Noise Pollution
Edited by A. Lara-Sáenz and R. W. B. Stephens

CHAPTER 16

Building Noise Control: The Main Problems, Available Technology and Future Trends

THEODORE J. SCHULTZ

16.1 INTRODUCTION

When the subject of noise pollution is discussed, people generally think of the noises of transportation, building construction and industry. Such noises obviously strongly impact those people who are outdoors with these sources; but such noise also penetrates into dwellings and office buildings to disturb their occupants. In addition, there are indoor sources of noise that have little effect on people outdoors but that constitute a source of serious disturbance and annoyance to people within the dwelling or office.

Thus, building noise control is clearly a fitting matter for discussion in the context of *noise pollution*. Indeed, we are quite accustomed to solving technical building acoustics problems and reporting the results at symposia and congresses concerned with noise pollution.

But it is important to realize that there are major acoustical problems that do not necessarily need *technological* solutions, and, in my view, the main problems in building acoustics today fall into that category. The necessary technology already exists to cope with most building acoustics problems, at least in the industrialized countries. (Newman *et al.*, U.S. Dept. of Health, 1975; Beranek, 1971; Doelle, 1972). The real problem is how to apply that technology effectively.

We should, therefore, perhaps, be speaking not of technical acoustics, but of *political acoustics* and *social acoustics*, because the route to successful achievement of an improved acoustical environment in buildings passes through the realms of politics and social concern.

16.2 THE MAIN PROBLEM: FIRST-ORDER SOLUTIONS TO FIRST-ORDER PROBLEMS

Like air and water pollution, *noise pollution* comes mostly from having made

particular technological choices without fully considering their impact on people who have to live with them. Technology, to date, has typically advanced by satisfying 'first-order' needs with 'first-order' solutions—for example, creating transportation facilities (the automobile and the highway system) to increase our mobility. Such conventional 'first-order' solutions have gradually come to defeat the purposes for which they were made: we now have traffic congestion instead of mobility, and we also have air and noise pollution as well. Specific problems have been considered in isolation, rather than anticipating the sociological effects of the solution; it has simply built systems, rather than designing them with an awareness of their potential impact on society.

So long as we attend only to first-order solutions, our technology is clearly not so advanced as we have sometimes boasted.

Now, with respect to noise, we have all read of the detrimental effects of intrusive noise on our health and welfare and there is no doubt that, in the long run, these repeated intrusions generate in the community the helpless feeling that something of great value—the quality of the environment, the right to quiet enjoyment of our homes, and the value of our residential property—has been taken away from us by 'somebody else', who cannot even be identified and blamed or enjoined to stop the disturbances: we find ourselves victimized by 'the system'.

These comments are relevant to the noise problems of the industrialized countries of the world, where the facts are already a matter of history. After years of heedless pollution, several countries are just beginning to achieve effective control of environmental noise.

To those of us who have lived through some of these problems, and who hope to have learned that prudence and restraint are necessary with respect to insults to the environment, it is distressing to see the same mistakes repeated in the developing industrial countries ... and mostly for the same reasons.

In the developing *pre*-industrial countries, matters are worse still. Building isolation is technically almost impossible in tropical countries where natural ventilation is the rule. Moreover, motivation for noise abatement is non-existent in the face of poverty and overpopulation.

Acoustical scientists from some of the developing countries have just begun speak of these matters (for example, in the recent Tenth ICA* in Sydney (1980), and it is clear that their problems are very great, indeed.

The question, as usual, is one of motivation *vs* economy. The contrast is between societies that are comfortably housed and overfed and those that are ill-housed and living in poverty and hunger. Inadequate privacy between dwellings is not important when three or four families are living in a single room.

Only a politician or a sociologist, can solve that kind of problem. Instead, we will deal with some acoustical problems for which we can begin to glimpse the

* International Compression Acoustics.

solutions, hoping that the day will come when we will learn more from history than that history teaches us nothing. I am concerned primarily with the impact of noise in our dwellings.

16.3 PRIVACY AS AN AMENITY

'Of all the complaints owners throughout the country hear about postwar apartments, lack of soundproofing heads the list most frequently. There isn't even a close second' (*Symposium on Noise In Multifamily Dwellings*, New York, May 1963) (Rose, 1964).

'Major property management firms report that noise transmission is one of the most serious problems facing managers of apartment buildings throughout the country. Managers and owners of apartments readily admit that market resistance is not only increasing as a result of excessive noise transmission but also that lack of acoustical privacy and noise control are the greatest drawbacks to apartment living.' (Harold B. Finger, Assistant Secretary for Research and Technology, HUD*, in a *Symposium on the Performance Concept in Buildings*, Philadelphia, May 1972) (U.S. Dept. of Commerce, 1972).

'No longer can noise problems only be associated with low-income apartment units. According to the Federal Housing Administration, both low and high income apartment building residents register the same number of complaints about bother-some noise.' (Cosimo Caccavari, U.S. Environmental Protection Agency, in NOISEXPO, Chicago, 1980) (Caccavari *et al.*, 1980).

This seriousness of noise intrusion and lack of privacy in dwellings has thus been evident for more than a decade and in the U.S.A. there has been a movement to do something about the noise. This has involved the United Nations, the Federal, State and local governments, as well as science, industry, the legal profession and citizens. However, the same issue remains important in the 1980's.

It is not a new movement; the issues were known and widely discussed in the 1960's and early 1970's. In the absence of substantial progress, the same issues remain important in the 1980's.

16.4 HOW TO ACHIEVE PRIVACY FROM NOISE

The first difficulty lies in the dual nature of urban noise.

1. It acts as a pollutant, an undesired product of somebody else's activity that imposes a cost upon third parties who are not partners to the action and may receive no direct benefit from it.

   Market forces alone, at present, are not strong enough to restrain the producers of unwanted noise; therefore, the control of these noisy activities is usually assumed to lie in the public domain. Unfortunately, regulatory action against noise pollution is slow in finding its way into law.

* Housing and Urban Development.

2. On the other hand, urban noise has a desirable effect: namely, the continuous low hum of traffic and ventilation noise provides a neutral acoustic background that helps mask out undesired *intermittent* intrusions, such as auto horns, neighbours' speech, TV, radio, etc. Without this continuous background of 'acoustic perfume', it would be quite beyond our technical capability to provide privacy in multifamily dwellings at a cost we can afford.

   We immediately see that the task of noise abatement is delicate: we do not dare simply to eradicate the noise (even if we could). Instead, we must control it, bring it into balance, and manipulate it to serve our purposes.

The technical reader will observe that this is a statement of a technical acoustics problem. As such, he is likely prepared to understand the balance between noise control and background noise that is required.

But try putting this into the framework of political and social acoustics. The image is not nearly vivid enough! *If* a goal can be simply-stated, it is easy to persuade people (or their representatives or the press) to support the project: 'Cut down that tree'; 'Build a bridge across a river'. It is impossible to win support to cut a tree down, but not all the way; to build a bridge *almost* to the other side of the river! It is equally difficult to get agreement on the question of *how much* noise, and *which* noise, must go.

We are presented with a double problem. The increase in population in urban centres means more and more noisy activity. For this reason alone, we need to improve the sound attenuation of *existing* construction, in order to preserve the present standards of comfort, such as they are. But, at the same time we must provide growing numbers of people with *new* housing, designed for better sound isolation and hopefully costing and weighing less. These are traditionally incompatible objectives; it is very hard to circumvent the acoustical mass law which says, 'Increased sound isolation requires greater mass.'

However, our most pressing need is not for novel technical production methods nor for magic new materials, but rather for the *proper application* of existing, traditional methods of building. The reasons are these:

(i) Considerations other than acoustics are given priority in determining the basic type of building structure, the method of assembly, and even the surface finishing materials.

(ii) Even if the acoustical requirements *have* been considered early in the building design and suitable noise control structures have been selected, a structure that is acoustically good in itself can be spoiled by failure to work out the architectural details carefully so that 'leaks' and 'flanking transmission' do not by-pass the intrinsic isolation that the structure can potentially achieve.

(iii) Even though the architect has chosen acoustically good building constructions and has developed details that avoid flanking transmission, the ultimate success of the building depends on the work of men with no knowledge of, and no interest in, acoustical problems: the contractor and individual trades people.

Carpenters and plumbers do not 'think acoustically'. They may be counted upon to introduce on-site changes from the specified construction for any number of reasons: habit, personal convenience, cost-savings, unavailability of specified materials, simple ignorance or flagrant indifference. Though these changes may appear harmless to the workmen, they frequently undermine the acoustical design of the building.

16.5 BUILDING CODES AS A MEANS OF DEALING WITH THE MAIN PROBLEM

No amount of ingenuity in the development of novel building techniques and new acoustical materials will transcend this problem of unthinking construction workers. No break through in acoustical isolation methods will be of any use whatever, unless a corresponding break through is made in assuring constant attention to construction details and continuous, effective on-site supervision. No matter what construction techniques and materials are used, an essential step toward improving noise isolation on dwellings will be to persuade contractors, builders, and trades people of the extreme importance of the details of proper construction, and also to motivate them to accept the responsibility for better supervision during construction.

Under the present set-up of the building construction industry (at least in the United States) this latter break through seems unlikely to occur in response to market demands alone. Ten years ago, it was a seller's market in the building construction industry; housing was needed too badly for the consumer to be very critical of details such as noise isolation.

Nowadays, *anything* that adds to the cost of the building will be scrutinized very critically before being approved. Clearly, it will not be easy, in this atmosphere, to attract the attention of the housing construction industry to acoustical matters.

The questions raised here are not technical but social; and, since the problems are far-reaching, their solutions (when they come) will have profound social consequences. They will require one or the other of two drastic changes in the building industry:

1. A thorough-going re-education and motivation of the contractors and trades involved in on-site construction, to require them to take as much care in achieving adequate noise isolation as they do now in providing suitably

strong structures and adequate heating and plumbing. Such an approach implies a major change in our handling of noise control in building codes.

2. The design, from the beginning, of complete and most prefabricated housing systems with final assembly procedures so simple and foolproof as to be practical for unskilled labour in the field; the noise isolation must be 'built in'.

The second choice seems feasible to organize on a large scale under purely commercial motivation. The scheme is by no means unheard of; in fact, the foundations already exist in the 'mobile home' industry. These are experimental 'apartment houses' built in the southern United States by stacking house trailers into a suitable structural framework that includes provision for electrical and plumbing facilities as well as access stairways.

This approach would entail, however, a very significant social change, namely, the ultimate transition in the building construction trade from a local 'craft industry' to more-or-less centralized machine production.

For the time being, a more practical approach is the first choice: the adoption and the effective enforcement of noise control requirements in our building codes.

Such requirements are included in the building codes of a number of countries, particularly in Europe, but unfortunately these requirements do not prevent complaints of inadequate privacy from the tenants of the buildings to which the codes apply. Figure 16.1 shows the means of building code enforcement in Europe; routine tests in the finished buildings (see line 6) are uncommon, except in West Germany when Government loans are involved.

For a number of European countries, there is a discouraging record of failure which can be expected when no special incentives are offered to encourage the effective enforcement of building noise control. Line 3 shows the typical failure rates.

The main trouble comes during construction, where poorly executed details of assembly allow serious flanking transmission and sound leaks.

The outlook is brightened somewhat by recent data from the Netherlands (van Os, 1981). Both in 1973/74 and in 1979/80 large-scale field-test programmes were carried out measuring the sound insulation in dwellings; the percentages of tests that met the Dutch minimum requirement for airborne sound insulation were as follows:

	1973/74	*1979/80*
Between living rooms:	29%	90%
Between sleeping rooms:	21%	80%

Evidently, a vigorous enforcement programme *can* have beneficial effects!

In USA and many other countries, the owners and tenants have no part in the selection of the building materials. When they suffer from inadequate privacy, they cannot therefore apply market pressure to the manufacturers for

Procedure \ Country	Belgium	Denmark	France	W. Germany	Netherlands	Sweden	Switzerland	U.K.[¶]	U.S.A.	Spain	E. Germany
1. Inspection of drawings	?	×●	×●*	×●	×●	×●	?	×●	×●	×	×●
2. Suggestion (or requirement) to use approved constructions		×		×	×	×	×	×	×		×
3. Exploiting market advantage			×†								
4. Giving financial bonus for higher quality			×‡		△‡						
5. Imposing market penalty (lowered rent)		○		○							
6. Test in finished building to demonstrate compliance	?	△	† ○ ○	△ ‡ ●	 ○ (<1%)	△	?	○ V			△
7. Corrective measures if building fails test		△ V		△ V	○	●					○
8. Pilot test of novel constructions				●	△	●		△			△

Key: ×—Officially required, permitted, or provided.
●—Always or usually done.
△—Sometimes done.
V—Done only when complaints arise.
○—Seldom done.

* Applies only to Government Subsidized Homes (HLM): no requirements in other buildings, and sound insulation is usually poor.
† In cases where the Acoustic Comfort Label is required.
‡ If built with Government loan.
¶ Except inner London.

Figure 16.1 Means of Enforcing Code Requirements

more realistic involvement throughout the construction process. The builders and architects who select the products almost never suffer from the acoustical consequences of faulty construction and hence, the design–construction–completion loop is never closed, as it should be.

The only way to break out of this situation is to focus on the quality of the finished product. The industry needs a complete package, comprising adequate incentive for seeking improved acoustical quality, reliable tools to achieve it (for example, simple and reliable test procedures and a code that works), and initial assistance (money and instruction) to help get started on a fresh approach to noise control in buildings.

Incentive can be provided by the local adoption of a building code that requires acoustical tests of a certain percent of the completed dwelling units, in order to demonstrate compliance with code requirements for noise isolation between dwellings, and that requires remedial action on the part of the builder in case of failure.

The necessary tools include a recently-developed simple test procedure (ASTM E597–77T) for measuring sound isolation between dwellings in terms of A-weighted sound levels; it is both reliable enough to demonstrate compliance credibly and simple enough to be performed by relatively untrained staff. This procedure requires a standard sound source and a simple sound level meter.

The final tool is a set of new noise control provisions for a model building code, which EPA* has recently completed. These include a performance specification for adequate sound isolation, to be demonstrated by acoustical tests in the finished building.

The practical advantage of training and education for the building trades is well illustrated in the following case history.

16.6 PERSUASION OF PEOPLE TO ACCEPT TESTS FOR COMPLIANCE WITH A SPECIFICATION

It is possible that there may be general opposition to the introduction of mandatory tests of acoustical performance in finished buildings; not simply because this approach introduces changes in an already established procedure, but because the architect, the owner and builder have no guarantee at the time the permit to build is granted, that the finished building will be approved for occupancy. Understandably, they may regard it as a considerable risk to go ahead with the project. On the other hand, when they *do* go ahead, they will undoubtedly be strongly motivated to provide good supervision all along the line, in order to prevent acoustical accidents during the construction.

As an illustration, we cite a case history from the San Francisco Bay area that arose from a particular historical incident. In the early 1960's, a great deal of

* Environmental Protection Agency (USA).

low-to-moderate-cost housing was financed by local insurance companies. Partly for budgetary reasons and partly because there was no tradition of concern with the provision of sound isolation in the buildings, no special attention was given to these matters. As a result, it developed that the insurance companies were stuck with a great many unrentable housing units, because of the poor acoustical isolation between dwellings.

Here an enterprising acoustical consultant entered the picture. He persuaded the insurance companies to adopt the following programme in the construction of future housing:

1. He would advise the architects on the choice of suitable constructions for party walls and floor/ceilings, and would provide further guidance on how to detail the structure so as to avoid damaging flanking transmission: avoidance of back-to-back electrical outlets and bathroom wall cabinets, proper sealing and caulking of floor and ceiling joints, avoidance of duct and pipe-runs between dwellings, etc.
2. When a project was partially completed, he would conduct acoustical tests on a small number of the units to determine that the desired acoustical isolation was being achieved. The results of these tests, on average, became the *de facto* acoustical performance specifications for the rest of the project. An important feature of these and subsequent tests was that the construction trades persons that worked on the project were required to attend the tests and to observe what was at fault when failures were discovered. An immediate result was that they became quite interested in achieving good sound isolation and even came up with suggetions for doing a better job with less cost or greater ease.
3. When the project was finished, about 10% of the remaining units were tested for compliance with the *de facto* specifications established in the pilot tests. These tests, as well as the pilot tests, were paid for by the insurance companies.

   At this point some flexibility in procedure was admitted. If all the tested units were in compliance, it was assumed that, by and large, the entire project was satisfactory. If many failures were found, further tests would be made, etc.
4. The contractor was required (by agreement in his original contract) to undertake remedial work on the units that failed to pass, and then to pay for the subsequent acoustical testing to demonstrate the success of this treatment. (At this point, the advantage of *de facto* performance standards, *established in that very project*, became obvious, in contrast to 'abstract' standards specified in some legal document. The contractor could offer no legitimate excuse for failure if it occurred: a mistake was clearly a mistake!)

The upshot of this programme was nearly 100% compliance with the requirements for adequate acoustical performance in these housing projects: a boon for the insurance companies, the owners and their tenants. In addition,

the contractors involved soon won a reputation for being able to produce acoustically trouble-free housing and were much in demand for other jobs.

An important feature was that there was not a significant long-term increase in cost. At first there were some mistakes; and the cost of the acoustical testing had to be borne by the insurance companies. But this was preferable to coping with unrentable housing, and soon the contractors and their trades learned how to put up the buildings without mistakes, and the required number of acoustical tests could be reduced.

As far as I know, this is the only example where the loop from acoustical specification to demonstrated compliance in the finished buildings has been successfully closed in a routine manner in the United States. It illustrates the singular virtue of enlisting the cooperation of *all* the people involved, from the beginning of the project!

In the absence of such a 'historical incident', however, we may expect some opposition to the new code approach from people mistrustful of change.

16.7 COUPLING NOISE CONTROL WITH ENERGY CONSERVATION

There is, under the Energy Policy and Conservation Act of 22 December 1975 (PL 94–163, Sec. 362), authorization for grants to States from the US Federal Government, up to $50 million per year for three years, to support a number of energy conservation measures. These may include the provision in building codes of conservation requirements for new and renovated buildings.

Of special interest is the installation of thermal insulation for conserving energy. The means to improve the thermal insulation of a dwelling are similar to those for increasing the acoustical isolation from outdoor noises. Therefore, the opportunity exists, under the new energy conservation laws, for achieving energy conservation in such a way as to get also improved sound isolation of the exterior walls and windows, with virtually no added cost.

Such an advantage could be made the subject of co-operative demonstrations, nationwide, to show that better protection against community noise intrusion can be had for a bargain.

One such demonstration programme is being carried out at the present time in Chelsea, Mass., under the joint direction of the US Environmental Protection Agency, the Department of Energy, the Department of Housing and Urban Development and the National Bureau of Standards. It is called the Energy Conservation and Noise Control Demonstration Program for the Decade of the 1980's (Keast and Berman, 1979).

16.8 CONCLUSION

The hopeful plans and projects described in the last sections reflect the mood of the 1970's, which assumed that persistent effort and public education would

evantually lead to both acceptance of a reasonable and economic improvement in the acoustical environment in our communities, and the funds to achieve it.

The 1980's look considerably more bleak. A sagging economy and increased energy costs are not favourable to the development of new ways to tackle old problems.

In the 1960's, the scientific personnel at sponsoring Government Agencies had the money and the authority to support good new ideas for promising research, and these were quickly and adequately funded. In the 1970's, government funding for research has been severely cut back. Where promising Federal programmes of noise abatement had been planned, they were falteringly implemented.

From the viewpoint of this survey, namely, the inadequacy of 'first-order' solutions, the present position with respect to building acoustics in industrial countries is as follows. The need has been seen for housing with more adequate noise control. In order to achieve this objective that attention to better noise control was needed, laboratory and field methods have been developed for measuring and rating sound insulation and isolation with considerable refinement. These matters are well known only in the technological community, but so far have not successfully involved the planners, architects, construction engineers and building trades in collaborating toward a balanced solution to the problem of noise control in buildings.

It appears that suitable enforcement tools have recently been developed and some progress is looked for in the near future.

But it is *also* the responsibility of industrialized countries to discuss technological progress in acoustics and noise control and to acknowledge the need for progress in political acoustics and social acoustics.

Finally, it is the duty of the acoustician to watch for, and to avoid, the deceptive attraction of the 'first-order' solution. Wherever it is possible, developing countries should be warned of the pitfalls that can lie in the path of the obvious first-order approach.

16.9 REFERENCES

Beranek, L. L. (ed.) (1971). *Noise and Vibration Control*, McGraw-Hill.

Caccavari, C., Montgomery, J. and Rieberry, B. (1980). An eight-step approach to abating noise in the multifamily and educational buildings. *Proceedings of the Technical Program*, Chicago, Noisexpo, p. 1.

Compendium of Materials for Noise Control (1975). US Department of Health, Education and Welfare, HEW Publication No. (NIOSH), 75–165.

Deolle, L. L. (1972). *Environmental Acoustics*, McGraw-Hill.

Keast, D. N. and Berman, D. D. (1979). Energy conservation and noise control in urban residences: Demonstration program plan, *Report No. 4156A*, Cambridge, Mass., Bolt, Beranek and Newman Inc., prepared for the Environmental Protection Agency.

Newman, B. *et al.*, (1981). Acoustics in *Time-Saver Standards*, McGraw-Hill, 6th edition.

van Os, G. J. K. (1981). Personal communication.

Proceedings of the Tenth International Congress on Acoustics, Sydney, Vol. 1, Part B: Acoustics in the developing countries, Part I, 117–128.

Rose, F. P. (1964). Owner's viewpoint in residential acoustical control, *J. Acoust. Soc. Am.*, **36**, 740; Symposium on Noise in Multifamily Dwellings.

US Department of Commerce, National Bureau of Standards (1972) *NBS Publication 361*, Vol. 2.