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DESIGN OF A QUIET DIESEL POWER STATION

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1. INTRODUCTION

Since the 'oil crisis' of 1973 there has been wide interest in energy saving schemes, particularly in the industrialised countries. One way of saving energy is generally referred to as CHP, the letters standing for Combined Heat Power. Often in these schemes a prime mover in the form of a diesel engine drives an alternator and a good proportion of the waste heat from the engine is used either industrially or for domestic space heating purposes. Domestic space heating in this sense is often referred to as District Heating.

Where the waste heat is applied to domestic properties it is clearly desirable to keep the diesel power station as close as possible to the properties in order to minimise the cost of heat conveying pipework and also to minimise heat losses from that pipework.

It only becomes economic to consider CHP when the electrical output of the station is numbered in the 'tens' of megawatts, which means that large diesel engines are called for rated in the thousands of horsepower. The sound pressure level in the vicinity of such engines is usually well in excess of 100 dB(A) and frequently greater than 110 dB(A).

Herein lies the problem for the power station designer; i.e. How to accommodate a major noise source close to domestic properties without disturbance to local residents.

Although perhaps not so acute, much the same problem arises when CHP is applied for industrial use only.

Whilst it can be said that diesel power stations of comparable size to CHP stations have long been used in developing countries and remote islands, it is also true to say that it is only the use of the waste heat which has brought the power station so close to centres of population and which has laid such emphasis on the control of environmental noise.

This paper will endeavour to review all aspects of the power station design from an acoustic standpoint whether the station output is for CHP, stand-by or electrical power only. Reference will also be made to diesel power stations in overseas locations.

2. ACOUSTICAL DESIGN CRITERIA

2.1 Environmental

The starting point for any design must be the criteria which is to be achieved. It might be thought that the designer is always provided with this information in usable form and can take it as read. In many cases nothing is further from the truth.

For example, in the case of overseas stations consulting engineers or main contractors often expect the acoustician to know the particular environmental noise criteria which is applicable. The acquisition of such data, therefore, is frequently considered to be part of the acoustician's job.

In overseas projects where a criterion is provided this often takes a simple form such as 'no greater than 50 dB(A) at the boundary'. The acoustician would be well advised to find out exactly what is meant by such a simple statement. Does it mean:

a) The station should be designed so that on its own in a totally free field the sound pressure level from the station alone would produce a sound pressure level of 50 dB(A)? Or perhaps:

b) The background at the boundary is already 50 dB(A) and the station is to be designed to make no contribution to this 50 dB(A) level.

There is a considerable difference in the cost of a suitable design between the two interpretations.

Other questions which arise at this stage:

1) Who is going to test the achievement?
2) How is the test to be carried out?
3) Should the designer be present during the test?
4) Will noise from other sources be making a contribution?
5) Ground and other conditions between the station and the boundary.

2.2 Structure

Often no boundary criteria are provided but a usual type of requirement is for the achievement of a dB(A) level at 1 metre from the structure.

It behoves the acoustician to make absolutely certain exactly where 1 metre from the structure is supposed to be. A ground level assessment point only will result in quite a different design from that which will result from a measurement being taken 1 metre from any part of the structure.

2.3 Diesel Engine

Sound pressure level information about the engine is nearly always available as part of the design information provided. The derivation of such information should always be questioned for the following reasons:

2.3.1) The measurements may have been extrapolated from those for another version of the engine. Engine manufacturers do not always have qualified acousticians on their staff and may not necessarily realise the importance of accurate acoustical data.

2.3.2) The room conditions in which the manufacturer's measurements were taken are seldom stated. They may have been taken in a large reverberant test house in which case the levels may be overstated or they may have been taken in a smaller chamber with significant absorption.

Unlike automotive diesels, noise levels are not usually a factor which enters into the purchase of large diesel engines so engine manufacturers do not always see the need for accurate acoustic data.

2.3.3) The noise from any diesel engine is particularly dependent on the power which it is producing, there probably being some 20 dB(A) or so difference between idling and maximum throttle. The question therefore arises as to the relationship between the engine operating condition when tested compared with its operating output.

2.3.4) Quite aside from structure borne noise considerations the use of anti-vibration mountings affects the noise output from an engine. No quantitative information is presented with this paper, but the author's subjective assessment based on smaller diesel engines is that fully flexible anti-vibration mountings are worth 3/5 dB(A).

It is also necessary for the acoustician to make enquiries about the use of anti-vibration mountings in as much as their use calls for flexible connections on all engine pipework and ducting, etc., which is a bonus from an acoustic standpoint.

2.3.5) Exhaust noise is a main contributor to total engine noise but when large diesel engines are tested in the manufacturers' premises they are compelled to use the fixed test house exhaust system and silencer(s). This means that diesel engine manufacturers seldom have exhaust noise information about their engines.

2.3.6) Invariably very large engines are water cooled. The heat being removed in cooling towers or radiators remote from the engine by ambient air.

Here again it is important for the acoustician to know about the noise of this air movement so it can be accounted for and dealt with if necessary.

Because of the high ambient temperatures in hot climates much greater quantities of air are required than in colder climates. The acoustician should again check the engine manufacturer's acoustic information which may not relate to tropical conditions.

Occasionally power is required at high levels, here again more air is required than at lower levels.

2.3.7) Whilst octave band information is almost always available from engine manufacturers it is important for the acoustician to realise that information should also be obtained about the generator and any coupling between the two.

3. POSSIBLE AVENUES OF NOISE TRANSMISSION

For the purposes of this paper the author has considered the station to comprise an acoustic structure, either conventionally built or constructed from modular acoustic panels.

It should be realised, however, that stations (particularly stand-by types) often are incorporated into existing structures - always severe limitation on the acoustician and meriting a paper just to themselves.

3.1 Ventilation and Combustion Air Intake Openings

Since the combustion air is transformed into exhaust gas and exits via the exhaust silencer, the intake on a diesel power station is always larger than the discharge.

Except in the very small stand-by sets, forced mechanical ventilation is invariably required. The acoustician will want to know about the ventilation fans which can be quite noisy in themselves. Ideally speaking the inlet air attenuation will be sited to deal with fan noise and also engine noise breakout.

However, the attenuators insertion loss capacity cannot be considered in isolation. Other items in the air train will have some attenuation capacity which may need to be taken into account; i.e. weather louvre or weather bends, air filter if fitted and ductwork.

The acoustician will also need to know the allowable air resistance of the attenuator so he can size its cross section. He will also need to know if the attenuator will be mounted externally or internally.

The casing and internals of an externally mounted attenuator will need to be of heavier section to accommodate weathering. The acoustician should also ask about local conditions in case it is necessary to protect the absorbent infill of the attenuator splitters.

If the acoustician comes under pressure to keep attenuation cross sections to a minimum, then velocity induced self-noise can sometimes be a factor which has to be considered.

3.2 Ventilation Air Discharge Openings

Sometimes these also are fan controlled but in any event attenuators are again required.

Air exhausting through these discharge openings may be 10°C greater than the ambient inlet air.

In both cases the acoustician should take into account the reduced air density not from any acoustic point of view but because of the changed resistance imposed by the attenuator.

3.3 Hot Gas Exhaust System

If the acoustician has any doubt that the engine manufacturer's silencer will not provide sufficient attenuation, then he should call up a secondary silencer to be put in series with the silencer supplied as original equipment. The engine manufacturer should, of course, be advised of this action so he can decide whether the fitting of an additional silencer will affect the engine's combustion characteristics in any adverse manner.

In large diesel generating installations the combustion gas outlet or stack can be some way from the engine or engines and must be considered quite separately from the main engines.

3.4 BUILDING WALLS

3.4.1 Conventional brickwork

The use of these materials usually poses no acoustic problem providing the wall is thick enough. A 9" solid brick wall usually being adequate for most projects, particularly if it is plastered on the inside. Such finishes, however, add to the reverberation within the building.

Blockwork or lighter forms of construction are not considered suitable for power station duty.

3.4.2 Brickwork + cladding

This is a popular form of construction at the present time. The steel or aluminium cladding being supported by the brickwork.

One of the acoustic problems which arises with this building method is the lack of transmission loss information available from the cladding manufacturers, of which there are many. The cladding takes the form of a series of castellations infilled with thermally insulating material.

Normal cladding would be unsuitable except for very light acoustic duties and it would, therefore, always need the addition of secondary acoustic material.

3.4.3 Modular Acoustic Panels

Whilst the acoustic performance of this type of equipment is well documented, such panelwork is not designed as a building material. Standard panels cannot generally be used because of their inability to carry additional weight from the perforated metal inner surface.

Providing the acoustic panel manufacturers are made aware in advance of a requirement for support steel it can always be incorporated into the acoustic panel in the manufacturing stage. However, it is not always possible to predict exact requirements in advance.

3.5 Buiilding Roof

In this part of a large diesel power station the acoustician may come under the strongest pressure from the architects and structural engineers associated with the project and needs more than ever to be certain of his design calculations.

Whilst the acoustician requires mass to deal with the low frequency content of the noise, which is always present in large diesels, the weight of the acoustic roof has to be supported down to the foundations.

The cost of supporting heavy rooves is a not inconsiderable item. Where boundary noiise criteria apply directivity factors as far as the roof is concerned become all important.

It would not be unusual if the walls comprised 9" solid brickwork for the roof to be constructed of 4" thick precast concrete slabs carrying an acoustic ceiling of robust construction.

The roof could, of course, comprise modular acoustic panels.

3.6 Foundations

The station will, of course, be designed with a normal concrete floor to carry all the usual items associated with the operation of large diesel generators and sometimes it is considered advisable to decouple the floor from the walls.

The foundation considerations which apply to the associated items do not apply to the diesel engine itself which, although multi-cylindered, is nevertheless not totally balanced and is, therefore, capable of subjecting the foundation to significant dynamic vibrationary forces and structure borne noise.

Both vibrations and structure borne noise can be dealt with by the use of properly designed anti-vibration mountings. The difficulty here is that being flexible the mountings permit the engine to move under the actin of the dynamic out of balance forces.

A less satisfactory approach, but a more usual one, is to mount the engine on a concrete block which is three times the mass of the generator itself. The block being isolated from the rest of the foundation by being supported on flexible matting or anti-vibration mountings.

3.7 Doors and Windows

Large doors are often called for to allow large plant items to be removed for maintenance purposes. It is necessary, therefore, for the doors to be of soundproof construction. In critical areas both plant and personnel access doors would be constructed in pairs with a vestibule in between so that one door would be closed at all timems.

The acoustician is advised to pay attention to the station internal air pressure due to the mechanical ventilation, as it may very well affect door operation.

Windows are not normally a feature of station design since the cost of incorporating large acoustically glazed areas cannot be justified.

3.8 Service Openings

If the acoustician is to accept responsibility for compliance with the acoustic criteria, then he really requires to know about all the openings into the structure; i.e. power cables, fuel oil and water pipework.

4. OTHER DESIGN CONSIDERATIONS

4.1 Prompt start-up in cold conditions

This consideration applies to stand-by generator sets of the mains failure type. In order to prevent cold air and snow gaining access to the genset house a building services engineer will call for powered louvres which open on engine start. Such powered louvre systems have an attenuation which can be taken into account.

4.2 Reverberation

Reducing the reverberant field will, of course, assist achievement of the criteria. It will also, of course, assist those personnel who need to work inside the station.

4.3 Internal noise

Even with reverberation control, internal noise levels can be of the order of 110 dB(A) which would allow about four minutes per day working for the undefended ear.

Plant operating personnel, therefore, require acoustically treated offices and workshops, not merely to protect their hearing but also for communications purposes.

5. CONCLUSION

Noise control for large diesel power stations presents a considerable challenge to the acoustician, not the least part of which is the need to convince other professions which are used to taking a more dominant role in any project.