Proceedings of the Institute of Acoustics

SILENCING FOR MOBILE GAS TURBINE GENERATING SETS

W C Hood

Sound Attenuators Industrial Ltd, Eastgates, Colchester, Essex

1. INTRODUCTION

This paper describes the design, supply and testing of acoustic equipment required for a mobile gas turbine generating set.

Carless Exploration, now part of Kelt Oil, are the operators of Humbly Grove Oilfield near Alton, Hampshire. The extraction of oil produces natural gas as a by-product which can be re-injected, but which can also be used as fuel for gas turbines. It was decided that since the new regulations allow private electricity producers to sell to the CEGB (National Power Corporation), there were significant commercial advantages in utilising the waste gas for power generation.

The Humbly Grove site is in a rural setting and in a noise sensitive area with local residents extremely active in monitoring industrial development and potential noise sources. For these reasons, planning permission was granted for a gas turbine generator set only if it would not be seen as a permanent feature and on the basis that noise levels were not likely to result in complaints from local residents.

To satisfy the first criterion, a Ruston TB5000 Nomad gas turbine was selected. This is basically a mobile unit which, with the wheels removed, can be used in a semi-permanent form. The noise level issue was addressed by retaining Acoustic Technology as acoustic consultants to assess the existing background noise and recommend criteria for the new installation.

After carrying out extensive background readings a basic criterion of 31.5dBA to be measured at the nearest residential building 900m away, was established for the gas turbine generator set. After allowing for distance factors, atmospheric absorption, shielding etc, the following overall PWL was calculated for the set:

31.5	63	125	250	500	1K	2K	4K
120	113	109	114	106	98	96	97

If these figures are compared with a conventional NR curve two points will be noted:

1. The lack of 8K specification which is due to the distances involved and significant natural screeening.

2. The low frequency bands are additionally weighted as a result of increasing evidence that noise in these bands, particularly the 31.5 band, is more annoying that the normally audible response spectrum indicates and also the difficulty in predicting accurately radiation from exhaust stacks under certain wind conditions.

Another factor in the noise level specification was that any pure tone noise components should be further attenuated by 5dB and all measurements/calculations should be carried out accordingly to EEMUA report 140 "Noise Procedure Specification" (OCMA NWG1 Revision 2).

All readings were to be taken under full load conditions, utlising the large source method with no meter tolerance. It was decided to carry out final readings both at Ruston Gas Turbines' works and at the site. The objective for the works test was to ensure that, in the event of the stipulated noise specification not being achieved, it could be corrected before alerting the residents to a possible noise problem.

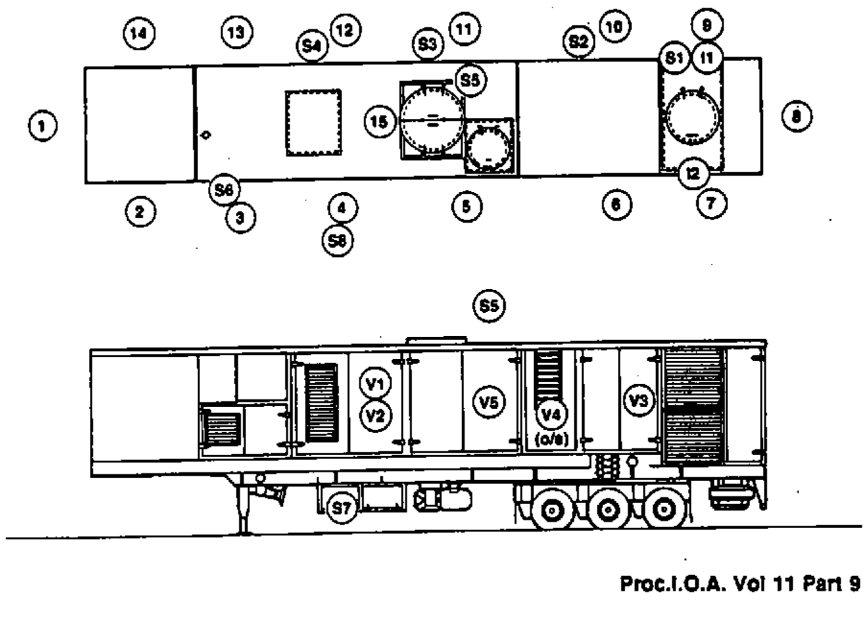
Whilst basic unsilenced noise data was available for the Ruston TB5000 mobile, it was decided that new readings would be taken in an attempt to predict accurately the contribution from the large number of individual noise sources.

Readings were taken by Acoustic Technology on a standard Nomad set which was unsilenced apart from a short parallel baffle absorption attenuator fitted to the gas turbine combustion air intake. The set was, of course, fitted with a standard package enclosure which is an 'acoustic' construction.

Three forms of readings were taken:

1. SPL readings at 1m generally around the set
2. SPL readings at 1m from specific noise sources
3. Vibration velocity readings on the skin of the package enclosure

READINGS TAKEN AROUND UNSILENCED TB5000 NOMAD at R.G.T. WORKS



With the results of these readings, Ruston Gas Turbines and Acoustic Technology approached Sound Attenuators Industrial Ltd (SAI) who, with their extensive experience in gas turbines noise control, and Ruston Gas Turbines units in particular, were ideally placed to design and manufacture the necessary noise attenuation equipment. From the readings taken by Acoustic Technology, historical information provided by Rustons and SAI's practical experience, the following individual noise sources were identified and quantified:

1. Package enclosure
2. Skid
3. Skid void
4. Combustion air intake
5. Combustion air exhaust
6. Oil cooler fan inlet
7. Oil cooler fan discharge
8. Turbine enclosure vent fan inlet
9. Turbine enclosure vent fan discharge
10. Electrical generator vent fan inlet
11. Electrical generator vent fan discharge
12. Combustion air intake ducting breakout
14. Combustion air exhaust ducting breakout

Items 1, 2 and 3 were the most critical from a noise contribution point of view, as it would have been extremely difficult to improve the acoustic performance of the package enclosure, skid and base plates significantly. From the various source information available it was possible to determine that the contribution from items 1, 2 and 3 could be limited to a PWL of less than 95dBA, assuming that the enclosure doors were provided with double seals and the void area was insulated acoustically.

The contribution from the main package was then subtracted from the specification to produce the contribution allowed from the other sources.

The remaining noise sources were then divided into two main groups:

1. Those that could be reduced significantly and economically, ie ventilation sources.
2. Those where, for constructional reasons, it was more expensive to achieve attenuation, eg gas turbine exhaust.

These parameters made it possible to determine the allowable contributions from all sources to ensure that the overall PWL specification would be achieved.

The attenuation provided was a combination of SAI's standard and individually designed units.

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The combustion air exhaust attenuator was basically a parallel splitter absorbent unit with thick splitters and relatively wide airways designed specifically for low frequency attenuation to handle gases at 500°C and also to restrict noise breakout through the attenuator casing.

The combustion air intake attenuator was again a parallel splitter absorbent unit, but with thinner splitters and narrower airways designed specifically for high frequency attenuation. Mechanically it was required to ensure no loose fixings or particles of sound absorbent would enter the air stream.

The lubrication oil cooler air intake, generator air inlet and discharge attenuators were parallel splitter absorbent units designed for mid frequency attenuation.

The lubrication oil cooler air discharge and engine compartment ventilation exhaust attenuators were cylindrical units with central splitters designed for both mid and high frequency attenuation.

The engine compartment ventilation air inlet attenuator was a single pass acoustic louvre again designed for mid and high frequency attenuation.

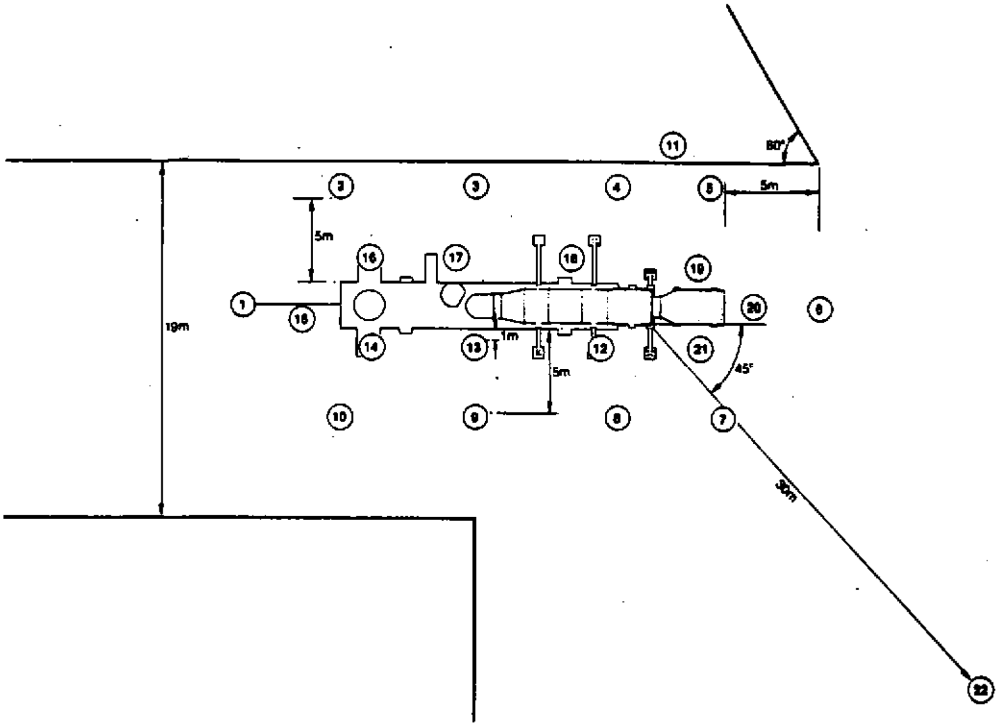
Combustion air inlet and exhaust ducting between the gas turbine engine and attenuator was insulated acoustically externally to prevent casing breakout.

Apart from the attenuation requirements, all units were to be as compact as possible, whilst compatible with pressure loss requirements particularly with regard to ventilation sources.

After fitting all attenuation equipment noise level readings were taken around the set operating at full load at the manufacturers' works. Whilst the site was not ideal as a result of nearby reflection surfaces, the results indicated that, in essence, the specification would be achieved.

SPL readings were taken at various positions around the set at 1m and 5m distances and produced the results as follows, based upon a log average of all positions:

READINGS TAKEN AROUND SILENCED TB5000 NOMAD at R.G.T. WORKS



	51.5	63	125	250	500	1K	2K	4K	8K
1m	89	83	79.5	78	71.5	70	69	75	84
5m	86	81	77	75.5	70.5	67.5	64.5	66.5	73.5

After adding the correction from SPL to PWL this indicates the following compared with the specification:

1m	116	110	106	104	96.5	95	94	100
5m	118.5	113	109.5	107.5	102	99	96	98
Spec	120	113	109	114	106	98	96	97

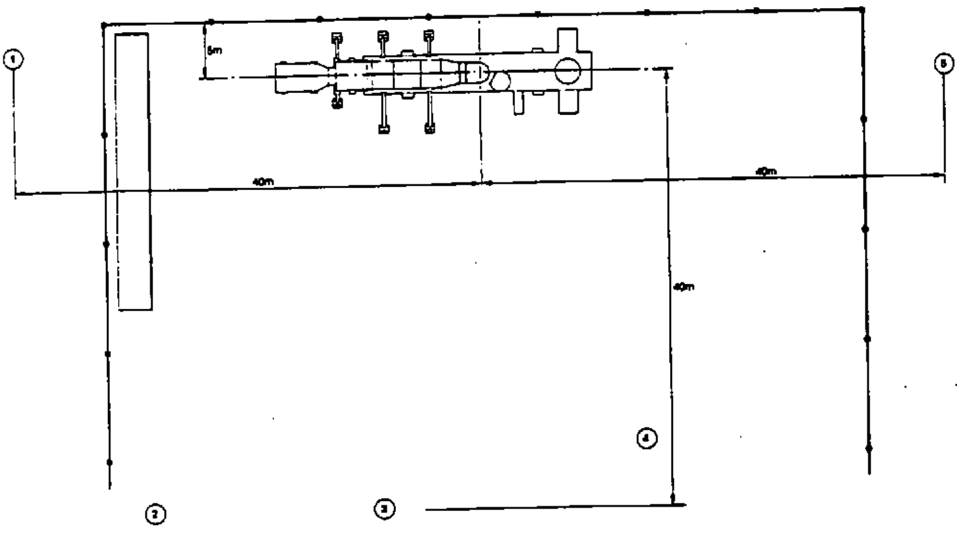
In view of the proximity of these works test results to specification, it was decided to deliver the unit to site to carry out final readings.

The only modification to the equipment was the provision of an additional combustion air intake attenuator specifically designed for the 8K frequency noise which, whilst not constituting a residential noise problem, was extremely distinctive and it was felt, would give visitors to the site the impression of "excessive" noise.

The site layout was close to an ideal for accurate measurements with background noise non-existant and a large area free of reflective surfaces.

SPL measurements were taken at five positions around the set which gave the following log average, PWL correction and comparison with specification

SILENCED NOISE LEVEL READINGS TAKEN ON TB5000 NOMAD at SITE



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	31.5	63	125	250	500	IK	2K	4K	8K
SPL @ 40m	77.5	73	68	63	58	53	47	45	51
PWL	117.5	113	108	103	98	93	87	85	
Spec	120	113	109	114	106	98	96	97	

6. REFERENCES

EEMUA Report 140 "Noise Procedure Specification"
Acoustic Technology Report ATT 2199/3

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THE ASSESSMENT AND CONTROL OF NOISE FROM PULSE CLEANING AIR FILTRATION EQUIPMENT

Roger J Chuter

Chief Acoustical Engineer
Locker Air-maze Ltd.,
PO Box 17, Folly Lane, Warrington, Cheshire, WA5 5NP

1. SUMMARY

First hand experience has been gained by Locker Air-Maze in the design, manufacture and installation of pulse cleaning, air filtration equipment. This type of filter was introduced as "state of the art" equipment in the mid-70's and has become popular with manufacturers and installers of industrial gas turbine driven equipment worldwide. Acoustically however, the pulse filter presents a challenge to Noise Control Engineers as it posesses sources of noise inherent to its function.

The basic characteristics of the pulse filter are discussed with particular reference to sources and attenuation of emitted noise. Some mention is also made of the application of various National and International Standards to the usage of this equipment in noise-sensitive environments.

2. INTRODUCTION

Gas turbines and other prime mover equipment require large quantities of clean air and are frequently used in hostile environments. Operational temperatures range from as low as -50 degrees C in the frozen regions of the Arctic to upper temperatures approaching 45 degrees C in desert areas. Air-borne contaminants can include sand, cement dust and ice, all of which can seriously corrode, erode or foul critical components. Many gas generator manufacturers have stringent air quality specifications for compressor entry conditions.

Most conventional filter equipment for use in these applications requires regular cleaning or replacement of the filter media. This means personnel, on-site stocks of replacement elements and costly down-time for maintenance.

The Pulse Filter can successfully eliminate the above contaminants but being self cleaning, reduces the need for element changes and prime-mover shut-downs.

3. THE PULSE FILTER

The Pulse cleaning air filter is a system by which air is filtered through conventional media which may be cleaned by a reverse-pulsed blast of air.

The mechanism of operation involves injecting a calculated amount of compressed air into an accelerating device via an orifice in a discharge pipe. The shock wave caused by this sudden injection of air then propagates through the accelerator and impacts upon the inside face of the filter element, momentarily reversing the flow of air through the filter elements. This efect efficiently removes the majority of the contaminant particles which fall away via gravity.

The magnitude of the shock wave is determined such that the optimum balance is struck between dislodging the maximum amount of contaminant particles and minimising structural damage to the filter media. For this reason the Hurricane type pulse filter elements are constructed to withstand high shock loadings without damage.

The principle of operation of the Locker Air-Maze Hurricane type pulse filter is illustrated in Figure 1.

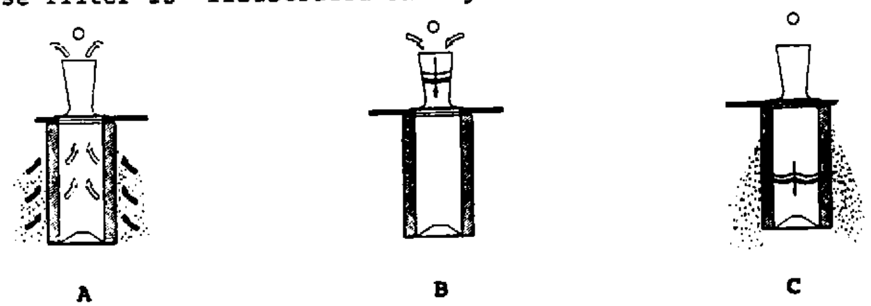

Figure 1
PRINCIPLE OF OPERATION

A) Normal operating condition

B) A pulse of compressed air is released from the discharge pipe orifice and the resultant shock wave begins to propagate through the venturi tube.

C) The shock wave travels through the filter element and is reflected from the end cap.

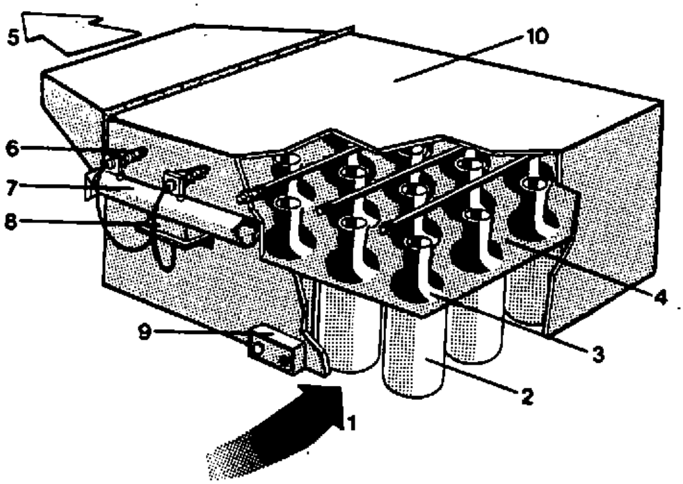

Figure 2
THE LOCKER AIR-MAZE HURRICANE FILTER

The intake air (1) flows through the filter element media (2) and venturi tube (3) into the clean air plenum (4). The clean air is then drawn into the gas turbine intake, usually via a silencer.

When the pressure drop through the elements reaches a pre-determined level, the cleaning cycle is initiated by an automatic control panel (9). Alternatively the cycle may be initiated manually for operation during less noise-sensitive periods.

The cycle of operation is repeated for each group of 4-or 6 elements and is interrupted as soon as the original pressure drop is re-established.

The advantages of this system over conventional disposable element type filters include:

- High efficiency filtration elements (above 99% AC fine)
- Ability to allow uninterrupted machine operation under severe atmospheric and environmental conditions
- Automatic control and operation of the cleaning process
- Quality and long life of filter elements

4. ACOUSTICAL CHARACTERISTICS

The pulse filter is not without it's drawbacks however. The effective operation of the cleaning cycle is dependant upon the generation of a shock wave which is accelerated and amplified by a venturi tube. The acoustical characteristics of the pulse, whilst essential to the operation are unwanted from an environmental point of view. Overall sound pressure levels in the region of 97 dB(A) may be measured at a distance of one metre from the free air inlet to a typical, vertically orientated unit.

Vertically orientated units, whilst generating the same sound power level as their horizontal counterparts, are generally noisier in the far-field. This is due to the fact that the generated sound propagates vertically downward in the horizontal unit as may be seen in figure 3. Figure 4 shows the propagation paths for a vertical unit. The line-of sight paths are clearly more direct.

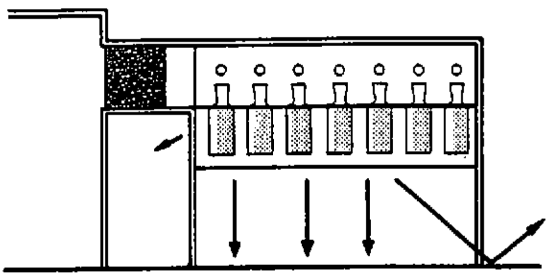

Figure 3
PROPAGATION PATHS FOR A HORIZONTAL HURRICANE UNIT

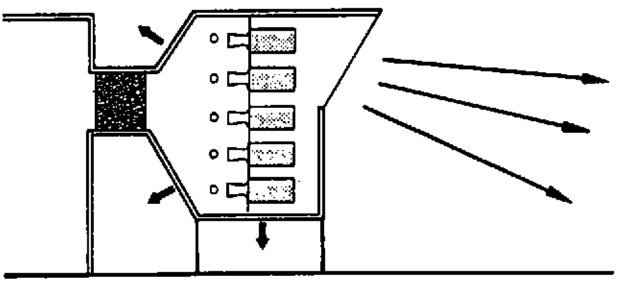

Figure 4
PROPAGATION PATHS FOR A VERTICAL HURRICANE UNIT

5. MINIMISING ACOUSTICAL IMPACT

Four main methods exist for minimising the impact of the noise from the pulse cleaning cycle on the environment. These are:

5.1 Full enclosure

Since for gas turbine applications, the gas generator must be supplied with air in quantities of typically 90m3/sec, any restriction to airflow would mean a corresponding increase in pressure drop across the intake. Since power output is proportional to intake back-pressure, full enclosure is only feasible where a reduction in efficiency and power output is acceptable to the end user.

The disadvantage with this system arises from the fact that ejected contaminants would tend to collect within the enclosure and, unless removed regularly, lead to re-entrainment. This is normally achieved in free-air conditions by ambient wind conditions.

5.2 Partial enclosure

Partial enclosure has proved effective however. An absorptive screen around three sides can provide attenuation in line with well documented barrier attenuation formulae. As with the full enclosure solution, ejected contaminants must be regularly removed to prevent re-entrainment.

5.3 Absorptive treatment of the filter skirt

As figure 2 shows, the filter elements in a horizontally orientated filter are surrounded by a section of intake duct or 'skirt'. Where space permits, the skirt can be lined with absorptive materials to reduce the higher frequency content of the pulse noise emissions.

Whilst adding absorption to the filter skirt may reduce the dB(A) level of the noise, the problem of propagation of low frequency energy over large distances still persists.

5.4 Timed operation

If the above treatments cannot be applied for economic reasons or lack of available space, by selective setting of the cleaning cycle initiation timer, noise generation can be limited to less sensitive hours. Effective consultation with nearby residents can result in a cleaning cycle operating during the local rush hour or some other period when ambient noise conditions can be used to mask the effects of the pulse.

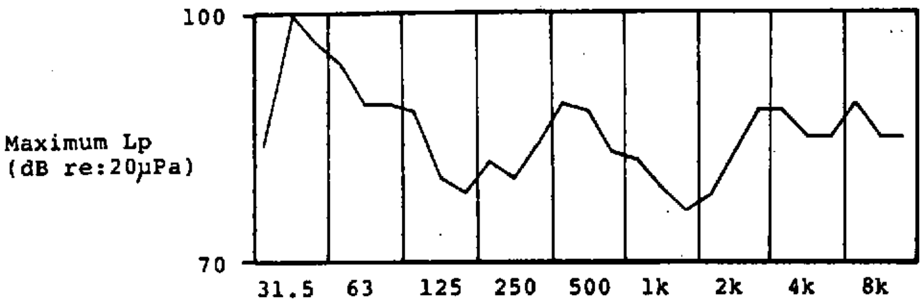

Figure 5
TYPICAL SOUND SPECTRUM OF PULSE CYCLE

Figure 5 shows a typical pulse spectrum from a HURRICANE unit. The values were determined using the Maximum Lp hold and impulse facilities of a Bruel & Kjaer type 2231 sound level meter.

The peak levels in the 31.5Hz, 1/3 octave band is characteristic of the noise generated by the propagation of the shock wave through the filter elements. Since this is fundamental to the operation of the cleaning cycle, any form of attenuation here would be counter-productive.

The broadening of the 31.5 Hz peak to the 50Hz band is due to the resonance frequency of the header tank as excited by the operation of the solenoid valves.

At the other end of the frequency spectrum, the broad spread of energy at frequencies above 2kHz is believed to be generated by turbulence in the air flow as it exits through the orifices in the distribution pipe. The flow velocities involved at this point are calculated to produce the most efficient shock wave prior to amplification by the venturi tubes. Again, this effect is fundamental to the efficient operation of the system.

The source of the peak levels centering around 400Hz is less certain. An analysis of air velocities in each section of the venturi tubes suggests that frequencies in the region of 350Hz to 700Hz could be generated. The practicalities of testing this theory present difficulties but if this does prove to be correct, then all of the frequency content of the sound generated by the pulse filter is due directly to the efficient operation of the cleaning cycle.

Since each bank of four elements requires a pulse of some 0.05 seconds duration, a typical 80 element filter will therefore require 20 such pulses for each cleaning cycle. A typical time period of 30 seconds is necessary between pulses to re-charge the compressed air header tanks. Each cleaning cycle will therefore be in the region of 9.5 minutes. This can easily be included in a normally noisy period or sub-divided to coincide with shorter local maxima.

The number of cleaning cycles required to return the pressure drop to a pre-determined acceptable condition is dependant upon the type of contaminants present in the atmosphere. Cycles tend to range from continuous operation to once per month so the cycle timing method may only be used on installations with low levels of contamination.

6. NATURAL ATTENUATION ADVANTAGES

The pulse filter posesses a natural attenuation during normal operation. This has the effect of reducing the amount of silencing required at the gas turbine intake. Typical values of sound power reductions are given below:

OCTAVE BAND MID-FREQUENCY	63	125	250	500	1k	2k	4k	8k
SOUND POWER REDUCTION (dB)	3	7	9	12	16	17	18	22

These figures are based on attenuation between inlet plane and discharge outlet.

The overall attenuation of a Hurricane unit is a complex function of air flow velocity, expansion of the source sound wave into the clean air plenum and breakout through the plenum walls. Any value for attenuation due to the complete filtration system must therefore be unique to the application for which it was designed.

Locker Air-Maze has developed a database from over 130 installations worldwide which is used to determine the correct filter configuration for each particular application.

7. MEETING LOCAL NOISE CRITERIA

When first approched with an enquiry for filter equipment for use in noise sensitive environments, the acoustical engineer must ascertain the criteria applicable for the installation. Traditionally, these have been at best sketchy, at worst non-existent.