(1A) GAS TURBINE NOISE

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Introduction

The compact configuration gas turbine plant and the apparent simplicity of noise control is somewhat offset by the massive throughput of ambient air, which is the working fluid. As with the steam turbine there seems to be little that can be done in the short term to reduce noise at source, due to the high design ratings applied by the basic thermodynamic cycle. However, modifications to the machine local to the exit of the power turbine may prove fruitful.

Noise control applied to plant is simply a high transmission loss enclosure controlling the casing radiation from the compressor, combustion chamber and turbine assembly with absorptive silencers applied to intake and exhaust systems. Similar forms of treatment are also applied to the generator and auxiliary plant.

Outside the electricity power industry the majority of turbines are less than 20 MW capacity and in typical installations packaged steel type enclosure and silencer systems are employed.

In the C.E.G.B. most existing installations have a capacity greater than 70 MW and in future may be as high as 300 MW, with individual turbine capacities of 25-50 MW. The size of these installations leads to an attenuation requirement 10-15 dB greater than that of packaged set installations. Location of plant nearer load centres would further increase these requirements.

At present we are operating aero type gas turbine sets. Two Olympus or Avon aero turbines (gas generators) fulfilling the duty of a compressor and combustion chamber in supplying high enthalpy air to an industrial power turbine.

Intake and Casing Noise

Typically the surface noise level near the casing of a gas generator is 122 dBA and the noise level in the intake air plenum and ducting 132 dBA.

Fortunately the high noise levels were recognised early in the development of the plant and the concept of remote operation and indication was used. Because of this it has been reasonable to adopt a system of local enclosure for the turbine.

Our general requirement for space average round level in the turbine hall to meet the hearing conservation requirements and to allow the use of lightweight building structures is 80 dBA. It has been found necessary to employ concrete for construction of enclosures and for the intake plenum and ducting to the inlet of the intake silencer. Theoretically a lined steel enclosure would just meet transmission loss requirements in a 100 MW station but many difficulties have been encountered due to the difficulty in sealing wall penetrations.

The high frequency characteristics of compressor noise and the ambient air condition in the intake present few problems in utilising absorptive splitters to deal with the intake noise, although in the larger installations the difficulties of flanking transmission through the support system may need resolving.

The power turbine surfaces presented to the turbine hall are small and the high surface sound levels of 100-105 dBA are estimated to offer a similar contribution to that of the other sources. Measurements suggest that these high apparent surface noise levels are due to radiation through small areas of the turbine casing. On current designs we find it an advantage to include the power turbine and gas generators in a common enclosure.

Recently the C.E.G.B. have ordered an industrial gas turbine installation because of the high capacity and efficiency of such units. The turbine generator capacity will in fact be between 50 and 58 MW.

Little information is available on the radiation of this plant but estimates from operating conditions and from data of European plant suggest acoustic power levels similar to the aero-type turbine. Estimates of average surface noise levels of the basic unit show levels of about 100 dBA at 1 metre. The turbo-generator layout is very similar to the steam turbine and here again we do not visualise the use of a bulk enclosure but have specified surface treatment to achieve the 10-15 dB attenuation required in some sections of the plant.

Exhaust Noise

Exhaust noise problems are similar for the aero and industrial gas turbines because of the similarities of the power turbine. Exhaust noise control is the most important aspect of gas turbine noise because of the high, low frequency, acoustic power and gas flow being handled. The requirements lead to the cost of the exhaust noise control for 100 MW of capacity being some fifteen to twenty times that of the rest of the applied noise control.

We have experienced four basic acoustic problems in the exhaust systems:-

(a) Identification of the origin of low frequency noise production observed throughout the system.

(b) The formulation of a reliable design procedure for silencers.

(c) Identification of the mechanisms causing periodic variations in the far field noise level.

(d) Providing a workable specification to limit annoyance in the far field.

(a) Low frequency noise produced by an aircraft power plant can be seen to originate in the jet efflux but no such efflux conditions are present in the power generation turbine. Final discharge velocities to atmosphere are controlled to about 135 ft/sec. Therefore we must look for other potential and significant sources in the system.

We look at the significance of the sources in relation to the weighted sound level in the far field after the noise has passed through an exhaust system of optimum pre-conceived design. The significance of the source must also be linked strongly to cost and reduction of low frequency noise at source by 10-15 dB could well reduce silencer costs by 30%.

It seems to us that the noise below 500 Hz originates after the last row of turbine blading but may well be influenced by the aerodynamics upstream. Considering the dynamic energy of the gas stream and the characteristic dimensions of the system it seems the source may well be located in the area of the turbine diffuser and its exit, in particular the wakes shed by the diffuser fixed blade supports are probably important. Other flow control devices in the system may also contribute to a lesser extent. Gas velocities at exit from the turbine diffuser are approx: 300 ft/sec and about 150 ft/sec through the rest of the system. Our immediate approach to the problem is to provide a very "clean" design of exhaust system with no sudden uncontrolled changes in velocity or direction.

Investigations into the noise source locations are being undertaken with specially designed probe microphones.

(b) Space is restricted on gas turbine sites and with 25-50 MW turbines we invariably employ absorptive silencers designed to provide attenuation down to 31 Hz with peak attenuation in the 250 Hz band.

Tests on installed plant show that the insertion loss specified has not been achieved and has been some 30% less than predicted. Currently a solution to this problem cannot be provided and we therefore find it necessary to inform manufacturers of silencers that they should provide 30% more attenuation than their estimates indicate. As far as can be seen at the moment this discrepancy in estimates of performance may be partly due to the compromise that has to be made between ideal flow resistance characteristics for the silencer pack and the structural stability of the mineral fibres employed to prevent erosion in the high temperatures and velocities ($T = 450^{o}C$ $v = 150$ft/sec). With noise levels of 120 dB incident on the silencer and peak attenuations of 40 dB there are probably losses of attenuation due to flanking transmission in the silencer structure and high velocity gradients near the absorptive facings.

Our research engineers are at the moment systematically considering all of these aspects.

(c) All the exhaust systems discharge to atmosphere through a stack approx. 200 feet high. Periodic variation from this type of discharge in the far field may be as high as 6-10 dB peak to peak in some weather conditions. The periodicity of these variations has been observed to be approx. 0.5 - 1 second and of course they provide a recognisable characteristic to what may otherwise be considered as a broad band noise.

Preliminary investigations in the laboratory show that part of variation of noise level in the far field is probably due to diffraction of the directivity pattern at the exit from the stack. Of course other diffractive mechanisms are operating in the transmission path to the far field.

(d) As a practical step to offset periodical changes in noise level and to provide what we believe to be a better correlation between the low frequency noise from gas turbines and annoyance we are employing a specification for far field exhaust noise which demands somewhat lower sound pressure levels at low frequency than an NR curve. In fact we have weighted a typical NR curve by 20 dB at 31 Hz and progressively less up to 250 Hz, after considering theoretically the practical aspects of silencer designs to meet the specification.

With costs of silencing a 100 MW gas turbine plant in the region of £300,000 clearly there is a need to concentrate a considerable effort into the investigation of exhaust systems. Although the practical difficulties of measurement and experiment are considerable we are hopeful of some solutions to this problem being provided in the next two years.

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