Noise radiated by a piece of industrial equipment: case study

Marc Asselineau[a]
Peutz & Associates, 10 rue des Messageries, F75010 Paris, France

ABSTRACT

For many years, a chemical company had been operating a plant on a large campus located in the suburbs of Paris. In order to improve the research and production of specific products, the construction of a new building was decided on the site. This future building would be subjected to noise generated by various sources (e.g., electric transformer plant, scrap yard, heavy traffic road, and planes) that warranted a specific study for its envelope. However, this new building was to be erected quite close to existing flats, whose higher floor could enjoy a view of all the technical appliances to be found on the roof.

In compliance with the regulations in force, a noise impact study was duly undertaken. It featured a diagnosis of the site in order to assess the background noise level in day and night time and inventory the noise sources. On the basis of this data, a predictive study was performed in order to dimension the noise power output of all the pieces of equipment to be implemented on the roof. During a visit of the manufacturer's facility, control measurements were performed on the pieces of equipment. Finally, commissioning measurements were performed.

This paper aims at giving a picture of the noise control engineering aspects of such a project through a case study. Following a brief look at applicable (French) regulations, the diagnosis procedure is explained, together with the consequences of its results, especially in light of such a multi-exposure case. Lastly, a procedure for the prediction of the noise radiated by a part of an industrial facility is submitted. The relevant prescriptions and eventual commissioning will then be examined.

One of the key conclusions drawn from experience is that the diagnosis is an essential part of such a project, as it enables to set properly the noise limits targets, both globally and in terms of noise climate.

1. INTRODUCTION

A large chemical company had been operating one of its research and production plants in a suburban area. That area was actually quite a mix: at the beginning it had been an industrial area, complete with car breaker yards and various workshops. More to the point, there was a highway close by and a power station too.

Over the year, most of those breakers had quietly disappeared but there still remained one such facility operating. Four stories dwellings had gradually taken over the available land close to the plant. And road and air traffic had steadily grown. Due to the complexity of the environment, this made for an interesting noise impact study when the chemical company decided to have a new production building, complete with technical equipment on the roof, built close to existing dwellings.

[a] Email address. m.asselineau@peutz.fr

2. INVENTORY OF NOISE SOURCES

A. Diagnosis of the existing situation

In the course of the impact study, one needs to assess the acoustic climate on site prior to carrying out a new project.

First of all, an inventory of all potential noise sources had to be compiled in order to carry out the impact study. While this sounds straightforward enough, there are quite a number of difficulties associated with such a task: to start with, on site the ear is assaulted by many different sounds and it is not always possible to identify them all. Giving a good try, one can first of all look hard at the site aerial photographs and try to identify dwellings and industries or transportation corridors. Next, a visit of the site is in order so as to crosscheck the previous findings. This is a good time to decide about the location of the measurement points (e.g. avoid the dog barking his day away or the roaring fan that did not appear on the photograph). Such measurement points will typically be located at the fence of the industrial premises or close to the sensible property around (e.g. neighbouring dwellings).

Investigating the initial acoustical climate can sometimes provide some excitement especially if neighbours are aware of the future project: while one may simply encounter people curious about the size of the project and its whereabouts, there might also be some rather hostile people wondering aloud whether the measurer is qualified for his task, questioning his choice of measurement points and conditions, and sometimes eventually pointing out to whatever unfortunate accident might happen. But talking with people can sometimes bring some answers: a number of residents had actually never realized that there was a power plant nearby, though the measurement results clearly featured the distinctive 100 Hz contribution. They were actually more concerned with the last car breaker in operation and its attending presence of youngsters.

The assessment of the ambient noise on site can then be carried out at the selected points. Such an assessment can be performed using a long time (e.g. 24 hours) measurement but one can also use a sampling technique provided the key features of the environment are reasonably known. One should keep in mind that those noise level values will ultimately be used to dimension the sound power emission of the project, therefore the use of the A weighted equivalent sound level may really prove a bit limited for such purpose and one should really be ready to use statistical noise levels as well as spectral information. Last but not least, whatever noisy event happening on site during those measurements must be accounted for and duly identified (e.g. fly by or motorbike or even dogs barking).

Of course, there still might be some nasty surprises in stock, e.g. youngsters performing stunts with their cars or bikes in the parking lot in the late evening. It is up to the measurer to decide what to do with such information then!

Another interesting point was found during the night time measurements: a significant part of the background noise levels actually originated from miscellaneous pieces of equipment of the chemical plant.

Finally, after the diagnosis the A weighted equivalent sound levels for the day and for the night periods were duly assessed, together with their origins (e.g. transportation corridor, industrial activity), so that all tools could be given to the designer to ultimately set the proper noise limits of the project.

B. Inventory of future potential noise sources

The project did include a number of new noise sources. Those had to be known as soon as possible so that provisions could be made for their eventual housing. Such an inventory featured a list of equipment but also such data as the sound power level output of each piece of equipment. This meant that some tracking was necessary to gather from the end user and the design team as well as the manufacturers the relevant data. For rather new pieces of equipment, measurements at the factory were considered right at the start.

3. IMPACT STUDY

A. Applicable regulations

Applicable regulations in France typically call for two rules:

- The noise levels generated at the perimeter of the plant must not be greater than specific values that are stated in the regulations [1]. Those values are a function of the period of time (i.e. day evening or night) as well as a function of the type of land zone (e.g. residential, industrial, ...)
- At 2 m in front of the façade of neighbouring dwellings, the gap between the ambient noise level (including the plant of interest operating) and the background noise level (without the plant of interest operating) must not be greater than a specific value that is a function of the period of time.

This does of course prompt a question regarding the relevant noise indicator. While the law text of 1985[1] merely used the equivalent A weighted sound levels L_{Aeq}, the law text from 1997[2] actually prompts the use of the L_{A50} when the gap between L_{Aeq} and L_{A50} is greater or equal to 5 dB(A). In such a situation as this chemical plant, the use of the L_{A50} seemed straightforward enough.

Another interesting question would eventually stem from the night time climate: first of all how does one assess the background noise level when the plant is constantly operating? The law text actually suggests that one might go on to an equivalent site further from the noise source of interest and perform the measurement there. While such a move is not unduly complicated in the countryside this is a bit more hectic in an urban case. In such a situation as this chemical plant, the idea was quietly discarded and it was ultimately decided (with the approval of the authorities) to consider the background noise level as it was (i.e. with the remainder of the plant operating). Next came another interesting question: what noise limit does one use when the fence of the plant is right over the border between residential and industrial zones? The official answer was to use the industrial one, making sure that the assessment point was located on the industrial plant's premises while the maximum 3 dB(A) gap was satisfied in front of the façades of the dwellings.

Funnily enough, the legal requirements from the appendixes of the building permit regarding the construction of a new building on the plant seemed more intent on making sure that the sound insulation of the façades would meet the requirements pertaining to the presence of a highway and an air traffic path close by than to prevent noise annoyance to the neighbours.

B. Collecting the data – and checking it

Once the acoustical targets were clearly defined, it was necessary to perform an inventory of the noise sources that would ultimately be found on the project. A complete list of equipment was drafted by the engineers and constantly updated along the project.

Next, one had to find the relevant noise power levels associated to those pieces of equipment. While this was pretty simple for ordinary fans, being a matter of picking up the relevant information in the manufacturer's documentation, it was more complicated for specific pieces of equipment required by the end user, especially when new.

As soon as the required sound power levels of those equipments were determined, the manufacturers were notified and measurements planned on a head of series at their plants prior to the actual manufacturing of the other pieces. Those measurements included sound power level measurements of individual fans or compressors in a reverberation room [3] so as to check the acoustical compliance of those fans with the contractor's documents, and sound level measurements of a complete unit in free field over a reflecting plate conditions [4] (actually the parking lot after working hours).

A potential conflict can erupt between the various targets for a piece of equipment: typically there will be a maximum noise power level value specified but this must be complied with the equipment working under given operating conditions. Therefore when making the relevant acoustical tests it is of uttermost importance that the other engineers be there too in order to check the compliance on their own conditions.

C. Predictive calculations and studies

A computer model was elaborated in order to assess the noise impact of the project on the site. Using this model [5] it was possible to compute the noise levels generated by all the miscellaneous noise sources on site taking into account the presence (and subsequent screening or reflecting effects) of buildings.

First of all a model of the initial situation was elaborated. It featured the existing buildings and noise sources, and computations were performed at a number of points including those positions used during the diagnosis measurements. This enabled to check the validity of the model regarding the situation prior to the construction of the project (i.e. one could actually find back the same value for computation and measurements at the diagnosis points).

Next, a model of the future situation was derived introducing the new buildings and their associated noise sources. The model also pointed out that due to the screening effect brought in by the new buildings the background noise level value on the site would be lower.

During the design phase a first assessment was performed using either the theoretical sound power levels that were available (e.g. for the fans) or a set of values given on the basis of experience. This enabled the design team to point out potential problems (e.g. freezing equipment compressors) that would need some extra precautions and to state maximum sound power levels for each piece of equipment.

The moment the manufacturers were allocated their contracts, the computational model was updated using their stated values. This enabled a better definition of the various noise reduction devices (e.g. silencers, noise barriers, enclosures) that would ultimately be needed for the project to comply with the required acoustical targets. Of course, the model was regularly adapted according to the unavoidable modifications of the project due to the unavailability of some specific products or to some last minute operational requirements changes.

The final predictive computations were eventually included in the relevant impact study submitted to the authorities in order to prove future compliance with the legal requirements.

The other parts of the studies were simply the usual construction and building acoustical engineering work.

4. FOLLOWING UP: SITE SUPERVISION

Site supervision starts with the designation of the contractors and eventually ends with the commissioning. First of all, one must make sure that the contactors have been allocated the proper documentation and are aware of the potential difficulties in the project.

Next execution drawings must be elaborated (usually by the contractor) and checked by the design team together with the relevant technical documentation. One often is for a very interesting time as some contractors often prefer to do the work first and submit whatever they consider suitable later on. It is not uncommon for the examination of such documents to turn up a serious lack of communication between contractors (e.g. a duct going through a beam) or a lack of adequate precautions (e.g. silencers or the resilient pads under a piece of equipment being avoided with the comment “we will put them later if necessary”). Either constructive talks take place and this phase works fine, or enough paperwork is amassed for the legal department to work its way through at the end of the project.

The moment the execution drawings have been submitted, construction work can really start. During construction, site supervision visits must be performed in order to check the compliance of the work with the design specifications. While such visits are sometimes rather dull, it is not uncommon to find some rather surprising situations (e.g. the resilient pads under a piece of equipment being "temporarily" replaced by bricks with the comment "we will put them later"). This is always a delicate phase where one must find an equilibrium between the customs and know how of the contractor and the needs of one's specialty. One has better put some conditional stops at key points (e.g. requiring an inspection to be performed by the design team prior to the closure of a ceiling) to avoid nasty surprises later on.

It is not uncommon that during construction some piece of equipment or material proves to be unavailable in the allocated time. A replacement is then proposed by the contractor and it is up to the design team to decide whether it is suitable or not. Sometimes, the contractor will not bother to indicate such a problem and will simply switch to a product that he judges to be suitable. One such situation often concerns the thermal lining of the walls: the acoustical engineer will typically request a mineral wool lining, and when the contractor eventually looks for such lining he can be quick to discover that polystyrene lining is much cheaper and available everywhere. If nobody is quick enough to point out the danger on the sound insulation then there sure will be a problem at the end.

During the whole construction phase one should be careful regarding the issue of construction noise. While neighbours can eventually be patient provided the end user and the design team explain why some construction phases will be noisy, their patience will grow thin when unchecked noisy operations are randomly taking place, especially when accompanied with dust emission. To add some motivation to the task, one might care to remember that it may be necessary later on to meet those neighbours during commissioning!

5. COMMISSIONING

Commissioning is performed at the end of the project that is supposed to be completed by then. It is intended as the final construction phase during which compliance with the various targets assigned to the design team and the contractors is proved to have actually been achieved. But it also marks the transition between the design team control of operations and the end user possession of the facility.

Unfortunately, there often is a rush at the end to accommodate some minor changes, and the end user is already investing the place. On the practical side, this means that the commissioning measurements will typically take place at night when nobody is drilling or hammering away.

Such a commissioning will typically feature sound insulation measurements to the outside as well as between spaces of the building. This may be an occasion to find the hard way that some prescriptions had actually not been followed (e.g. a finishing layer on hollow concrete blocks that had subrepticiously been replaced by a plasterboard), or products submitted to approval not been used (e.g. the seals of doors as required by manufacturers replaced by much simpler seals).

Noise levels measurements must be performed inside the premises. Such measurements often have to be performed with the HVAC engineer to make sure that the mechanical systems are operating correctly. It is sometimes necessary to perform a noise measurement and a flow rate measurement.

Noise level measurements also have to be performed outside. Those will include noise level measurements close to specific louvers or pieces and equipment, as well as measurements at the fence of the plant and close to the neighbouring buildings. Regarding the later, one has to make sure that the measurement conditions are similar to those of the initial diagnosis so as to be able to compare the initial and the final situation and prove that the legal requirements have been complied with. The choice of measurement points has to be performed with as much care as the initial choice during the diagnosis (i.e. one wants to avoid undue noise sources such as a radio blaring or an irate neighbour shouting).

Another complication may come from the end user attitude: while such measurements may be reassuring to the acoustical engineer, the end user often fears a reaction from the neighbours (e.g. if the engineers are performing a measurement there surely exists a cause of complaint so there might be some money to gain out of it). It is not unusual for an end user to forbid the acoustical engineer to perform the final measurements in front of the neighbour.

Apart from the actual measurements being performed, this is a good time to give the end user a couple of practical hints regarding the operation of his facility (e.g. make sure the lorries performing the deliveries will not come honking at 5 am, nor the bleeding of excess compressed air be performed at 2 am). While some of those recommendations might seem straightforward enough, some might look innocuous enough to be disregarded by an enthusiastic end user (e.g. keeping doors opened to the outside to speed up some transfers or maintenance operations).

4. CONCLUSIONS

Performing the noise impact study of a new addition on an existing site can be a very exciting experience. To start with, the applicable regulations are not always appearing straightforward and clear. Next, due to the multiplicity of noise sources on the site, it is not always clear to decide what should actually be considered as background noise. And performing measurements on the existing site does not always help to make up one's mind.

Meeting the neighbours and asking questions may sometimes help clear the interrogations but it is not always easy and is often uneasily perceived by the end user of the project.

Choosing the right pieces of equipment always is a challenge: it must be economical, it must be quiet, and it must satisfy the other technical requirements too. More to the point, it is not uncommon for a selected piece of equipment to be unavailable during the construction phase. One must then be ready to find a suitable replacement.

Checking the validity of the noise emission data is quite important, especially for purpose built pieces of equipment, as adding up uncertainties on such large projects can lead to disastrous results. One should especially make sure that the data submitted by the manufacturers is indeed pertaining to the operating conditions of interest.

Commissioning is not only the final verification for the engineers, it also is the right time to hand the end user some hints regarding his day to day operations of the new facility, and such advice should not be forgotten.

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