A COMPARISON OF ACTIVE AND PASSIVE METHODS FOR SILENCING GAS TURBINE EXHAUSTS

P A Brewer,

British Gas, Design Standards Department, London

1. INTRODUCTION

Once natural gas was discovered beneath the North Sea it was necessary to provide for its transport from the coastal reception terminals to the customers. This involved British Gas in a massive construction programme including the laying of thousands of miles of pipeline and the construction of many compressor stations to pump gas along the pipelines to all regions of the country. This programme still continues today.

During the development of this national transmission network British Gas has paid considerable attention to environmental protection and looks very carefully at noise emission as part of this environmental concern.

Each unit at a compressor station consists principally of an industrial aero-engine derivative, for example a Rolls-Royce Avon whose exhaust gas turns a power turbine which is directly coupled to a centrifugal gas compressor. One single unit can now deliver up to 24 MW of compression power.

This paper presents a case history of one such early station constructed in the mid 1970s where low frequency noise problems existed and describes how they have been overcome by active and passive means. The station comprises two units consisting of Rolls Royce Avon machines powering Cooper gas compressors. Each machine has a maximum power output of about 12 MW.

2. "AS-BUILT" 1974-1975

2.1 Planning Consent

The planning consent noise limit was given as 5 dB(A) above existing ambient noise measured at the boundary or outside the boundary of the station. Ambient noise levels around the station were relatively high, for one of our sites - the lowest value being 37 dB(A), giving a 42 dB(A) planning consent. This corresponded to NR50 at 300 ft from the unit but for various reasons a design target was established that was more strict than this. However with the benefit of hindsight it can already be seen that a dB(A) limit or even a conventional NR curve overlooks the potential problems caused by low frequency noise occurring in the 31.5 Hz octave band. Our current practice in controlling environmental noise is covered in Reference 1.

2.2 Noise Complaints

Complaints from a local resident were received and investigated by British Gas during operation of the station during late 1976 and early 1977. Levels measured at a complainant's house 1,300 m away were typically 70-74 dB in the 31.5 Hz octave under light downwind conditions, which corresponded to on-site noise levels at 100 m of about 84-85 dB in the same octave. As can be seen from these figures, when favourable propagation conditions existed only 10 dB reduction occurred over 1300 m which is about half that which might be expected from simply hemispherical spreading. The complaints were considered justified and British Gas carried out modifications to the internals of the power turbine exit which had produced useful reductions at other stations. These modifications produced a reduction to about 79 to 80 dB on-site but this was not considered sufficient to guarantee that there would be no further noise complaints. Consideration was also given to raising the height of the exhaust stacks which had been successful at another station but the need for this was not considered justified because of the low anticipated utilisation of the station in the following 4 years.

3. ANR

3.1 Experimental System

In conjunction with British Gas Engineering Research Station an experimental active noise cancelling system was installed by outside consultants at the station, and trials were carried out in April 1981.

The system in its various forms consisted of a ring of loudspeakers at the top of the stack, 3 or 4 microphones, power amplification and signal processing devices, and it is not the intention here to describe the details of the its operation. The attenuation produced by the system in the early days of operation was typically 7 - 9dB in the 31.5 Hz octave measured on-site and this was certainly considered a valuable reduction. In addition the previously prominent peak at 25 Hz, which probably corresponded to a resonant frequency of the exhaust stack, was greatly reduced.

3.2 System evolution, results and evaluation

Development of the system continued, involving re-positioning of microphones for example, further into 1981, and on completion British Gas did an evaluation of the system as it stood in March 1982. Substantial reductions, of about 8 dB in the 31.5 Hz octave were measured both on and off site with the active noise system on, although it was observed that low frequency noise was also emanating from a nearby factory. The unsilenced noise levels - no active noise attenuation, at 100m, were about 79 to 80 dB in the 31.5 Hz octave.

Although the development of the experimental prototype had ended it continued to operate during the mid 1980s and it was observed that during high powered running of the machines in 1985-1987 no noise complaints were received.

Thus despite a few operational failures including speakers, one amplifier and a microphone, the active noise system was then considered a possible long term solution to low frequency noise problems.

4. MACHINERY UPRATING

4.1 Winter 1987 tests

The last tests on the ANR system were carried out in March 1987 during an especially cold spell of weather which helped enable the machines to run at powers of above 12.5 MW, whereas most of the previous tests had been carried out at powers of 8-10 MW. On this occasion the performance of the active noise system was a little disappointing with measured reductions at 100 m of only 2-3 dB in the 31.5 Hz octave. On this occasion though the unsilenced level with no ANR was about 84 dB in this octave. It is believed that the ANR system installed, operating at this time with 66 out of its 72 loudspeakers, was not able to cope with such a high source noise level. This increase in unsilenced noise levels was most probably caused by the higher power, and deterioration of the passive silencer itself because of infill settlement.

4.2 Uprating Project

This project involves uprating each of the units to 14 MW and at the project launch near the end of 1987 it was decided to attempt to replace the prototype/experimental ANR system which was not the property of British Gas with a permanent system. This would have been a commercial project subject to commercial and contractual constraints and our task was to derive expected unsilenced source noise levels and the degree of silencing required from the active system. Accounting for the power increase, a figure of 86 dB at 100 m was derived for the unsilenced SPL in the 31.5 Hz octave, and a required attenuation of 11 dB was specified - to meet a 60 dB limit at the affected dwellings. This corresponded to an on-site noise limit at 100 m of 75 dB.

The system as specified should be robust, reliable, have a long design life, turn on and off automatically, have overload protection built in and so on.

The response to our invitation to do the work indicated that current ANR technology, particularly loudspeaker technology, would have difficulty achieving our specification because the anticipated unsilenced noise levels were so high - a sound power of 134 dB in the 31.5 Hz octave. This caused us not only to re-consider our approach to the ANR system but also to review the whole subject of gas turbine exhaust silencers.

A COMPARISON OF ACTIVE AND PASSIVE METHODS FOR SILENCING GAS TURBINE EXHAUSTS

5. REVIEW OF PASSIVE SILENCERS AND UNSILENCED NOISE LEVELS

5.1 Historical Data

Two points were apparent from investigations:

i) The quoted unsilenced noise levels were originally claimed to be only 78 dB in the 31.5 Hz octave.

ii) Hot gas probe microphone measurements indicated that low frequency noise levels in the volute of the power turbine for two different units with nominally identical machinery but different type silencers were quite similar, although far-field data were quite different.

Both of these points tended to suggest that the silencer itself might be exacerbating any low frequency noise rather than reducing it and that doing away with it altogether would improve the measurements in the far-field. It had been previously thought that the 25 Hz resonance was excited in some way by turbulence in the power turbine exits and at the base of the silencer. However it was now suggested that the design of the silencer internals could be causing the resonance to be excited, similar to the way sound is generated in an organ pipe, and although changing the flow profile to the base could well also have an impact it was of less fundamental importance.

5.2 Current Sites

It was noted in addition that current exhaust silencer designs have different internals to the original silencer. In particular the new silencer bullets have a dished or rounded base section compared with the original sharp edged cylinder. Given the difficulty of achieving the specified noise reduction by active means it was decided to change-out the internals of the exhaust silencer and install modern design acoustic bullets like those used currently. This amounted to a large scale acoustic experiment in effect and although it was subject to the usual commercial contractual and programme constraints work was successfully and quickly completed.

5.3 Improved passive silencer

The aim of this modification was principally to eliminate the stack resonance, thus removing the particularly offensive 25 Hz tone which had always been a source of annoyance to site staff as well as a cause of noise complaints from a local resident. The station is still in its non-uprated form but so far the results have been promising with the maximum noise level in the 31.5 Hz band at 100 m being only 75 dB compared with the previous maximum of 84 dB. In addition the 25 Hz tone is subjectively far less prominent and the response of site staff has been favourable.

The effect of the machinery uprating on this figure will be determined during runs this winter but it is expected that it would not increase by more than 1 or 2 dB even at maximum uprated power and hence would probably be acceptable, as 75 dB was the original design target.

6. CONCLUSIONS

1. Before making a commitment to ANR as a remedial measure understand the nature of the problem, in order to determine whether it really is the best solution.

2. Designing-in ANR at the front-end is difficult unless the source noise levels are known with great accuracy.

3. Improvement of secondary source capability is one of the most important aims in current ANR development.

7. REFERENCES

1. "Effective Control of Environmental Noise" C D Lyle, Gas Engineering and Management, Volume 27 : No 4, pp 98-112, April 1987.

ACKNOWLEDGEMENTS

British Gas acknowledgements the contributions of British Technology Group and Topexpress to the project and subsequenctly British Gas notes the contributions of Sir Henry Lawson Tancred to the study of active noise attenuation technology.