conclusively and had cast suspicion on the pipe rack connecting the compressor house to the main building, which was suspected of causing the outer wall of the building to vibrate.

The Evidence

Previous attempts by the car manufacturer to link the noise problem to particular running conditions of the compressors had not been successful, so tests were planned for a weekend when the plant was shut down so that we had control over how the compressors were run.

It was found that when the various compressors were run on and off load, the highest noise levels of noise occurred when a single Alley compressor was unloaded. Under this running condition, there was a powerful 10 Hz component in the noise produced. At ground level about 5 metres below the air intake the sound pressure level at 10 Hz was 118 dB. The noise in the factory area was considered by the factory personnel to be similar to the problem noise but rather less loud.

When the other two Alley compressors were unloaded the level of the 10 Hz component reduced considerably and there was no audible beating due to speed differences between the three machines.

An examination of the drive motors showed that they were 10 pole synchronous induction motors, which are frequently used on large continuously running loads to provide power factor correction to cancel the effects of the multiplicity of induction motors on the site. Synchronous motors run locked to the grid frequency so this meant that once again we had coherent low frequency sound sources. In this case however there is the complicating factor that since the motors were 10 pole machines, the second and third machines was each capable of synchronising with the first in any one of five relative positions. This in turn meant that there were twenty five possible running combinations for the three machines.

Table 1 Relative Probability of Possible Noise Levels for 2 or 3 Compressors Off Load Relative to the Noise Level for 1 Compressor Running

1 Compressor running	2 Compressors running	3 Compressors ruhning	3 Compressors running ranked in order of level
0	-4	-4	-4
		+2.5	+2.5
		+4	+2.5
	+4	+2.5	+2.5
		+4	+4
		+8	+4
	+6	+2.5	+8
		+8	+8
		+10	+10

The three air intakes were close together compared with the wavelength of the sound involved, so the combined effects of the three compressors at a distance could be estimated simply from the possible phase angles, between the three machines. Examining these it was found that three compressors would be expected to produce noise levels ranging from 4 dB below the noise level from a single compressor to 10 dB above that level. Thus there was a possible variation in noise level of 14 dB for the three unloaded compressors, according to the starting positions of the three motors.

Stopping and restarting two of the compressors did indeed lead to an increase in noise level when all three compressors were unloaded. The previous running condition had been one of the few possible combinations that produced a reduced noise level when all three compressors were unloaded.

We thus had a plausible explanation of the capricious nature of the noise problem, and the "Monday morning effect." For the highest noise levels to occur, it was necessary for all three compressors to be off load and running in phase with each other. Monday mornings, before the start of production, were one of the few times when all three compressors were off load. At other times, there was either sufficient demand on the system to keep at least some of the compressors on load, or at times of predictable light load, one or more compressors was shut down.

The localised nature of the noise problem was suspected to be due to reflections from walls inside and outside the buildings, and the vibration on the stanchions was suspected to be the effect of the sound field on the building structure, rather than the other way round as others had previously suspected.

The outer wall of the building consisted mainly of glazing. When vibration measurements were made on framework, the vibration levels were indeed high enough for radiation by the structure to account for the the noise levels within the building. However, when noise levels were measured outside the building, it was found that the noise levels there were 15 dB higher than inside the building, and too high to have been produced by the vibration of the glazing. It seems that no-one had been outside that part of the building at a suitable time to experience the very high noise levels that occurred out there. It was a simple case of sound transmission from the outside, through the relatively light glazing and cladding of the building.

The solution

In this case, so far there has ben no simple solution. Although the method of unloading the compressors, disabling both cylinders simultaneously was a non standard arrangement adopted for this particular installation, the more standard alternative method of disabling only one cylinder, which was indeed quieter, produced unacceptable operational problems which jeopardised the integrity of the system.

Modifications to the strategy of deciding which compressors to run to share the load between the various sizes to minimise the off load operation of the compressors has reduced the frequency of occurrence of the problem.

The remaining possibility of modifying the intake ductwork to minimise the noise from off load running has still to be investigated, following a decision on the long term future of the compressors.