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ENVIRONMENTAL NOISE ASPECTS OF A GAS TURBINE POWER GENERATING PLANT

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INTRODUCTION

The early part of this decade saw extensive exploration activity for hydrocarbons throughout the south of England. Areas of land were licenced, in a similar way to the offshore licencing activity which had been going on since the early 70's. The number of drilling rigs operating in this country reached a peak sometime in the mid 80's but has now declined. From all this drilling activity there were several finds of hydrocarbons but only a fraction of them have been developed into commercial production.

One of these developments came on-stream in 1986. It was located in the heart of a very attractive rural setting in the south of England. Its operator had to comply with very strict environmental standards, of which noise was one consideration. Unfortunately a combination of circumstances, including the collapse of the oil price at that time, a rising dollar/sterling exchange rate, and a disappointing reservoir performance meant that the economic viability of the field become questionable. In particular, the reservoir was providing far greater quantities of gas than had been expected which had the effect of increasing operating costs due to the need to compress larger quantities of gas for re-injection.

The operator looked at the possibility of selling the gas directly, rather than re-injecting it. However, there was no heavy industry in the area which might be interested in its purchase. It was also considered too expensive to build a plant to treat the gas to meet British Gas's specification and also construct a transmission pipeline. The alternative option was therefore to generate power using a gas turbine generator, use the electricity to drive the production facilities and sell the excess power to the CEGB. The use of the gas would also have the economic benefit of allowing higher crude oil production from the reservoir. The operator therefore decided to apply for planning permission for a scheme which would minimise capital expenditure but could also be flexible and maximise use of existing oilfield facilities.

It was realised that if the scheme was to be granted planning permission it would have to be considered environmentally "friendly", and be able to achieve all the environmental constraints imposed on the main production facilities, of which noise was one of the more onerous. Acoustic Technology Limited acted as consultant to the operator and worked with him from early design concepts through to the installation and successful commissioning of the set. This presentation describes some of the considerations which were given to the noise aspects of the scheme.

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DESCRIPTION OF GENERATING SCHEME

The scheme was based around the use of readily available trailer mounted generating set, known as a Nomad. It is basically a Ruston TB5000 gas turbine driving an AC generator and delivery up to 3.5 MW of power. Also located on the trailer are a lube oil cooling package and a control cabin. The units are housed in steel enclosures lined with sound absorbent material. The external dimensions of the container are about 15 m x 2.4 m x 3.3 m high. Access to the set is via a number of doors located around the set. The Nomad is sold as standard with some degree of silencing associated with it but it was realised that additional silencing measures would be required for this application.

It was planned that the set would be located on a wellsite close to the production facilities. Space was available, which was attractive in planning terms and no additional land-take was required.

NOISE CONSULTANCY BRIEF

There were three phases identified for the noise consultancy brief for this project. These were:

i) **Planning phase**, at which a fairly detailed design had to be undertaken in order to convince the planning authorities that the agreed noise planning conditions could be achieved.

ii) **Procurement and construction phase**, at which close vendor liaison had to be maintained and proving noise tests made.

iii) **Check-out and monitoring phase**, to show on-going compliance with the planning conditions.

PLANNING PHASE

Noise Limits

It was proposed to attempt to agree the planning limit as a level of 35 dB(A) L_{90}, outside the nearest dwelling (approximately 900 m away) because this had been the level set for previous activities on the wellsite. Although in absolute terms the level is not high, it should be realised that at night, in rural locations, the background noise level can drop to less than 20 dB(A).

Although use of an 'A' weighted sound pressure limit is common in planning terms it has to be used with great caution particularly where low frequency noise is prevalent [1, 2]. It is fundamental to realise, as pointed out in Planning Circular 10/73 [3], that compliance with planning conditions will not necessarily provide protection against legal action by private citizens in respect of noise nuisance. In the UK this course of action is available under Section 59 of the Control of Pollution Act 1974 [4].

It was felt necessary, therefore, to strictly control the noise character from the set to ensure, as far as possible, that the resulting level, could not be

judged to be a nuisance. An octave band design sound pressure limit was prepared based around the equivalent dB(A) planning limit with a design tolerance built in, together with an allowance for noise from the gas supply

Item	Design Level @ 900 m
Planning Limit Design Tolerance	35 dB(A) -3 dB(A)
Design Limit Gas Supply System	32 dB(A) 22 dB(A)
Gas Turbine Alternator Set	31.5 dB(A) 22 PNC

system. An octave band limit approximating to a PNC (preferred noise criteria) curve was chosen [5], to give a reasonably balanced spectrum and avoid "rumble" problems which can result from the use of NR curves, for example. It was then possible to calculate an octave band sound power limit for the set as follows:

Item	Octave Band Centre Frequency, Hz							
	31.5	63	125	250	500	1k	2k	4k
Sound pressure level spectrum, dB re 20 μPa at 900 m (modified PNC22)	57	48	40	34	28	22	17	15
Attenuation factor, dB, over 900 m	63	65	69	80	78	76	79	82
Sound power level limit gas turbine alternator set, dB re 1 pW	120	113	109	114	106	98	96	97

The octave band attenuation factors are those which would reasonably be expected to occur under light downwind or moderate temperature inversion conditions (eg. under a clear sky at night), over open grassland [6]. These attenuation figures encompasses the observered phenomenon of "negative excess attenuation", at low frequencies, ie. sound attenuation with distance at a rate of less than 6 dB/doubling of distance. At mid frequencies ground effects have been allowed for and at high frequencies, atmospheric absorption effects became significant.

Preliminary Noise Tests

Noise data had been provided by the vendor on his standard packaged unit and it was clear that further noise control would be required to achieve the design noise limit for this project. The data was not sufficient to identify what further measures were required so arrangements were made to visit the vendor's works and take noise measurements on a unit which was undergoing performance tests for another customer. The tests proved difficult because the unit was not fitted with an exhaust silencer and exhaust noise tended to dominate all the measurements. Also the test environment was not ideal (they never are), and the test duration was limited because it was expensive to run the set on load.

A number of noise and vibration tests were undertaken, including sound intensity measurements, sound pressure level measurements and panel vibration velocity measurements. After the results had been analysed the following was concluded:

* The exhaust noise was dominant and would require extensive silencing.

* Separate silencers would be required to all cooling and ventilation compartments to the unit. The lube oil cooler, in particular required fairly extensive silencing.

* The engine air intake, which was already fitted with a silencer as standard, would only require a small amount of additional silencing.

* The basic panel construction was considered satisfactory.

* Careful attention would be needed during the construction of the set to achieve good sealing on all access doors into the unit.

Following the tests, sound power levels were calculated for the various components of the set. Preliminary discussions were then held with silencer manufacturers to obtain an idea of the size and cost of the silencing measures likely to be required. At this stage a preliminary report was prepared which was designed to accompany the planning application. This included a schematic of the probable noise control requirements for the set, as shown in Figure 1.

PROCUREMENT AND CONSTRUCTION PHASE

Equipment Noise Specification

Whilst informal discussions were being held with the planning officer to assess the viability of the scheme, the procurement phase of the project was already underway. A noise limit specification was prepared for inclusion in the bid package. This specified the following:

* Noise limits to be achieved

* Information required from the vendor

* Advice on the anticipated noise control requirements
* The requirements for noise acceptance testing
* Actions to be taken in the case of non-compliance

Information Required From Vendor
The vendor was requested to specify the size and performance of all the noise control measures proposed. For gas flow silencers this included the dynamic loss insertion figures at the design operating temperatures.

It was felt particularly important to obtain evidence from the vendor that the attenuation characteristics of the silencers proposed could actually be achieved, by reference to test data on similar silencers. The importance of this was that the vendor had never supplied the packaged generating set to such a stringent noise limit before and could not provide evidence from previous test data on the packaged unit, that the noise limits could be achieved.

Interaction With Vendors
The major concern was to ensure that the exhaust silencer would be adequate in performance. The proposed silencer was 4.5 m long with an internal arrangement consisting of 300 mm side splitters, 300 mm airways and a 600 mm central splitter.

As the vendor had only previously tested a silencer up to 2.4 m long, and this was a cold static test, it was necessary to obtain confidence in the way corrections had been applied to take into account the increased length of the silencer and the way in which temperature and flow effects were accounted for. For a gas turbine exhaust, temperatures of 500^{0}C are common, which result in an apparent frequency shift of about 2/3rd octave.

The outcome of the discussions was that it was agreed that provision would be left for the horizontally mounted silencer to be extended by a bolt-on section, if this proved necessary after the proving tests.

Interaction With Planning Authority
The planning authority had appointed its own noise consultant to review the noise aspects of the power generation project on its behalf, and thus it was necessary to interact with him and answer some points of concern. Once these had been agreed, the application went before the planning committee and permission was granted to operate the set for a finite period.

Works Noise Tests
The equipment noise limit specification had called upon a noise test to be undertaken at the vendor's works, with all the noise control measures in place. Because of the presence of buildings and other reflective surfaces the "large source method" as given in EEMUA Report 140 [6] was specified. This gives a method of correcting for local reverberant effects, by comparing the

determination of sound power levels from measurements made over two different prescribed surfaces. It also specifies a correction for the so called "geometrical near field effect". Serious doubts were expressed as a result of these tests as to whether the latter corrections were physically correct. Fortunately it was possible from the vendor's works tests to obtain one far field measurement which indicated quite strongly that the sound power level limit would be achieved, so it was agreed that the set should be delivered to site.

One slight problem had arisen in that when off-load, the intake of the gas turbine emitted a high intensity tone in the 4 kHz band. This moved to the 8 kHz band when the set went on-load. Although this was not going to be a problem from community noise considerations it was felt the installation of an additional intake silencer would subjectively improve the impression of the set on-site.

CHECK-OUT AND MONITORING PHASE

Site Measurements

The set was finally delivered to site, and commissioned. The site environment was ideal acoustically as it consisted of a large flat concrete area with no other reflecting surfaces. Final proving noise tests were then undertaken to determine the sound power level of the set, by taking sound pressure level measurements at distances of 40 m from the assumed acoustic centre of set. The final results turned out as follows:

Item	Octave Band Centre Frequency, Hz							
	31.5	63	125	250	500	1k	2k	4k
Specified sound power level limit dB re 1 pW	120	113	109	114	106	98	96	97
Calculated sound power level from site measurements dB re 1 pW	117.5	113.5	109.5	103.5	97.5	93.5	90	89

It can be seen that the set met specification at 31.5 Hz, was marginally in excess (0.5 dB) at 63 Hz and 125 Hz and well within specification at all other frequencies. The results were considered very satisfactory, the 63 Hz and 125 Hz slight excess being insignificant.

Community Measurements

The final proof of acceptability was to undertake noise measurements in the community to prove that the planning limit was being achieved. As part of the planning agreement a test specification had to be prepared and agreed. This was done, and the tests subsequently undertaken in the presence of the planning authority's consultant. The tests had to be taken late at night when the background level due to distant traffic and wind induced noise in vegetation had fallen to very low levels. Even under these conditions the gas turbine generator set was only just audible. The noise level due to the set was measured as less than 30 dB(A) L_{90} which was considered completely satisfactory, bearing in mind that the noise level could increase slightly under more adverse meteorological conditions.

Monitoring

The final part of the noise consultancy brief was to undertake regular monitoring of the community noise levels to ensure that the planning noise limit was being met during the operation of the set, and that no deterioration of the noise control measures, with age, was occurring. The monitoring data would also provide important evidence to the planning authority if an application were to be made to extend the operational life of the set beyond that for which permission has been granted.

CONCLUSIONS

The installation of the gas turbine power generating plant has improved the financial viability of the oilfield. The whole scheme was planned and completed in less than 12 months. The set had to be satisfactory from environmental considerations, and noise was one of the major issues of concern. This presentation has described the approach taken by the noise consultant appointed to this project to ensure that the final outcome would be satisfactory. Probably the most important factor in the success of the project was the close collaboration achieved between the consultant, the client, the planning authority, the planning authority's consultant, the vendor and the vendor's sub-contractor. The planning noise limits were achieved, the noise character was satisfactory and there is every reason to believe that planning consent would be granted for a requested extended operating period.

REFERENCES

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3. Circular 10/73, Circular 16/73 "Planning and Noise". Joint circular from the Department of the Environment and Welsh Office.

4. Control of Pollution Act 1974, 1974 Chapter 40, HMSO.

5. L.L. Beranek "Noise and Vibration Control", McGraw Hill.

6. AT674 "The Propagation of Noise from Petroleum and Petrochemical Complexes to Neighbouring Communities". Acoustic Technology Limited Report to Stichting Concawe, December 1977.

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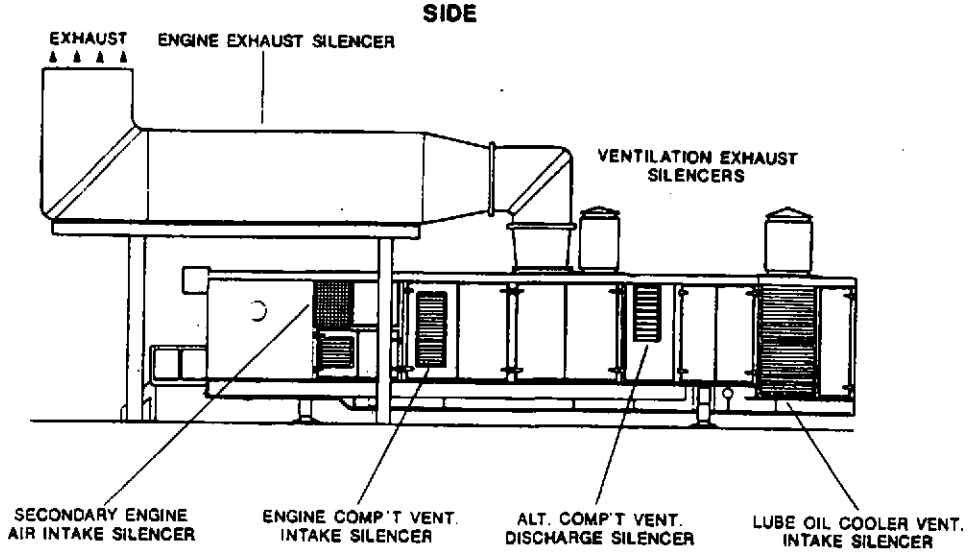

FIGURE 1: Noise Control Scheme for Gas Turbine Generating Set