4. NOISE CONTROL MATERIALS

In this chapter, we describe the four types of materials most often used in noise control: absorbers and isolators for airborne sound, and vibration isolators and damping materials for controlling vibration solidborne sound. Guidelines are also given for selecting materials on the basis of nonacoustic considerations.

ABSORPTION MATERIALS

With absorption, small amounts of sound energy are changed into correspondingly small amounts of heat energy. Suitable materials are usually fibrous, lightweight, and porous. The fibers should be relatively rigid. If a cellular material is used, the cells must intercommunicate. Foams should be reticulated to the proper degree.

Examples of absorbent materials are: acoustical ceiling tile, glass fiber, and foamed elastomers. Physically, the flow resistance of fibrous materials is the most important characteristic. For optimum results, the flow resistance must usually be increased as the thickness of the absorbent decreases, to maintain peak absorption. Absorbent materials are employed in several applications, including muffler linings, wall, ceiling, and enclosure linings, wall fill, and absorbent baffle construction.

The flow resistance can be sensed – rather crudely – by attempting to blow through the material. Comparison with an accepted material of the same thickness provides a personal calibration. The effectiveness of an acoustically absorbent material is measured by the absorption coefficient. Ideally, this is the fraction of the sound energy flowing toward the material that enters it and is not reflected; thus, a perfectly absorbent material would "soak up" all the sound incident on it. Industrially useful acoustically absorbent materials have coefficients above 60% in the frequency range from 500 Hz and up.

Absorbent materials on room surfaces reduce the amount of reverberant sound in a plant space (see Figure 2.12), and thus reduce the effects of reflected sounds. It is very important to recognize that absorbents do not materially affect the transmission of sound; thus, they should never be used as shields or barriers or enclosure walls. The reduction of reverberant sound pressure levels that could be expected by addition of an absorbent material is given as approximately 10 times the logarithm of the ratio of the room constant obtained after adding the absorbent material, divided by the original room constant. It is relatively simple, then, to estimate the new sound level from the new sound pressure levels. Table 4.1 shows average absorption coefficients of various absorbent materials. Table 2.5 shows absorption coefficients of relatively nonabsorbent construction materials plus those for some special materials.

Table 4.1. Sound absorption coefficients of common acoustic materials.

Materials*	Frequency (Hz)					
	125	250	500	1000	2000	4000
Fibrous glass						
(typically 4 lb/cu ft) hard backing						
1 inch thick	0.07	0.23	0.48	0.83	0.88	0.80
2 inches	0.20	0.55	0.89	0.97	0.83	0.79
4 inches thick	0.39	0.91	0.99	0.97	0.94	0.89
Polyurethane foam (open cell)						
1/4-inch thick	0.05	0.07	0.10	0.20	0.45	0.81
1/2-inch thick	0.05	0.12	0.25	0.57	0.89	0.98
1 inch thick	0.14	0.30	0.63	0.91	0.98	0.91
2 inches thick	0.35	0.51	0.82	0.98	0.97	0.95
Hairfelt						
1/2-inch thick	0.05	0.07	0.29	0.63	0.83	0.87
1 inch thick	0.06	0.31	0.80	0.88	0.87	0.87

*For specific grades, see manufacturer's data; note that the term NCR, when used, is a single-term rating that is the arithmetic average of the absorption coefficients at 250, 500, 1000, and 2000 Hz.

Note that for each doubling in the amount of absorption, you can expect a 3-dB noise reduction in reverberant levels. The first 3-dB reduction is therefore relatively cheap to obtain; you must add twice as much material to obtain a second 3-dB reduction. Note, also, that the ultimate noise reduction potential would be limited. You would not be able to reduce the sound level to below that which would be obtained if there were no confining walls present in the workspace.

The absorption coefficient depends not only on the material but also on what is in front and back of it. Most coefficients are stated for an unobscured front, but with a rigid impervious backing spaced various distances away from the material. Noise control engineers use designations of the Acoustical and Insulating Materials Association to describe the material mountings:

(1) Cemented to backing with about 1/8 in. air space

(2) Spaced 3/4 in. away by furring strips

(4) Laid directly on surface – very little air space

(7) Suspended 16 in. from the backing.

When the mounting is not specified, usually it is No. 1 or 4.

Absorbent materials may have special facings. For resistance to grease and water that would clog pores, a thin plastic film covering is often used. Such films, as well as perforated vinyl or sheet metal facings, tend to produce a maximum in the mid-frequency absorption coefficient. Absorbents protected by a film still have exposed edges. These may be sealed by a latex paint that anchors itself to the pores of the absorbent and closes the edges. Some thin construction materials, notably plywood, can show increased low-frequency absorption by panel resonance, if they are not securely fastened down.

The standard reverberation room method of measurement of absorption coefficient (ASTM C423-66, or latest version) essentially subjects the absorbent to sound from all angles. Data on absorption coefficients cannot be regarded as useful and meaningful unless they have been obtained in this standard fashion.

TRANSMISSION LOSS MATERIALS

The sound isolation properties of materials are stated in terms of transmission loss. As with absorption, the concept of energy flow is used; here it is the energy transmitted through the material, relative to that flowing toward it. Transmission loss is 10 log (incident energy)/(transmitted energy), and it ideally increases with frequency at the rate of about 5 to 6 dB per doubling of frequency. Only a few laboratories in the United States are qualified to make the standard measurement for determining transmission loss (ASTM E90-61T, or latest version). Data on the transmission loss of materials appearing in advertising literature cannot be regarded as meaningful unless they have been determined in this standard manner.

As a result of the search for a single number to indicate the average full transmission loss, the concept of sound transmission class (STC) was developed. It is useful specifically in assessing the degree to which intelligible speech is prevented from being transmitted through a wall. Use the STC with caution in industrial work, however, because the noise spectrum can be much different from that of speech. You will need the transmission loss in each octave band for the proper application of isolating materials.

DAMPING MATERIALS

Damping materials are used to reduce resonance effects in solids. Essentially, damping materials are absorbents for solidborne sound, converting the vibrational energy into heat.

Damping materials are used in many applications. If a machine panel (such as a belt guard) is subjected to vibration, it will radiate sound strongly at its resonant frequencies. Damping the panels or guards can reduce this radiated sound. In another application, parts that fall into (and are carried along) metal chutes can excite the chute panels by repeated impact. Installing damping materials along the chute surfaces will reduce the noise, but these materials must be selected with heat resistance and mechanical integrity in mind. Damped stock tubes are available for quieting screw machine operation. Panels for isolating enclosures can transmit large amounts of sound in certain frequency regions. Damping can help retain transmission loss in those regions.

There are two types of damping materials: homogeneous and constrained layer. A homogeneous layer material is sprayed or troweled on in a relatively thick coat, depending on the thickness and type of metal to be damped. A constrained layer material consists of a thin layer of the actual damping material with a backing of thin metal or stiff plastic. The mechanical action is one of making the damping layer much more effective than if it were homogeneous. Constrained layer damping materials can be purchased as an adhesive/metal foil tape combination, where the adhesive is selected for its energy loss properties as well as its adhesion. These damping tapes are especially useful on thin panels (1/16-in. steel or less).

VIBRATION ISOLATORS

Vibration isolators act on the same principle as isolators for airborne sound: introducing into the transmission path a material whose wave-transmitting properties are as different as possible from the medium carrying the wave. For vibration in solids, such materials are spring-like. Examples include resilient elastomer and metal springs, elastomer pads, and, in extreme cases, air springs. The weaker the spring, usually the greater the isolation. Solid rubber or rubber-fabric pads are not too effective, because the displacement is small and is not proportional to the load.

If an isolator is too weak vertically, it may not be laterally stable. Side-restrained metal spring isolators are available to avoid this difficulty. In extreme cases, it may be necessary to use many isolators, all acting along lines that pass through the center of gravity of the machine. Vibration isolators can also be used when the vibration situation is reversed, i.e., when a delicate mechanism is to be protected from external shock and vibration.

The proper amount of damping is needed with vibration isolation in many applications. Steel springs alone are highly undamped; if they rest on elastomer pads, there is much improvement.

MATERIAL SELECTION

The most commonly used materials for control of noise in industry are absorbers and transmission loss materials for airborne sound and vibration isolators and dampers for solidborne sound. Selection of materials is governed by factors other than acoustical. These factors may be broadly classified as environmental and regulatory. Environmental factors include:

- Moisture, water spray, water immersion
- Oil, grease, dirt
- Vibration
- Temperature
- Erosion by fluid flow.

Regulatory factors include:

- Lead-bearing material forbidden near food processing lines
- Restrictions on materials that may be in contact with foods being processed — glass, monel, or stainless steel permitted
- Requirements for material not to be damaged by disinfecting
- Firebreak requirements on ducts, pipe runs, shafts
- Flamespread rate limits on acoustically absorbing materials
- Fire-endurance limits on acoustically absorbing materials
- Restrictions on shedding of fibers in air by acoustically absorbing materials
- Elimination of uninspectable spaces in which vermin may hide
- Requirements for secure anchoring of heavy equipment
- Restrictions on hold sizes in machine guards (holes can reduce radiated noise of vibrating sheets).

A good example of the influence of these factors is seen in the selection of absorbent materials for use inside machine enclosures. It is typical of ordinary maintenance practice to overlubricate rather than to install or service oil or grease seals. Hence, it is common to find oil and grease deposits on machines, often with dirt, metal chips, and other debris. Such deposits greatly degrade the performance of absorptive coatings, which are porous materials that easily wick oil and water. However, absorbent materials are now available with a thin imperforate skin or film covering of Mylar, Saran, or Tedlar, which prevents fluid wicking. Nevertheless, the sheer weight of grease deposits will degrade higher frequency performance even without wicking; fire hazards will also be increased. Therefore, the film must be strong enough that the deposits can be cleaned off with a cloth wet with warm detergent, plus mild rubbing. Such maintenance will be necessary with machine enclosures lined with absorbent materials. The time between cleanings can be greatly lengthened if oil and grease seals are installed or if deflecting shields are used on severe oil spray, such as those from impacting parts in a punch press.

Curtain types of isolating materials, such as lead-loaded vinyl, are convenient for constructing an enclosure rapidly. Where leaded materials cannot be used, as in some stages of food processing, a barium-loaded type is available. Monel and stainless steel are the only common metals usually permitted in contact with food.

Fibrous absorbing materials in shop-made silencers and mufflers can be eroded by high-speed gas flow, say, above 15 m/s (50 fps). The fibers may pose a health hazard and can also interfere with machine operations. The situation is worsened if vibration is present, as it tends to break and shake out small fibers. The material used should have some bonding agent to hold fibers securely in place. In addition, the absorbent can be covered with wire screen or perforated metal. If the latter is used, the ratio of open to total area should be greater than 0.3. The effective absorption will be decreased if lesser open areas are used. Foamed absorbent materials shed much less than fibrous types, but all need sealing of raw edges by a film-making paint or by a thin plastic cover.

Fire resistance is often required by building codes. Absorbent materials are available with several degrees of resistance. With suitable materials, fire breaks are sometimes unnecessary in isolating walls that are filled with absorbent material. Since local building codes may not be applicable to structures that can be described as a part of the machine, prudent language must be used in describing the function of the enclosure.

A most important nonacoustical factor in the selection of noise control materials is net cost. You must always be aware of this factor and should design so that labor-plus-materials cost is minimized. A part of the net cost is also the loss in production while a machine is being treated, so time to restore production must be considered. Ease of maintenance must also guide the selection. Achieving a viable design means that material selection cannot be accomplished on a purely acoustical basis.

5. SELECTING AND USING A CONSULTANT

KNOWING WHEN A CONSULTANT IS NEEDED

Having read the previous chapters, you know you can deal with some noise problems on your own. If you are still unsure of the solution or if preliminary measures have proved unsatisfactory, it may be time to consider the use of a consultant.

A consultant may be needed when the machine to be quieted is complex, with many noise sources of approximately equal strength. Locating the sources and obtaining their relative noise strengths will perhaps call for more sophisticated equipment and procedures than you may have. If you find that the A-weighted sound level at all points at a constant distance from the machine (but within the critical distance) covers a range of 5 dB or less, this is likely to be the case.

You may also need a consultant for unusual situations. With belt-driven blowers, for example, you may find a slow but considerable variation in sound level. Another is impact noise, as from a punch press, where several events take place in rapid succession. A narrowband analysis of a tape recording is usually called for. Inadvertent tuning of some part of the machine may lead to pure tone ringing that is difficult to locate. For such situations, using a consultant is often the most rapid way of getting results.

If you have installed noise control means that don't work, you may (albeit reluctantly) have to use a consultant to correct the situation. Although this may be a painful decision, it will usually occur but once. You should document the situation thoroughly and use the consultant to supply information on what went wrong.

Sometimes you may be approaching a lawsuit, where data must be obtained and presented (as an expert witness) by a disinterested third party. Many consultants can provide this complete service.

Once you have decided to obtain a consultant, how do you proceed? You should first be warned that currently there is no legal bar to anyone offering services as an "acoustical consultant." Consequently, it is up to you to avoid those who are unsuitable because of lack of training or experience, as well as simple venality or greed.

SELECTION OF A CONSULTANT

People billing themselves as consultants can be broadly classified according to whether or not they have a special interest in recommending a particular acoustical product or solution. Both types, properly used, have their special advantages and disadvantages. "Special interest consultants" are individuals who vary in their backgrounds from product salesmen to professionals who are quite capable in their line of business. Members of this group, who are most commonly indicated by the degree of their association with manufacturing or retail sales of acoustical products, should be used directly only if, by use of the techniques described in previous chapters, you have satisfied yourself that their solution is applicable to your problem. In this case, you have progressed to the point where the "consulting" aspect consists mainly in soliciting proposals for design and installation. The main problem remaining is to write your contract in such a way that you are guaranteed (to the extent possible) a solution to your problem that is cost effective. The advantage of using this group directly is that you avoid consultant costs. In effect, you are acting as your own consultant.

The disadvantage in dealing with a product-oriented consultant is that a costly mistake, out of proportion to the independent consultant's fees, is rendered more likely. Examples abound of cases in which thousands of dollars were spent in implementing a particular solution, only to find that no good was done. (A common mistake is to use acoustical tile in situations where reverberant noise is not the problem.) If there are any doubts in your mind as to the proper method for solving your problem, then an "independent consultant" (one free from ties to a particular line of products) should be called in. Since this "independent consultant" is what is usually meant by the word "consultant," it is this type of professional that will be discussed for the remainder of this chapter. The word "independent" will be dropped.

In choosing a consultant, a first step is to inquire of the two organizations in the field that are interested in the qualifications of their members. The most inclusive is the Institute of Noise Control Engineering (INCE), P.O. Box 1758, Poughkeepsie, New York 12601. This group will have as members only those who have passed suitable examinations. Applicants must pass both the Engineer-in-Training examination given for registered professional engineers and a special examination on noise control engineering that was first given in 1974. There will be no grandfathering — the term applied to certification purely on the basis of past activity in the field. It is expected that this certification of noise control engineers will receive approval by and support from the government agencies needing such engineers directly, or in the contract work they support.

The second source of information on qualified acoustical consultants is the National Council of Acoustical Consultants (NCAC), 8811 Colesville Road, Suite 225, Silver Spring, Maryland 10910. This group has a rigorous code of ethics requiring (as with all registered professional engineers) that no member be associated with the saleof a product. Consequently, some consultants, otherwise well qualified, are not members because of this association. A membership list is available. Not all the completely classified consultants are yet members.

You can also question the prospective consultant yourself. A series of questions is given below. These questions are rather completely presented here, and you may wish to ask only those that are pertinent to your particular task.

GUIDELINE QUESTIONS

Education

(1) What schools did you attend?

(2) What courses did you take bearing on acoustics?

(3) What degrees did you receive? When?

(4) In what special conferences, seminars, symposia, or graduate courses in acoustics have you been involved, either as a student or as an instructor?

Experience

(1) For how many years have you been professionally active in acoustics?

(2) Please supply a list of recent clients that you have served, preferably in my geographical area, and on problems similar to those in which I am interested.

(3) What teaching or training have you done in acoustics, and to what groups — university, industry, trade associations, civic groups, engineers, symposia?

Status

(1) Are you now an independent consultant? For how many years? Full time or part-time?

(2) If part-time:

(2.1) Who is your chief employer or in what other business ventures are you involved?

(2.2) Is your employer aware and does he approve of your part-time activity as an acoustical consultant?

(2.3) May we contact your employer concerning you?

(2.4) What restrictions does your employer place on you as a part-time acoustical consultant?

(3) Are you associated with the manufacture or sale of a product that could create a conflict of interest in your activities as an acoustical consultant?

Professional Affiliations

(1) Of what engineering or scientific societies or associations are you a member? (Representative ones are the Acoustical Society of America, the Institute of Noise Control Engineering, and the National Council of Acoustical Consultants.)

(2) What is your present grade of membership and length of time in that grade, for each association?

(3) Have you been accorded any professional honors in these associations, such as offices, committee chairmanships, awards, or prizes?

(4) Are you a registered professional engineer? In what states? In what disciplines?

(5) Of what professional engineer associations are you or your firm a member?

(6) Of what trade associations, chambers of commerce, or similar business groups are you or your firm a member?

Special Capabilities

(1) In what areas of acoustics do you specialize?

Noise measurement and control
Architectural acoustics
Hearing conservation
Shock and vibration measurement and control
Nondestructive testing
Medical ultrasonics
Underwater acoustics

(2) What equipment do you have for conducting acoustical measurements in the field? In the laboratory?

(3) With what national standards do you comply in conducting your acoustical measurements?

(4) Are you listed by any governmental or trade association body as an acceptable or certified acoustical test laboratory?

(5) What equipment do you have for the absolute calibration of test apparatus?

(6) Can you serve as an expert witness, either for your client or as a friend of the court? What experience have you had?

Business Practice

(1) Please indicate your fee structure. Do you handle this by hourly charges, estimates for total job, retainer charges, or all of these?

(2) If you use a contract form, please supply a sample.

(3) In your charges, how do you treat such expenses as travel, subsistence, shipping, report reproduction, and computer time? (Note: Consultants usually charge to you the time spent during travel for you on Monday through Friday, 8:00 a.m. to 5:00 p.m. There may be a charge for use of highly specialized and expensive equipment.)

(4) What insurance and bonding do you have?

(5) Are you operating as an individual, partnership, or corporation?

(6) What statements do you have in your contracts covering commercial security, liability, patent rights?

(7) What restriction is there on the use of your name in our reports, in litigation, in advertisements?

(8) What is the character and extent of reports that you prepare? Can you give examples?

(9) What facilities do you have for producing design shop drawings on devices that you may develop for the specific purposes of a consulting task?

(10) Where is your principal office? Do you have branch offices? Where?

(11) What size is your staff? What are their qualifications? Who will be working on this project?

The Proposal

Once you have selected a consultant, you can arrange to obtain his services in several ways. With most professional people a verbal commitment is sometimes all that is necessary. However, you may wish to request a written proposal that spells out the steps to be taken in the solution of your problem.

Often, in a larger job, proposals from several points of view are evaluated and used as one of the bases for the final selection of the consultant. In this case, answers to pertinent questions in the preceding section may be sought in the proposal rather than in the interview. If so, evaluation of the proposal from this point of view is self-evident from the above discussion. If the questions you are interested in are not answered to your satisfaction, don't hesitate to ask for further clarification. In the discussion below, we are concerned with the section of the proposal that outlines the consultant's approach to your problem.

Aside from background qualifications of the consultant, the proposal should answer the questions:

(1) How much is the service going to cost? Smaller jobs are often bid on an hourly basis, with a minimum commonly specified of one-half day's work, plus direct expenses. Larger jobs are usually bid at a fixed amount, based on the work steps described.

(2) What is the consultant going to do? The answer to this question may range all the way from a simple agreement to study the problem to a comprehensive step-by-step plan to solve it.

(3) What will be the end result? The answer to this question is all too often not clearly understood; the result is usually a report that specifies the consultant's recommendation. If you do not want to pay for the preparation of a written report, and a verbal one will do, specify this in advance. Since the recommendations often call for construction to be carried out by others, whose work is not subject to the consultant's control, results usually cannot be guaranteed. Rather, an estimate of the noise reduction to be attained is all that can be expected. If the consultant is to provide drawings from which the contractor will work, you must specify sketches or finished drawings. Generally, sketches are sufficient. If special materials are required, the consultant should agree to specify alternative selections if possible. If you want a guaranteed result, experimental work will usually be necessary.

In the case of a proposal to quiet machine noise, the proposal, if detailed, will probably call out the following steps:

(1) Determine the daily noise dose, so that the amount of reduction required is known.

(2) From diagnostic measurements, determine the location and relative strength of the major noise sources on the machine in question, all other competing noise sources being more than 10 dB below the intended noise.

(3) Design preliminary noise control means; discuss design with production people for possible interference with access to the machine.

(4) Prepare and submit final recommendations in a report, with construction data.

(5) In a post-report conference, resolve any questions or compromises; submit memorandum of conference.

(6) If experimental work is needed, it can be added between (3) and (4) above.

Other Services

If you wish, the consultant can also, as additional services, provide monitoring of construction to determine compliance with specifications. The consultant can also make post-installation measurements to confirm predictions and supply oral briefings as needed.

By working with the consultant during his measurements, you can learn a great deal about how to handle the special situation for which he has been retained. However, he brings to the job an instrument that is most difficult to reproduce: ears trained to listen and to guide the use of the physical instruments. It takes much practice and not a little aptitude to achieve this condition. This aspect of a consultant's expertise is most difficult to replace.

If the consultant is to serve as an expert witness for you, you will find that he is not automatically on your side. Rather, he is more like a friend of the court, devoted to bringing out the facts he has developed, with careful separation of fact from expert opinion. Complete frankness is needed if you want to avoid unpleasant surprises. For example, the consultant may be asked by the opposing attorney for a copy of his report to you. Thus, this report should be prepared with this eventuality in mind.

If the consultant is retained to develop a quieter machine for you, there should be a meeting of minds on handling of patent rights. Ordinarily the patent is assigned to the client, with perhaps a royalty arrangement for the inventor.

For many situations, the consultant will need photographs and plans of machines and shop layout to facilitate his evaluation. Permission to obtain these data can be handled in a manner consistent with your industrial security system. A qualified consultant will not have to be told to regard this material as private, not to be divulged to others without your prior consent. If you regard him as the professional person he is, your association can be fruitful to all concerned.