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ACOUSTIC DESIGN OF LARGE PROCESS PLANT

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1 OBJECTIVES

There are three basic objectives which are

a The avoidance of nuisance to local residents

b The control of noise inside the plant to level which is not hazardous to hearing

c Control of noise intrusion into nearby office blocks, control rooms etc

These are usually of mutual benefit but there can be occasions when they conflict with each other. The various noise levels developed for specificatior or evaluation purposes on UK projects are based on two official documents

(i) BS 4142 (Ref 4)
(ii) Health and Safety Executive Code of Practice (Ref 2)

combined with data abstracted from various references to fill in the gaps left by these documents. With overseas projects one must use the guidance documents relevant to the particular location.

For practical purposes it is useful to separate nuisance to employees from that for local residents because the latter is a function of location, existing noise levels, and effects of other nearby factories whereas the former is constant irrespective of these modifying factors.

The essential aim of a noise control procedure is thus to control the effect of noise on people in both an acceptable and economic fashion. This paper is concerned with the procedures necessary for the specification and design required to achieve satisfactory noise levels.

2 NOISE SPECIFICATIONS

Having decided on the noise criteria applicable to a project, one can produce a specification for incorporation in the main project document to which the various design groups in the division or contractors will be working. To date, most general noise specifications have been produced by individual companies or trade associations. An example of a recently drafted detailed plant specification is that prepared for an Ammonia Plant commissioned in 1976 and this is given in Appendix 1. A reading of it shows that limiting noise levels are set for a series of specific circumstances which encompass both hazard to hearing and nuisance. No attempt was made to lay down calculation methods, as in the OCMA specification (Ref 3) and this specification is limited to a statement of the required results. This approach requires that the main contractor's expertise be assessed so that a decision can be made on the amount of supervision which needs to be exercised by the user.

A particular feature of the specification in Appendix 1 is Section 3.4 which deals with items of equipment which are likely to be major noise sources thus ensuring that potential problem areas receive adequate early attention. Experience has shown that a noise specification which in itself is adequate can fail to produce a satisfactory plant because insufficient effort is put into identifying potential problems and devising adequate solutions. It should be clearly understood that individual noise specifications are required for each item of equipment so that the whole will add up to meet the general specification. On recent projects the Specification is supplemented by a Co-ordination Procedure document which clearly defines responsibilities and actions to be taken.

3 DESIGN, CONTRACTUAL AND ECONOMIC ASPECTS

Interaction of these matters is inevitable and the basic philosophy involved is outlined below.

3.1 Design

Noise is best tackled in the design stage. Five basic points should be considered at the start of a project.

(a) If the contractor's bid does not specifically consider noise, then determine if this is a positive decision. Many projects have provided problems on commissioning because the contractor failed to consider and make adequate provision for noise in design, despite his having a noise specification to work to. Government based Codes of Practice and Legislation makes it important that this factor does not go by default.

(b) Noise specifications should be discussed with the contractor so that the bases on which they were drawn up are clearly understood. From this the sensitive local areas can be pointed out as well as the "in plant" policies which have been adopted. Revisions may be needed to avoid vague statements and provide an agreed working document.

(c) Adequate expertise must be applied in a mutual consideration of problems arising. In this connection ICI experience is that noise specifications must be followed up in depth with contractors and suppliers, or difficulties will arise.

(d) Noise is best suppressed by tackling the source rather than by using barriers and enclosures which may inhibit good maintenance and fall into disrepair. Careful attention to detail is necessary in the design of all barriers and enclosures which have to be employed.

(e) Optimum solutions to some problems depend on a knowledge of the system and are unlikely to be put forward by equipment vendors.

If expertise is not available within the contractor's organisation, then help should be given directly or consultants employed. It is essential that any consultants used have relevant experience of the type of work involved.

3.2 Contractual aspects

These relate mainly to specifications and the main points which need to be agreed upon if successful design is to proceed. Thus:

(a) The user's noise specification will have to be transposed into purchasing specification by a main contractor and the latter must not:

(i) Fail to use a noise specification because possible suppliers cannot provide data or because it is new to certain types of equipment.

(ii) Allow bids to be submitted without a noise specification being considered.

(b) Where the user wishes to carry out part of the acoustic design using his own expertise this must be clearly defined and responsibility for this openly accepted. In some areas there may be a joint responsibility with the main contractor but responsibility for much of the design must inevitably be taken by the main contractor because he alone has the bulk of the data on individual plant items.

(c) Noise specifications must be enforced and it may be necessary to reject equipment because of noise problems encountered during test: the temptation to accept noisy equipment so that one can adhere to a tight construction programme should be resisted.

(d) Noise specifications need to be unambiguous and adequate time needs to be spent at the tender stage to remove anomalies.

(e) Community noise may be difficult to measure, especially if the design has successfully caused no rise in the overall background level. Agreement on the procedure for evaluating this aspect is essential.

3.3 Economic aspects

The cost of producing a quiet chemical plant varies with the type of plant but may be between 0.3% and 1.5% of the capital cost for plants on existing sites situated in industrial areas. Should the plant be on a green field site, then the cost could be up to three times these figures. Typical expensive items to control in terms of noise include:

(a) Large furnaces and fired heaters

(b) Large steam systems with blow down steam often desuperheated for process requirements.

(c) Pipe noise: this can be controlled by proper sizing to permit low velocities and/or by the use of acoustic lagging. The choice is conditioned by cost and lagging can be £6 per foot run for large pipes/ducts.

(d) Cooling systems for electric motors.

(e) Grinding and granulating equipment.

Noise control costs money and time: both must be allowed for when costing a project and failure to do so inevitably leads either to over-expenditure or to excessive noise levels.

4 ACOUSTIC ASSESSMENT OF A PROJECT

This usually takes place in two phases, the first being at the flowsheet stage and the second at the detailed design of those items identified from the flowsheet.

ACOUSTIC DESIGN OF LARGE PROCESS PLANT

4.1 Assessment at flowsheet stage

Take as an example the fictitious plant complex defined in Figure 1. One can simply list the major probable noise sources from experience and in this example they are

1 Heater furnaces/burners
2 Reformer furnaces/burner noise
3 Process vents
4 High velocity piping systems
5 Control valves with high pressure drop
6 Electrical drives
7 Centrifugal compressors
8 Air fin coolers
9 Pneumatic conveyors

If the complex contains equipment about which there is no previous factual data from which judgements can be made, then one must seek such data from possible manufacturers or from users of the equipment. Experience has shown this is a difficult but not impossible task. One is identifying problem areas by such an examination and care should be taken to ensure nothing is overlooked and that it is as numerate as possible.

4.2 Assessment of individual items of equipment for the detailed design stage

At this point one is gathering actual data from suppliers to compare with predicted levels from published or internal data. The data should also be compared with the requirements laid down in the specification supplied with the original enquiry. Increasing amounts of data are now available as Industry has pushed equipment manufacturers into an increased awareness of the noise problem and this situation is improving.

Care must be taken when doing these comparisons to determine if the data supplied is realistic. Predicted noise levels can be over or under-emphasised for equipment where the possible supplier is new to the topic of noise. As an example, one case in which a batch of centrifuges were under consideration the quoted noise levels were abnormally high and cross-questioning revealed that this was a fall back position based upon another installation with a different, and very noisy, driving unit. This situation could have led to large and unnecessary expenditure on noise control.

In the absence of actual data it is possible to predict probable noise levels from the increasing amount of literature on noise sources. This is by no means fully comprehensive but all of the items listed above could be estimated by this means. Inevitably, there is an element of judgement and experience involved. Even given adequate control of the noise from individual items of equipment supplied by vendors, much noise prediction and control will still lie in the hands of the project team. In particular, the provision of sound absorption to reduce reverberation in buildings; adequate sizing or acoustic treatment of pipe lines; proper design of pressure let down and vent systems, need to be examined if problems are to be avoided.

5 EARLY ASSESSMENT OF POTENTIAL PROBLEMS

As stated, these are identified at an early stage and require that action be taken at this time if a satisfactory, and economic, solution is to be found. Generally one is concerned with high energy equipment or sources which are in an elevated position. For the purposes of the example described in the fictitious flow sheet one can readily see that

(i) large air cooler systems

(ii) major plant vents

and

(iii) the compression plant

fall into the above-mentioned categories. The following paragraph deals with how a large air cooler system can be handled at the flow sheet stage thus avoiding difficulties and delays in the detailed design stage.

The A weighted sound power of banks of identical air coolers is given by the following equation based on work done in ICI since Ref 4 was published.

$$L_{W(A)} = 91 + 10 \log_{10} KW - 13 + 30 \log \frac{V_T}{61} \quad \text{where } V_T = \text{Tip Speed m/s}$$

which can be usefully turned into a graph (Fig 2) from which one can deduce the noise output over a range of tip speeds and total installed shaft power. On a recent project this information was used to assess the proposals returned by potential vendors and it is worth noting that detailed discussions with vendors has shown that their data has shown the prediction method to be valid.

Assuming that the installed power is 20 kW per fan and 30 fans are required to provide adequate cooling then a sound power of 102 dBW(A) will be produced for a tip speed of 9,000 feet per minute: to reduce this to 99 dBW(A) a reduction in fan tip speed to 7,000 feet per minute is necessary. Alternatively, one can consider the use of

(a) two speed fans for day/night operation, e.g. 9,000 feet/min day operation and 7,000 feet/min night operation.

or

(b) variable speed fans which can be expected to operate at low speeds during the night when the most onerous noise criteria need to be met: this is the most efficient method of working but is also the more expensive which is important in times of capital limitation.

Because these considerations may control the number of coolers utilised it has a knock on effect into plant layout and piping design and decisions must be made very early in the life of a project if satisfactory progress is to be sustained.

6 CONCLUDING REMARKS

The brief summary presented here attempts to show how one tackles the acoustic design of large process plants. The need to minimise the unnecessary use of scarce capital and human resources makes it imperative that noise control is effected efficiently and in this respect the incorporation of the Acoustics Engineer into a Project team is a prerequisite.

ACOUSTIC DESIGN OF LARGE PROCESS PLANT

7 ACKNOWLEDGEMENTS

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REFERENCES

1 BS 4142:1967; amended 1975 Method of Rating Industrial Noise affecting Mixed Residential and Industrial Areas.

2 Health and Safety Executive Code of Practice for reducing the Exposure of Employed Persons to Noise ISBN 011 88 0340 9

3 Oil Companies Materials Association Specification NWG1 (Revision 2) March 1980, Procedural Specification for limitation of Noise in Plant and Equipment for use in the Petroleum Industry: Heyden & Son Ltd.

4 J B Erskine/J Brunt: Prediction and Control of Noise in Fan Installations: Institution of Mechanical Engineers Conference on Vibration and Noise in Pump, Fan and Compressor Installations, September 1975.

APPENDIX 1

EXAMPLE OF A NOISE SPECIFICATION FOR A COMPLETE PROJECT

1 SCOPE

This document is intended for inclusion in the general Project Specification document for dealing with the proposed plant, which may be issued to a Contractor or used internally. For individual manufactured plant items, separate Noise Specifications are to be set up which satisfy the general requirements outlined in this document; these will be the subject of a separate and more detailed agreement. The definitions for the various terms employed can be found in BS 661:1955 - "Glossary of Acoustical Terms" (Ref 16). (See also Section 2.1).

The Company is concerned in the light of previous experience, and impending changes in Noise Legislation, that the noise limits specified below are not exceeded. It is expected that evidence will be supplied, in detail, by potential contractors during bid discussion as to how they intend to achieve the stated objectives.

2 SPECIFICATION

2.1 Noise Levels Within a Plant

In areas to which personnel require access in the normal course of their duties, the noise level from all sources shall not exceed that stated in Table 1 including abnormal conditions, e.g. venting and flaring, compressor start-up on by-pass. These levels are given for each of the preferred octave bands and refer to continuous broad band noise. If the noise is expected to contain very narrow band or pure tone components, these levels are to be reduced by 10 dB in the octave which contains the pure tone. If the noise is impulsive in character the levels are to be reduced by 10 dB throughout, when measured by its instrumentation referred to in Sub-section 3.2.

Attention is drawn to the Noise Rating Curves (see Fig 3)

Table 1 sets out the limiting levels which must not be exceeded in locations on and around a plant. The "On" Plant level is regarded as the level at which impairment of hearing will not occur from long term exposure whilst the remainder are nuisance levels. The octave band figures for the desired noise rating from Table 1 must be used to derive the noise levels to be specified to equipment suppliers in the specifications for manufactured plant items.

Noise Rating	Limiting Sound Pressure Level in Decibels re 2 x 10^{-5} N/m^2									
	Octave Band Mid Frequency Hz	63	125	250	500	1000	2000	4000	8000	dBA
85	"On" Plant	102	96	91	87	85	83	81	79	90
65	Workshops	87	79	73	68	65	63	61	59	
55	Control Room/ Plant Offices	78	70	63	58	55	53	51	49	
50	General Offices	75	65	58	54	50	48	46	44	
45	Canteens	71	60	54	49	45	43	41	38	
40	Private Offices	67	56	49	44	50	38	35	33	

Table 1 - Noise Levels Within a Plant

2.2 Perimeter Noise

At specified points in the residential areas adjacent to the plants, the noise levels which are attributable to the plant working must be low enough to ensure that justifiable complaints will not arise and that the possibility of litigation is avoided. In this connection, it is probable that legislation may be in force before the plant is commissioned and the limits in Table 2 below must be considered with this in mind. The sound pressure level at the specified point(s) must not exceed the levels set out in Table 2 and the Contractor must endeavour to achieve lower levels if possible. These points are sufficiently close to the plant to avoid noise at the sensitive areas but still allow for a realistic measure of the actual plant noise.

The specified levels are as follows:

Frequency Hz / Specified Points	Limiting Sound Pressure Level in Decibels re 2 x 10^{-5}								
	63	125	250	500	1000	2000	4000	8000	dB(A)
100 m East of A	79	71	62	57	53	52	52	54	60
100 m North of A	79	71	62	57	53	52	52	54	60

Table 2 - Perimeter Noise

3 NOTES

3.1 Treatment

Where noise levels are expected to exceed these given in Table 1 or Table 2 the Contractor shall discuss with the Company the proposed methods of treatment to meet the stated limits: in this connection it should be noted that ear protectors for plant operators are acceptable only for cases of occasional short term exposure. To establish clearly likely problem areas, the Contractor shall prepare a note defining the likely noise sources, their octave band sound pressure levels and the resultant octave band sound power levels. Against each source a description of the means of reducing noise shall be outlined for the purposes of subsequent discussion; this must be accompanied by a statement of the expected cost of acoustic treatment.

3.2 Instrumentation

The octave band levels are to be measured with a sound level meter which complies with BS 4197:1967 (Ref 15), and a filter set which complies with BS 2475:1965 (Ref 17). Linear or weighting characteristic "C" is to be used, the response set to "slow" and the maximum reading at each measurement point is to be taken. If the filter is adjustable, it must be set up in accordance with the maker's instructions to provide a linear characteristic. The weighted sound pressure level is to be measured with the weighting characteristic "A".

3.3 Pure Tone

A pure tone is present in the noise when a component in a given octave band is within 10 dB of the total level in the chosen octave band. Such a pure tone would be detected normally by ear but special instrumentation is necessary if a quantitative analysis of the tone is required.

3.4 Previous Experience with Noise on other similar Plants

Experience has shown that the following plant items are major noise sources; they are given as a non-exclusive guide to expedite co-operation and assist in the acoustic design of the plant:

1 Fin Fan Coolers

2 Naturally aspirated furnaces and their burners: this is particularly important when the fuel gas can have a low molecular weight due to hydrogen being present.

3 Steam and gas pipeworks subject to high velocities.

4 Pressure let-down systems and venting systems.

5 Motor cooling fans.

6 Large fans in cooling towers.

7 Control valves with pressure drops exceeding 10 per cent of system pressure: this is particularly important with steam/gas mixing systems.

8 Heat exchangers whose acoustic resonances are excited by flow noise set up by vortices.

9 Gear pumps in lubricating oil systems.

10 Lobe and screw compressors.

11 Large centrifugal compressors, and prime movers.

12 Centrifugal pumps with large minimum flow kick-back systems which produce two-phase flow in low pressure pipework whose diameter equals that of the high pressure section.

13 Gearboxes are frequent sources of high noise levels and in the past recourse has been made to ground gear teeth or easily fitted acoustic hoods to overcome this effect.

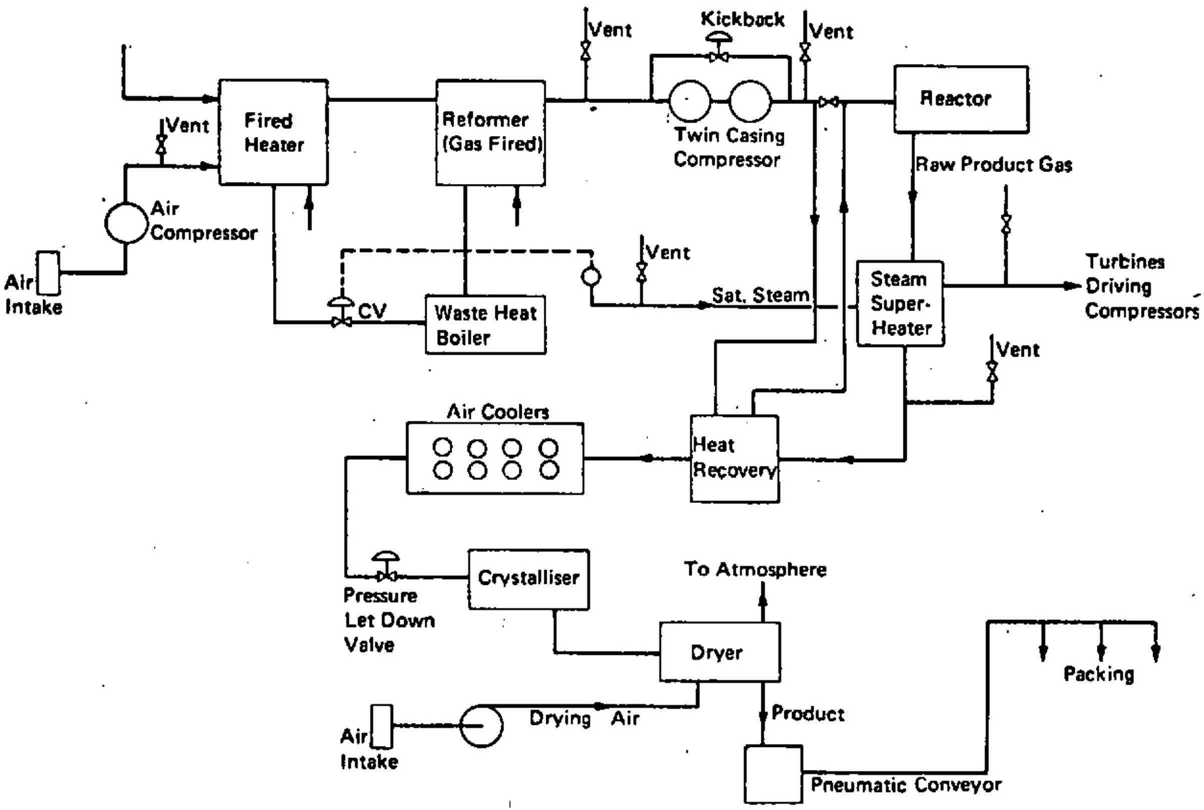
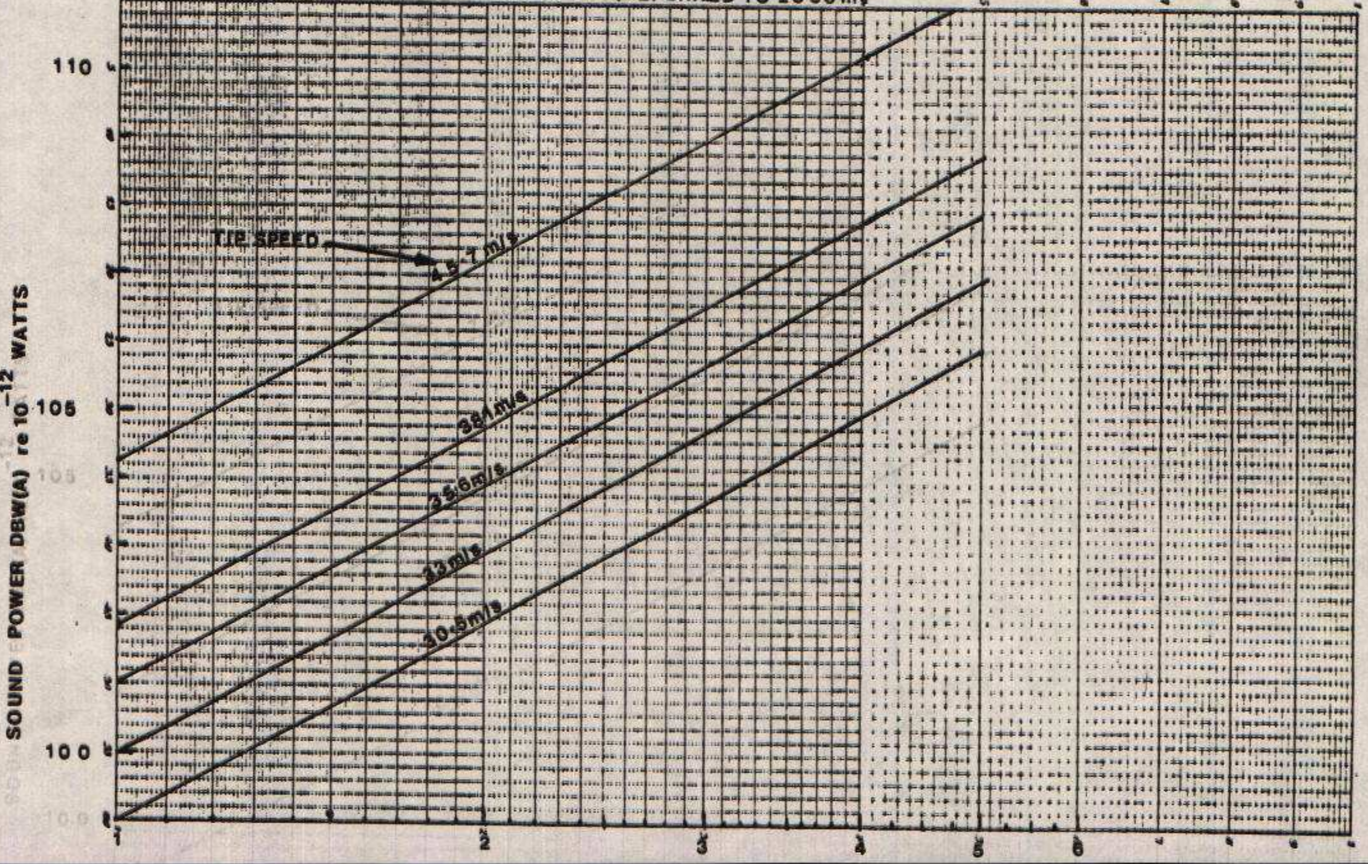


Fig 1 Block Diagram of a Chemical Plant

FIG 2 AIR COOLER NOISE - TIP SPEED(REFERRED TO 2000m)



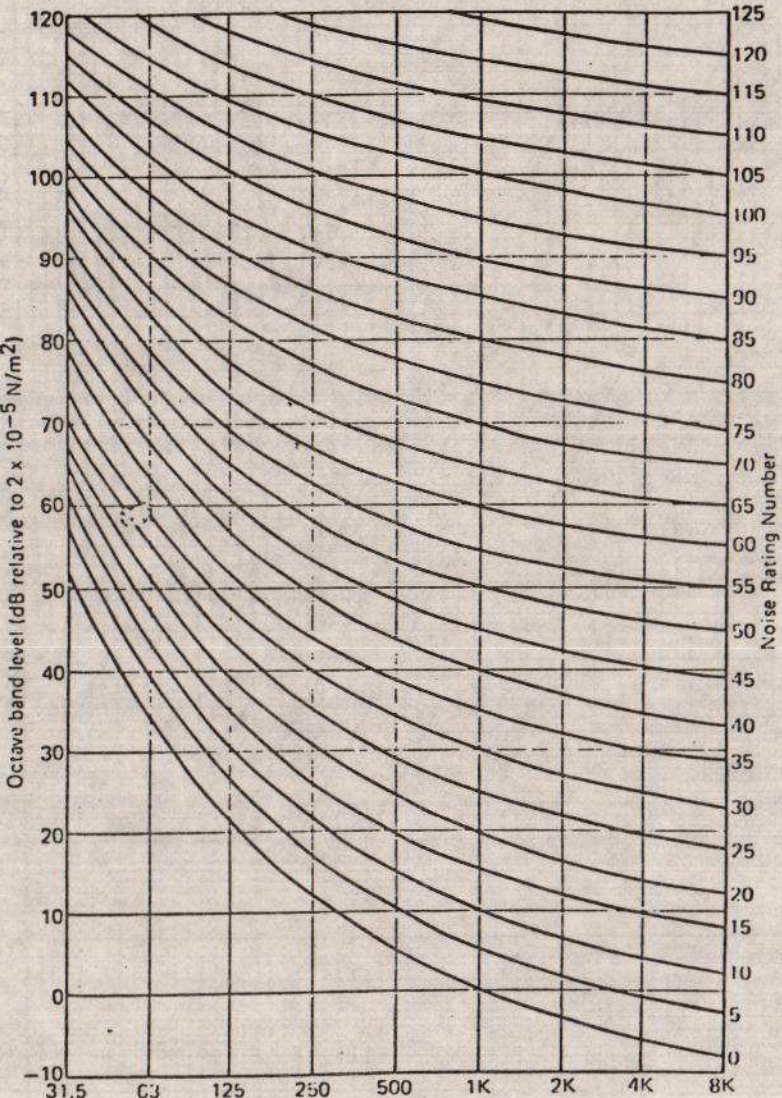


Fig3 Noise Rating Curves