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BRITISH ACOUSTICAL SOCIETY.

SPRING MEETING: 5th-7th APRIL, '72.

AERODYNAMIC NOISE SOURCES IN INDUSTRY SESSION: University of Loughborough.

# INDUSTRIAL GAS TURBINE NOISE

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## 1. SUMMARY

The particular type of gas turbine considered is the industrial derivative of an aero engine. The basic noise sources of the industrial gas turbine are those of the aero engine, with the exception that there is no generation of jet noise. A fairly standard industrial installation design has evolved, using the dissipative splitter type of silencer to reduce the intake and exhaust airborne noise and enclosures for the reduction of carcase noise. In the future higher gas flow velocities will have to be tolerated. To avoid breakdown of the silencer acoustic infill under these conditions a suitable infill protection will need to be developed.

## 2. INTRODUCTION

The particular type of gas turbine to be considered is the industrial derivative of an aero engine. The noise produced by an aircraft engine is a well known problem. When the aero gas turbine is applied industrially it becomes more amenable to silencing and a fairly standard installation design has evolved.

There are three main markets which industrialised aero gas turbines serve, namely, electrical power generation, gas and oil transmission and marine propulsion. The attractions of this type of power unit are the high power to weight ratio and the very compact design.

The industrial gas turbine can be marketed at a competitive price because an aero version is already in quantity production, the research and development costs thereby being spread over a large number of engines. Due to this economic tie the industrial engines are essentially the same as the aero versions from which they are derived. The blading and combustion systems are unchanged aero-dynamically and hence the intake, carcase and exhaust noise levels are those of the aero engine. There is, however, one important aero noise source which is not present with an industrial power unit: that is jet noise. With an industrial installation the exhaust gases are ducted away via a chimney. Chimney efflux gas velocities are only of the order of 100 to 200 ft/second and as such there is no significant generation of jet noise.

For an industrial power unit shaft power must of course be provided. With a turboprop engine this is no problem, but with the industrialisation of a jet engine a power turbine must be added. The effect of adding a power turbine is to mask the turbine and combustion noise of the jet engine (now referred to as the gas generator) and impose its own noise upon the exhaust spectrum. The intake, carcase and exhaust noise sources are therefore fixed. For an installation to achieve a noise level acceptable to its surroundings it is necessary to silence these sources by the most suitable methods considering cost, space and effect on the performance of the gas turbine.

## 3. METHOD OF SILENCING

Gas turbines are highly sensitive to inlet and exhaust pressure losses. The precise effects upon performance of pressure losses due to the installation are governed by the design pressure ratio of the gas generator. Fortunately, compared to an aero installation, the industrial gas turbine has a major advantage in that a far greater space is available for incorporating silencers. It is therefore possible to provide the necessary silencers whilst maintaining reasonably low gas velocities and hence pressure losses.

Since gas turbine produce wide band noise spectra and to achieve the minimum pressure loss the natural choice of silenceer is the dissipative splitter type.

To reduce the gas turbine carcase noise to the required machinery room level an enclosure is incorporated. The encloseure can take the form of either a brick cell or a steel hood with external damping treatment to reduce any resonance effects.

## 4. INSTALLATION DESIGN

The cost of silencing an industrial gas turbine unit accounts for only 2% of the overall installation costs. As such, cost is in no way influential in determining the degree of silencing offered with a unit.

For the purpose of this paper the design procedure used in the determination of the silencing requirements for a single Industrial Olympus 'A' Power Unit installation will be considered. The site noise level requirement is NR 50 (ISO Noise Rating Number) at a distance of 300 ft. from the Power Unit: this being a typical residential area requirement for 24 hour operation.

The Olympus Power Unit consists of an Olympus 201 gas generator exhausting directly into a two stage power turbine. The Peak Rating power output is 17.5 MW under ambient conditions of 15°C and 14.7 psia, with a corresponding mass flow of 230 lb/sec.

### 4.1. Machinery Noise

Of the three noise sources to be silenced the machinery space noise has, in the past, been the least restrictive. It is only recently that customers have begun to specify a level suitable for full shift habitual exposure; usually NR 85 to allow for an 8 hour shift. The particular installation under consideration does not have such a requirement and only the gas generator is enclosed, the power turbine being left untreated.

By the use of a brick enclosure the gas generator carcase noise is reduced below that of the power turbine. The resulting machinery space noise level at a position 10 ft. from the machinery centre line is NR 101.

## 4.2. Intake Noise

The unsilenced intake noise for an Olympus gas generator was measured at a position 10 ft upstream of its inlet flare in a concrete duct 10 ft square. By first converting the measured sound pressure levels to sound power levels the spectrum was transposed to a distance of 300 ft in the free field where the level is NR 93. A certain amount of silencing is provided by the air inlet filter, storm louvres and ducting bends. Knowing the noise level requirement to be NR 50 the additional silencing to be provided by the splitters was then determined.

In order to minimise the inlet air pressure loss the duct blockage due to the silencer should be kept low. Conflicting with this aerodynamic requirement is the acoustic requirement of small air gaps between the splitters for high frequency attenuation and large splitter widths for low frequency attenuation. The resulting compromise design consists of a 4 ft. 3 in. long high frequency bank of 2 in. wide splitters with 4 in. air gaps between them and a 15 ft. 6 in. long low frequency bank of 12 in wide splitters with 20 in air gaps. The velocity in each splitter bank is 40 ft/second.

## 4.3. Exhaust Noise

Ideally, the unsilenced exhaust noise of an Olympus Power Unit should be measured immediately downstream of the power turbine. This has been attempted using a probe microphone but due to the highly turbulent gas flow and the poor response of the probe the results have so far proved unsatisfactory. For silencer design purposes it was therefore necessary to measure the exhaust noise of an installation having no exhaust silencer. This spectrum was obtained at a distance of 300 ft. from the base of a 100 ft high 7 ft 6 in. diameter steel stack, the level being NR 61. By this method the attenuation of the bends into the stack, directivity at the stack outlet and divergence are automatically taken into account. With this information the necessary insertion loss of the silencer could be determined. Most sound pressure reduction is required in the lower frequencies, to allow for this without excessive duct blockage a splitter width of 8 in. was selected. An annular splitter arrangement was then designed such that the majority of silencing is achieved within a 10 ft. long central ring of 3 ft. 2 in. internal diameter. The gas velocity is 200 ft/second in this section. The remaining low frequency silencing is obtained by an extended 27 ft. long external lining of 7 ft. 8 in. internal diameter.

## 4.4. External Noise

To achieve the external noise level requirement the walls of the turbine hall and roof must provide sufficient transmission loss to reduce the machinery noise below the requirement. The choice of building material lies with the customer and his civil engineering contractor. For this particular installation prefabricated steel panels were chosen with a specification to provide NR 45 at 300 ft.

To determine the overall noise level at 300 ft. the silenced intake, exhaust and building levels were combined.

5. DISCUSSION

There are, of course, other noise sources in a gas turbine installation besides the gas turbine; such as the AC generator, pumps and coolers. Fortunately the silencing of these other sources is relatively easy and their silenced levels are chosen such that they have a negligible effect upon the overall install-ation level.

6. CONCLUSIONS

Although the details of the design described are by no means unique, the general design approach is common to all industrial gas turbine installations. By the use of dissipative splitters for the reduction of airborne noise and enclosures for the machinery it is possible to achieve a noise level satisfactory for operation in residential areas.

7. FUTURE TRENDS

The future requirements of the industrial gas turbine market are higher power, improved thermal efficiency and longer service life. To satisfy these requirements design work is in hand for uprating the present engines and for the possible introduction of industrialised versions of the RB 211 and the Olympus 593.

The present approach to silencing industrial installations will still be applicable but the higher powers will bring problems of a practical nature. The engine massflows will be higher and the exhaust gas temperatures will increase, rising to the order of 600°C. This will mean either larger ducts to maintain the present silencer gas velocities or simply allowing the velocities to rise. With the intake silencer larger ducts or increased velocities could be tolerated but with the exhaust silencer the present velocities and duct dimensions are already high. Due to the more restrictive space limitations of a ship's installation this situation has already been reached with marine applications. Breakdown of the exhaust silencer infill has occured when gas velocities are in excess of 200 ft/second. Experiments are in progress to find the most suitable means of protecting the infill from higher gas velocities and to also determine the actual level of velocity that can be tolerated. This information will certainly need to be read across to industrial applications if the demands for higher power are to be met.

ACKNOWLEDGEMENTS

The author wishes to thank Burgess Products Co Ltd. and Cullum Detuners Ltd. for permission to publish their silencer designs and Rolls-Royce (1971) Ltd. for their assistance in the preparation of this paper.

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