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Noise control of laboratories: case studies

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Laboratories for research and production usually feature work areas complete with exhaust equipment as well as specific equipment (e.g. heaters, shakers, etc.). More to the point, such research and production areas are often linked to open plan offices where workers process their results, as well as partitioned offices where supervising engineers or researchers work.
Such fitting out is supposed to help circulate information around the team and save valuable space. Unfortunately, it easily can be noisy and rather uncomfortable, especially when coming from older fully partitioned laboratories and offices.
This paper aims to illustrate a few acoustical highlights of laboratories through a few cases studies, looking at such parameters as spatial sound level decay, background noise level and reverberation time, but also at such additional factors as general background and psychological aspects, and looking at tentative standards. It turns out that both the acoustical quality of the room and the space planning must be developed according to the users' needs.

1 Introduction

Laboratories can prove to be some rather complicated places where one may find noisy research and production apparatus, noisy building equipment, and noisy yet sensible people to go with it too. Therefore, it can be quite a challenging job for a noise control engineer to be tasked with the acoustical design of laboratories!

This paper aims first to review a few acoustical constraints of such places. Next, it will illustrate those constraints and the relevant typical prescriptions through a few case studies.

It turns out that the design of such places can be tricky, as one does not want any undue noise, yet has to perceive any unusual sound. More to the point, one wants to be able to comfortably write reports and be able to hold phone calls in privacy.

2 A few acoustical constraints

Laboratories can be part of research or even production facilities. In any case, they will typically feature different kind of spaces allocated to specific tasks:

- laboratory rooms (for preparation and actual practical work)
- technical staff office, close to the laboratory room
- researcher rooms, usually close to the technical staff room
- head of department room
- Library / Documentation
- Stores
- Heavy equipment rooms

In addition, there often are some more usual spaces, e.g.:

- Cafeteria
- Meeting rooms
- Offices
- Corridor and toilets
- Technical rooms.

Depending on the speciality of the lab, noise levels generated by the specific research and production equipment can be rather high. For example, crushers can easily generate noise levels in excess of 85 dB(A) at 1 m [1]. While an absorptive ceiling would be very welcome, there often are some rather severe restrictions regarding the use of porous or fibrous material in the research or production rooms.

Whenever possible, noisy equipment should be relegated to sound insulated rooms, yet such relegation must not hinder the supervision and operation of the equipment by the technical staff.

A sizable number of laboratory equipments can be sensitive to vibrations; therefore the relevant vibration control solutions must be implemented to protect them. More to the point, some laboratory equipments can generate significant vibrations in the building structure unless proper precaution is taken. In both cases, there are consequences regarding the structure of the building.

Most of the time, production of heat by the laboratory equipment as well as the elimination of gases, lead to significant air flows being handled by the mechanical equipment of the building. This means that such equipment can be noisy unless properly dimensioned. More to the point, there often are some extractors in the lab whose operation has to be coordinated with the regular ventilation of the building.

Lastly, most laboratories are considered to be hazard areas, with the relevant fire and safety precautions to be applied (including significant smoke exhaust ducts and louvers, and fire retardant partitions and floors).

Meanwhile, whatever the specialty of the lab, there is a need for privacy for at least the head of department office, and often for the researcher too, as well as for the meeting room.

Last but not least, one should also take care regarding the noise emission of all those pieces of equipment to the outside environment, as the neighbourhood will not take it lightly to be subjected to undue noise levels.

3 Basic acoustical targets

First of all, one must stress out that a preliminary diagnosis of the site is an absolute need, so as to spot any such source of noise and vibration as, e.g., railways and motorways.

Next, an analysis of the user's needs must be performed to understand what the acoustical needs are, and how to translate them into acoustical objectives.

To start with, the noise levels inside the facility must comply with the legal requirements in force [2]. More to the point, should the noise exposure levels of the workers be liable to reach 85 dB(A), the spatial sound level decay must comply with the legal target [3].

A range of suitable ambient noise levels is submitted in an annex of standard ISO11690-1 [4]. Also, some acoustical objectives are submitted in French standard AFNOR S31.080 [5].

On the basis of those legal or standard requirements, as well as the wishes of the user, it is possible to state acoustical objectives for the project. Those will at least cover the following aspects:

- Noise control of the noise radiated to the environment. This aspect will of course influence both the sound power output of the technical equipment of the facility and the sound insulation of the façades.

- Sound insulation with regards to the environment (i.e. noise from the activities radiated to the outside, but also noise from the environment intruding inside).

- Sound and impact insulation between spaces of the premises.

- Background noise level inside the premises.

- Reverberation time and / or spatial sound level decay inside the premises.

Typical values are as follows:

- On the basis of the acoustical diagnosis of the site, the noise levels radiated by the facility must not be greater than 3 dB(A) over the background noise level value in front of occupied neighbouring buildings [6].

- The sound insulation of the façades $D_{nTw}+C_{tr}$ of normally occupied rooms (i.e. offices, laboratories) will typically range from 30 dB to 45 dB according to the location of the building with regards to transportation corridors and the neighbourhood [7,8].

- The sound insulation between rooms of the premises $D_{nTw}+C$ will of course depend on the nature of both the receiving room and the potential noise levels in the emission room. The targeted value can range between 30 and 50 dB according to the situation. In addition, typical sound insulation values are submitted in [7] and [5].

- The impact insulation between rooms of the premises L'_{nTw} will of course depend on the nature of both the receiving room and the emission room. The targeted value can range between 55 to 62 dB according to the situation. In addition, typical impact insulation values are submitted in [7] and [5].

- The background noise levels inside the premises will typically range from 35 dB(A) to 50 dB(A) according to the nature of the room. In addition, typical background noise level values are submitted in [7] and [5].

- The spatial sound level decay inside the empty laboratory research or production rooms should not be smaller than 3 dB(A) per doubling of distance [3]. In addition, the equivalent absorptive area of the corridors should not be smaller than one fourth of their floor area [7]. Last, typical reverberation time values are submitted in [7] and [5].

4 A few constructive solutions

To start with, on the basis of the user's needs with regards to the location of the various entities one to another, one must define the nature of the envelope of the rooms, starting with such structural elements as floors and walls. Those elements will often be made of reinforced concrete due to both noise and vibration control purposes and fire and safety purposes. During dimensioning, care must be exercised to reserve enough space for the eventual inertia mass under the relevant apparatus as well as for the usually huge technical and mechanical ducts layout. Quite often, one will eventually find quite a number of pieces of technical equipment located on the last floor or even on the roof, and this must be taken into account too.

Next, the nature of non structural envelope elements such as partitions windows and doors must be defined according to the acoustical targets as well as the safety requirements, especially fire proofing. There will sooner or later be a choice to make between ease of access or direct sighting and the acoustical performance of the envelope of the rooms, and that will have to be explained to the end user.

Then, the projected technical and mechanical layout must be investigated in order to ensure it does not act as a sound bridge between spaces, nor does it generate undue noise. This can be quite tricky as the usually are quite a few apertures in the envelope of the rooms for such safety purposes as fresh air and smoke exhaust. Precautions regarding most of those will have to be discussed with the safety engineer and the relevant acoustical prescriptions will be drafted accordingly. These will typically cover the selection and use of silencers and louvers in coordination with the other parties. A particular problem may arise from the use of exhaust laboratory equipment, which must be coordinated with the regular ventilation of the building so as to avoid exercising too much negative pressure in the laboratories.

Lastly, ceiling and wall cladding must be defined in accordance with acoustical and safety requirements, but also with such operational requirements as cleanliness. A few examples of such absorptive materials have been described in the literature [9].

Due to the tight interaction between all specialties, it is necessary for the noise control engineer to be associated to all decisions regarding changes that might be considered during the construction phase.

5 Case studies

5.1 A laboratory between tracks

During one of its reorganisation fits, a major electronics company decided to sell its cramped older facility located in valuable downtown area to a much cheaper place while making a rational looking building. The management took to the task in earnest and quickly found a cheap piece of land to build its facility. Next, heads of departments hotly discussed their share of floor surface and then an architect was hired to squeeze the required surfaces in the available land surface. The project quickly gained the approval of both the management and the economist.

On looking at the design development drawings, the technical people were flabbergasted: for the aforesaid piece of land was actually located between two busy rail lines, which did not augure too well for such a vibration sensitive place as a laboratory (but certainly explained at long last why it was so cheap). As usual, the clean room was topped by a huge technical room to house all the required air handling units and filters. What was less usual was that in order to save space the other technical rooms of the building had been located close by. But the one feature that eventually did leave the techs breathless was the presence of a metal cutting workshop right under the cleanroom, complete with hydraulic cutters and hammers. Confronted with the shrieks of the techs, the management sheepishly admitted that they had solely looked at the problem from the economic angle. They also pointed out that with the company having committed itself by buying the land and submitting the required building permit, there was no way one could back from the project.

A noise control engineer was hired to look into the problem. First of all, a noise and vibration diagnosis of the piece of land was performed so as to decide on noise and vibration noise control measures with regards to the outside environment. Next, a diagnosis of the existing laboratory site downtown was also performed so as to have a comparison with a situation deemed acceptable. It quickly turned out that while the whole building would not need to be resiliently decoupled due to rail vibrations, special care would have to be exercised on the clean room both because of the rail vibrations and the potential nuisances from both the workshop and the technical room. This initially resulted in the clean room being designed as a resiliently supported box by means of spring boxes in order to meet the vibration criteria as forwarded by the techs. However, the techs eventually grudgingly admitted that the vibration levels in the existing facility were actually quite compatible for most of their needs. Therefore, a new project was drafted, with the clean room now rigidly connected to the building, but all the relevant sensitive apparatus being treated to passive isolation featuring a huge inertia mass and spring boxes supported by separate foundations, while the heavy pieces of equipment from the workshop were treated to specific vibration control measures also involving a huge inertia mass and spring boxes supported by separate foundations for each of them.

While the acoustic and vibration objectives were eventually successfully met, this was a tricky job that did not go as cheap as the management was initially planning.

5.2 A laboratory on a busy campus

An industrial company decided to improve its existing facility by adding a new building complete with laboratories and offices. The design called for a building featuring partitioned engineer's or researcher's offices, and open plan offices for the technical staff with glassed partitions onto their own laboratory room. Noisy pieces of equipment were grouped inside specific apparatus rooms. The technical equipment of the building was located either on the roof or in the basement.

First of all, a diagnosis was performed in a similar lab of this company. This enabled the noise control engineer to assess the typical ambient noise levels in the various rooms as well as the sound power level of the heavy equipment. A site diagnosis was also performed in order to assess the background noise levels on site.

The acoustical performances of the building, including technical equipment, were specified on the basis of this diagnosis. One also tried to provide comfortable acoustics by using absorptive yet cleanable ceilings.

During construction, it was noted that the sound power levels of the technical equipment were often slightly over the requirements. It was necessary to check at the factory the real value of the sound power level of the equipment to be mounted on the roof. More to the point, it was found out on commissioning that the contractor had not really bothered to properly balance the various flow rate values in each part of the layout, and time was spent on that. The contractor found difficult to maintain a good balance of flow rates and tried to avoid coordinating the laboratory exhaust with the building ventilation. Lastly, it was found out that additional safety measures had resulted in air transit louver being installed in some partitions, thus ruining the expected sound insulation between laboratory room and own office.

5.3 A laboratory in an industrial area

A research and demonstration lab was erected in an industrial estate. Due to the client not willing to disclose the exact location, no diagnosis was performed on site. This eventually resulted on completion of the building in the neighbours complaining about noisy behaviour (e.g. the emergency generator being located right under the windows of a neighbour!).

While the design team proposed a set of ceilings for acoustical purposes, the end user did reject it on the grounds of cleanliness and economy, thus resulting in a noisy environment in which intelligibility was difficult and tiredness set in quickly. This eventually had to be remedied amid much grumbling of the laboratory staff.

5.4 A laboratory moving in an existing building

A major reorganisation prompted a large company to regroup several of its smaller laboratories and offices into a large facility. An existing building large enough for such purpose was located and promptly acquired as its price was attractive for such a conveniently located building and the required floor surface was available.

However, company's policy was to try and improve the communication between workers by using large open spaces. More to the point, a rational organisation of the floor was set: there would be a technical space in the middle of each open space for such items as printers or even laboratory equipment. As the workers had previously enjoyed small partitioned rooms in older premises that they had known for years, they were first reluctant and then quickly seized on the noise issue as grounds for complaints. An acoustical diagnosis was ordered by the management and the noise control engineer first of all found rather low background noise levels, as well as a poor spatial sound level decay due to the lack of absorptive materials. Reactions from the interviewed workers were clearly bivalent: while some would praise the fact that they now could supervise their own apparatus from hearing its operation without bothering to look at it, others complained that they were often startled by the sudden remote operation by somebody else of a piece of apparatus they could hear but not see. Eventual proposals suggested an increase of the background noise levels to 40 dB(A) and a more systematic use of absorptive material, while regrouping people by teams.

6 Conclusion

On the basis of sheer experience, there are a number of lessons that often have to be learned the hard way again and again:
- Never trust the management when it comes to technical implications (sorry but the economist got there first!)
- Be ready to change everything (and one does mean everything) should one of the essential criteria not be met.
- Always perform a diagnosis of both the future location and the existing facility.

References

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