Acoustics'08 Paris
June 29-July 4, 2008
www.acoustics08-paris.org

Don't forget the quench pipe when installing an MRI

Carel Ostendorf

Cauberg-Huygen R.I. BV, Postbus 480, 6200 AL Maastricht, Netherlands
c.ostendorf@chri.nl

An MRI is a useful medical device but it makes a lot of noise. A sound level of 90 dB(A) or more in the MRI room is not unusual. Placing an MRI into an existing hospital means that extra care has to be taken to prevent the noise from the MRI causing nuisance in adjacent rooms. In this paper the situation is discussed in which complaints appeared after the installation of the MRI. First sound measurements were done to see if the sound level in the office above the MRI fulfils the noise ratings. This way it would be clearer if the acoustic measures did their jobs. Whatever the outcome, the hospital wanted to put an end to the complaints. So, more sound measurements were done to establish the cause of the nuisance and to point out what extra measures had to be taken to solve the problem. It turned out that the quench pipe played an important role in this situation.

1 Introduction

In 2004, a 3T (tesla) MRI was placed on the 4th floor in the Leiden University Medical Centre. During the construction of the MRI room, extra acoustic measures were taken to prevent nuisance from the noise of the MRI. The sound level in the rooms above the MRI should not exceed 40 dB(A). Nevertheless, complaints appeared from the rooms on the floor above the MRI (5th floor) when the MRI was performing a CASL sequence. The CASL sequence sounded like a phone ringing but no one could find the phone.

First sound measurements were done to see if the sound level in the room above the MRI meets the noise ratings. This way it would be clearer if the acoustic measures were doing their job. Whatever the outcome, the hospital wanted to put an end to the complaints. So, more sound measurements were done to establish the cause of the nuisance and to point out what extra measures had to be taken to solve the problem.

2 Sound measurements

2.1 General

In order to make sure the right sound level was reviewed, two microphones were used. One microphone, type B&K 4165 was placed in a small machine room next to the MRI room. In the machine room there was a small gap in the wall to the MRI room for cables. The microphone was placed in front of the gap. With this microphone changes in sound level due to the sequence of the MRI, could be measured clearly.

The second microphone, also type B&K 4165, was placed in the room directly above the MRI. This room was used as a small office and for study. The microphone was placed at a height of 1.6 m above the ground.

Both microphones were connected to a two channel real time frequency analyzer type 2144 from B&K. So, the sound measurements were done simultaneously for both locations.

Every second an averaged sound level L_{eq} was logged so it was possible to view the profile of the noise in time. At the same time a CPB frequency analysis was made in 1/3rd octave bands.

2.2 Result overall level

Figure 1 shows the result for the A-weighted overall level during a CASL sequence. The top graph shows the sound level in the machine room, the bottom graph the sound level in the office above the MRI room. Every slice in the graph gives the L_{Aeq} over 1 second.

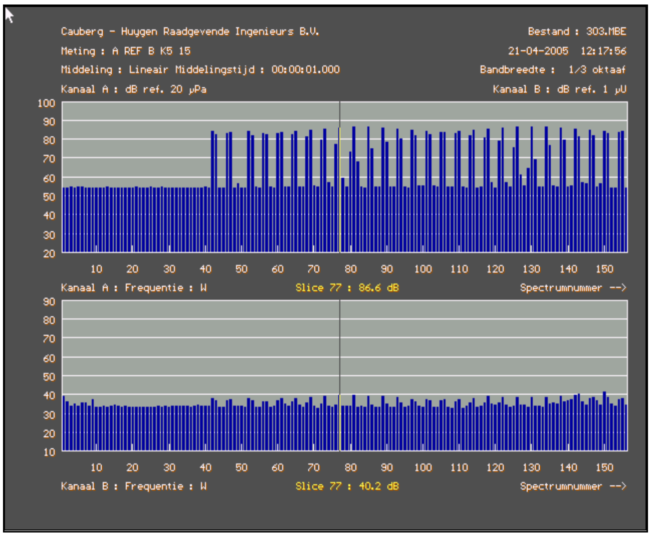

Fig. 1 Profile of A-weighted sound level during CASL sequence. Top graph shows sound level close to MRI, bottom graph the sound level in the office.

The effect of the CASL sequence is clearly visible in the top graph. Every 2 seconds a 2 second noise pulse is given. The difference between the situation with and without noise is about 30 dB(A). In the office, the background sound level is 34.5 dB(A). The CASL sequence produces about 40 dB(A).

The averaged sound level of a complete CASL sequence is 36.2 dB(A) in the office. This is only 2 dB(A) above the background level. When corrected for the background level, the sound level of the MRI is 31 dB(A) which fulfils the required 40 dB(A).

Nevertheless, the noise of the MRI is very audible. This is caused by the specific frequencies of the CASL sequence. Figure 2 shows the frequency analysis in 1/3rd octave bands of the period the CASL sequence is producing sound.

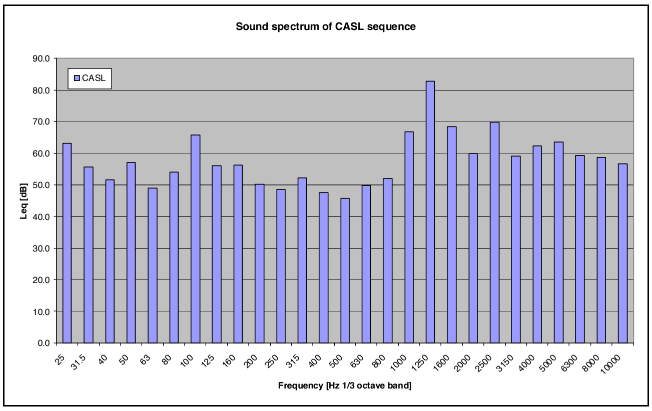

Fig. 2 sound spectrum in 1/3 octave band of CASL sequence

Figure 2 shows that the 1250 Hz is very prominent in the sound spectrum. Therefore in figure 3 the profile of the 1250 Hz band is given.

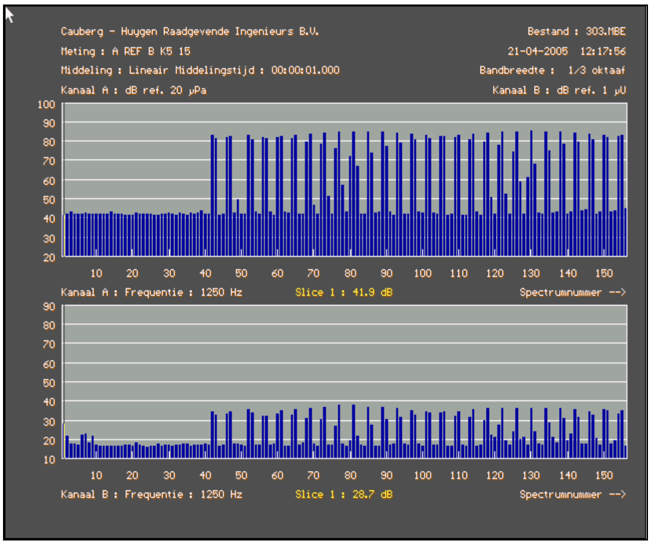

Fig. 3 Profile of 1250 Hz sound level near MRI (top graph) and in office above MRI (bottom graph).

Now it is clear why the noise of the CASL sequence can be heard so clearly. The difference between background level and CASL sound level is about 12 to 18 dB in the office.

3 Cause of the sound level

3.1 General

In general three causes are possible for the sound level in the office:

1. Airborne noise from the MRI room to the office;
2. Construction noise from equipment attached to the MRI and attached to the building construction;
3. Combination of both.

By listening to the sound of the CASL sequence in the office, it appeared that the sound was everywhere although close to the window it could be heard better. After opening the window, it became quite clear that the main sound source was outside the room. A small pipe on the roof terrace was the outlet of the quench pipe. In order to operate, the MRI uses a coolant to enable the superconducting capabilities of the electromagnetic coils within the MRI. The most commonly used coolant is helium. In case of emergency, the magnet of the MRI will be shut down. This causes the helium to boil and change from liquid into gas very rapidly. The expanding gas should leave the machine and building as soon as possible and for this the quench pipe is used. The quench pipe is a safety device. Figure 4 shows a picture of the situation.

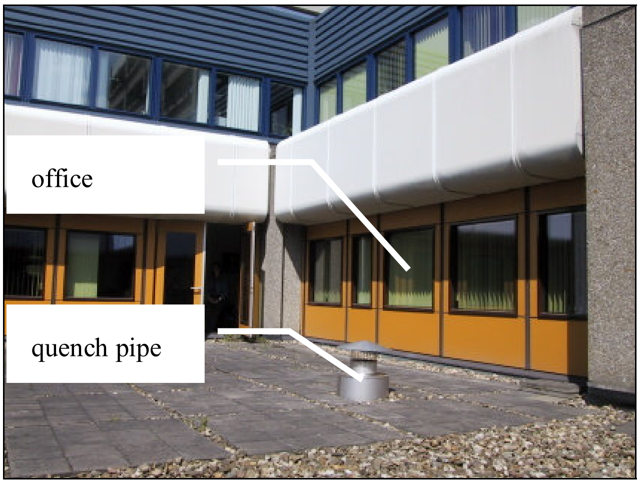

Fig. 4 Situation of quench pipe and office

From this situation it was clear that airborne noise was a factor in the noise problem. Construction noise could be involved as well because the quench pipe inside the building was attached to the building construction which was in this case the floor of the office. Figure 5 shows this in detail.

Fig. 5 Construction detail of quench pipe connected to the building.

3.2 Airborne or construction

In order to determine whether the noise in the office was caused by airborne noise, construction noise or a combination of both, the noise of the quench pipe was reduced. If airborne noise was the only cause, the reduction in sound level for 1250 Hz close to the quench pipe would be the same as the reduction of sound level in the room. If construction noise is the only cause, reducing the airborne noise of the quench pipe would not have any effect on the sound level in the office at all.

The sound reduction of the quench pipe was achieved by placing an enclosure around the quench pipe. The enclosure was made of sound absorbing panels which happened to be stored in the hospital because they were not used at that time. Since the quench pipe is a safety device, it was not allowed to build a rigid construction. If an explosion would occur during the sound test, the sound enclosure had to be easily blown away. So the panels were just placed against each other and gaps were closed with extra sound absorbing material. Figure 6 shows the result.

Fig. 6 Sound enclosure quench pipe.

Before and after the enclosure was placed, a sound measurement was done at approximately 1 meter distance of the quench pipe. The result of the measurement with and without enclosure is shown in figure 7.

Fig. 7 Sound spectrum of quench pipe (distance 1 m) with and without reducing enclosure.

Figure 7 shows the relevance of the 1250 Hz band. The temporary enclosure has achieved a reduction of 7 dB in this frequency band. If only airborne noise is the cause of the problem, the sound level in the office will be reduced with 7 dB as well for the 1250 Hz band. If the reduction is less, construction noise has an influence.

In figure 8 the result is given for the influence of the enclosure on the sound level in the office. Three lines are shown in the graph: the background level if the CASL sequence is not active, the sound level with active CASL and the sound level with enclosure around the quench pipe.

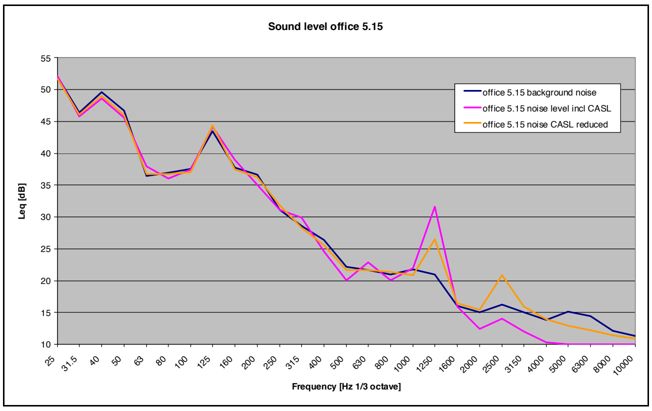

Fig. 8 Sound level in the office with and without enclosure.

Without the enclosure, the sound level of 1250 Hz is an averaged 10 dB over the background level in the office. With the enclosure the sound level of the CASL sequence is reduced by 5 dB. This is not as much as the reduction close to the quench pipe. This means that construction noise has some influence but that airborne noise is the most important factor. So, the first measure is to reduce the noise of the quench pipe. If after those measures the noise of the CASL sequence is still a nuisance, then measures to reduce the influence of constructing noise have to be taken.

4 Sound reducing measures

To reduce the noise of the quench pipe, four simple measures can be taken:

1. put a silencer in the outlet of the quench pipe;
2. put the quench pipe in a enclosure which isolates sound well;
3. replace the glass of the windows of the offices with better isolating glass;
4. change the setup of the CASL sequence.

Due to safety regulations it was not allowed to build a rigid enclosure with sound dampened outlets. Putting a silencer in the quench pipe wasn't allowed either because of these regulations. The width of the quench pipe is carefully chosen and related to the length of the pipe, the amount of coolant gas and the time needed to let the coolant gas escape. Changing the length or diameter of the pipe would change the reaction of the quench pipe in case of an emergency. Furthermore, welding things to the pipe would cause weak spots and potential danger.

Replacing the glass in the windows is a simple but effective solution. To be able to place the right acoustic glass, it turned out that most of the façade would have to be replaced. Because of the number of windows that had to be treated this way, this solution was too expensive. Besides, users of the offices wanted to be able to open their windows or doors without hearing too much noise of the pipe. So reducing the noise of the quench pipe was strongly preferred.

The MRI technicians of the hospital were able to change the setup of the CASL sequence thus producing fewer specific tones and less noise.

5 Conclusion

Only by changing the setup of the CASL sequence, it turned out to be possible to solve the noise problem of the MRI. This solution means that the use of the MRI is limited instead of using technical measures to prevent the noise from causing nuisance. For a research hospital, this is not a desired situation. The MRI department wants to do whatever is necessary without having to be concerned about the neighbours.

In this case, technical measures to reduce the noise of the MRI *after* installation of the MRI could only be taken against high costs. During the engineering process of the MRI installation, the outlet of the quench pipe has to be taken into account. This increases the chances of unlimited use of the MRI and decreases the chances of nuisance. Everybody happy!

Acknowledgments

Thanks to the Leiden University Medical Centre for their support.