GENERAL STANDARD

FOR

NOISE CONTROL AND VIBRATION

CONTENTS :

PAGE No.

PART 2:

APPENDICES:

0. INTRODUCTION

Noise can disturb human's work, rest, sleep and communication, it can damage hearing.

Indeed the most important issue is industrial noise problem and a need for noise control and hearing conservation programs.

This Standard provides guidelines comprising:

a) Brief explanation of the principle and essential standards for noise emitted by machineries and equipment.

b) Brief explanation of the principle underlying standards for noise in workplace areas, and noise control procedures in plants/complexes, offices, conference rooms, etc.

c) Brief explanation of the principle for vibration control.

This Standard is prepared in two Parts:

Part 1 Noise Control

Part 2 Vibration Control

1. SCOPE

This Standard defines the procedures for noise control of plant and equipment. It specifies how to derive maximum allowable noise levels for equipment installed in oil refineries, chemical plants, gas plants and, where applicable, in exploration and production facilities and supply/marketing installations.

It applies equally to design and construction of new plants and to modification of existing plants.

This Standard is not considered suitable for reference in requisitions of individual equipment. The actual noise limits for the equipment under consideration shall be specified in the equipment requisitions under guidance of the management and appropriate medical and safety authorities.

Part 1 of this Standard also deals with the particular requirements for installing the acoustic insulation and is intended for the noise control engineer to consider the acoustic design of the plant.

Part 2 of this Standard defines the vibration control of particular equipment.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor/Consultant/Contractor.

ROYAL DUTCH/SHELL STANDARDS

DEP 31.46.00.31-Gen.	"Acoustic Insulation for Pipes, Valves and Flanges"
DEP 31.10.00.94-Gen.	"Data/Requisition Sheet for Equipment Noise Limitation"
DEP 31.10.00.95-Gen.	"Data/Requisition Sheet for Vent/Blow-Down/Air-Flow/In-Line Silencers"
DEP 31.10.00.96-Gen.	"Data/Requisition Sheet for Rotating Equipment Acoustic Enclosures"

API (AMERICAN PETROLEUM INSTITUTE)

API RP 521	"Guide for Pressure Relief and Depressuring Systems"

BSI (BRITISH STANDARD INSTITUTION)

BS 4142	"Method of Rating Industrial Noise Affecting Mixed Residential and Industrial Areas"
BS 3593	"Recommendation on Preferred Frequencies for Acoustical Measurements"

EEMUA (THE ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION)

EEMUA Publication
No. 140 "Noise Procedure Specification"

Note:

Formerly OCMA Specification NWG-1, 2nd revision of March 1980.

EEMUA Publication
No. 161 "Guide to the Selection and Assessment of Silencers"

ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

ISO 3864	"Safety Colors and Safety Signs"
ISO 266	"Acoustics Preferred Frequencies for Measurements"
ISO 1683	"Acoustics-Preferred Reference Quantities for Acoustic Levels"

3. DEFINITIONS AND TERMINOLOGY

Narrow band noise

When the noise from a source contains a pure tone or narrow-band component which is noticeable to the ear as a noise of distinguishable pitch, and which represents a dominant feature of the total source noise, then the source noise shall be regarded as containing narrow-band noise for the purpose of this specification.

Note:

Where there is doubt about the subjective assessment of narrow-band noise it shall be resolved by narrow-band analysis, using an instrument with a band width not more than 10 Hz or 1%, whichever is the less (See Appendix E of EEMUA 140).

Octave bands

Refer to the preferred octave frequency bands of BS 3593 or ISO 266.

Reference surface

Is the smallest possible imaginary parallel-piped enclosing the source and terminating on the ground (excluding re-entrant sections and minor protruberances which are not significant emitters of noise).

Sound level

Is the A-weighted overall sound-pressure level.

Sound-power level

Is defined as 10 log (W/W_o) in dB where W is the sound power in watts, and W_o is the reference sound power of 10^{-12} watt.

Sound-pressure level

Is defined as 20 log (p/p_o) in dB where p is the measured sound pressure in N/m^2 and p_o is the reference sound pressure of 2×10^{-5} N/m^2.

Machine

Any sound source of which the acoustical characteristics are to be measured.

Decibel

Decibel (dB) is a logarithmic scale unit expressing the relative magnitude of two sound power.

Band

A band is a range of frequencies determined by the highest and the lowest frequencies in the range. Frequencies are measured in Hertz (cycles/second).

Steady noise

Noise that gives fluctuations over a range of not more than 5 dB on a sound level meter set to frequency weighting "A" and time weighting "S".

Sound transmission loss, TL

The Sound transmission loss of a partition in a specified frequency band is the ratio, expressed in decibels, of air borne sound power incident on the partition to the sound power transmitted by the partition and radiated on the other side transmission coefficient, T fraction of the incident energy that is transmitted through a wall.

Vibratory-velocity level

Is defined as 20 log (v/V_o) where v_o is the reference velocity of 5×10^{-8} m/s.

Note:

This is not the preferred reference velocity required by ISO 1683 but it is the most suitable value for relating vibratory-velocity levels with sound-power levels.

Work area

Is any position not less than 1 m from equipment surfaces which is accessible to personnel, or any position where an operator's ear may be exposed to noise in the normal course of duty. It includes any platform, walkway or ladder.

Impulsive noise

When a noise contains significant irregularities, such as bangs, clanks, or thumps, or if the noise is only existent momentarily and is of a character to attract attention, then it shall be considered as impulsive for the purpose of this specification.

4. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

PART 1
NOISE CONTROL

5. GENERAL

5.1 The control of noise in a plant is required for the following reasons:

- to conserve the hearing of personnel;
- to reduce speech and work interference;
- to provide quiet accommodation for personnel;
- to prevent annoyance to the neighboring community.

Noise limits can be given for each of the above aspects of noise control, relative to certain areas inside or outside the plant. For the purpose of this specification they shall be referred to as "General Noise Limits". They are specified in Section 10.

Noise limits for each item of equipment shall be derived from the general noise limits, as applicable for the equipment in its specific position in the plant. They are commonly referred to as "Equipment Noise Limits". Procedures for deriving equipment noise limits are specified in Clause 11.

Each potential noise source shall be subject to the requirements of this specification.

The specified limits shall be met for the design operating conditions of the plant and for other operating conditions which occur occasionally, such as start-up, shutdown, regeneration and maintenance. The only requirement for emergency situations, i.e. any conditions other than just described, which can be foreseen or predicted (e.g. relief) is that the absolute limit given in Clause 10.2.1 shall not be exceeded.

During construction, noise levels should not exceed the limits applicable for operation of the completed plant.

5.2 Community Noise

Community noise problems are solved through the elimination or preventation of annoyance to neighbors and/or reduction of noise levels to within the Standard limits.

6. SOUND AND DECIBELS

Sound is a disturbance which propagates through a medium having the properties of inertia (mass) and elasticity. The medium by which audible sound is transmitted is air. For definition of Decibels refer to the heading of definition and terminology.

7. INTENSITY AND POWER

As with any energy source, the power of an acoustic source may be expressed in watts. In a free field, sound will propagate from a non-directional source in a spherical manner. Since the area of a sphere increases proportionately with the increase in distance from the source, the intensity, or power per unit area, decreases because the power is being distributed over an expanding area.

8. NOISE CONTROL AND HEALTH PROTECTION

Noise control can be implemented by the use of noise standards. These standards can be met by noise control at, source, control of sound transmission, physical separation of noise source and people and other elements as follows:

8.1 Noise Control at Source

The most efficient action against excessive noise is the reduction of the noise at source. In industry, noise control technology is available for solving many typical noise problems arising from the use of machinery.

Usually the most effective approach is to redesign or replace noisy equipment. If this is not possible, significant reductions in noise levels can be achieved by structural and mechanical modifications, or the use of mufflers, vibration isolators, and noise protection enclosures.

8.2 Control of Sound Transmission

A further reduction in noise can be obtained by increasing the distance between people and the noise source. This can be achieved in the community by planning the location of transport facilities and, in industry, by the careful selection of work sites. Sound transmission can also be controlled by the use of partitions or barriers, e.g., around particularly noisy or disturbing machinery. Reverberant noise levels can be reduced by sound-absorbing materials.

8.3 Reduction in Length of Exposure

A reduction in the length of exposure can be used in industry to supplement the previous measures, if necessary. This may be accomplished by job rotation or by restricting the operation of the noise source.

8.4 Education of Workers

It is vitally important that persons who are exposed to potentially hazardous noise levels should be educated in: (a) the possible consequences of excessive noise exposure; (b) the means of protection; and (c) the limitations of these means (e.g., improper use of ear-muffs).

8.5 Ear Protection

If it is absolutely impossible to reduce noise to a harmless level then some form of ear protection, i.e., ear-plugs, ear-muffs, and/or helmets, should be used. They should also be used during infrequent exposures that may not be part of a worker's normal routine (see IPS-M-SF-325).

9. GUIDELINES FOR NOISE CONTROL ENGINEER

The following documents shall always be available to the noise control engineer:

- project approval notes;
- basis of design;
- project specification;
- plot plan;
- contractor and vendor reports on noise.

For major projects in the design and engineering phase and the procurement phase, the required documents should be submitted to the noise control engineer if close guidance by the owner is required.

The appropriate issue, or issue to be decided by the engineer concerned:

- process flow schemes;
- plot plan;
- equipment summary, project specification;
- heat exchangers (air coolers only);
- furnaces, burners;
- mechanical handling equipment;

- extruders, ejectors, etc.;
- pumps, compressors, including drives;
- valves (including control valves);
- flare and vent stacks;
- external insulation, sound proofing only;
- transformers, generators only;
- electric motors;
- cooling towers;
- fired steam generators
- silencing equipment (silencers, enclosures, screens).

In special cases, it may be necessary also to submit the following documents:

- process engineering flow diagram;
- buildings.

10. GENERAL NOISE LIMITS

10.1 Local Regulations

10.1.1 In-plant noise

It shall be investigated whether any national regulations exist with respect to noise in the plant, for example for hearing conservation, speech and work interference, accommodation, etc.

For locations where national standards are more stringent than this Standard, the applicable more stringent limits shall be stated in the project specification, or any other document defining the scope of the project.

10.1.2 Environmental noise

Limits for environmental noise are not given in this Standard since they will depend on the local situation.

It shall be investigated whether local regulations exist with respect to environmental noise, which may include noise limits, methods of measurement and/or calculation, etc. The interpretation of such regulations shall be discussed with local authorities with the object of arriving at agreed environmental noise limits.

Environmental noise limits may be different for different times of day or night and for work-days or weekends. The most stringent of the above requirements shall be the basis of design, taking due account of the period of operation of the plant.

It shall be ensured that any allowances for occasional higher noise levels that may be acceptable to local authorities are included in the environmental noise limits, e.g. such as for emergencies.

Where local regulations for environmental noise do not exist, this aspect of plant design shall still be considered at the project definition stage to anticipate adverse community reactions at some later date. BS 4142 may be used for guidance.

Authorities usually specify environmental noise limits in terms of maximum allowable sound pressure levels at specified locations in the vicinity of the plant or at the plant boundary line. Such limits shall be converted into limits in terms of a maximum allowable sound power level for the plant or composing parts of the plant under consideration. The resultant limits shall be included in the project specification or any other document defining the scope of the project.

Conversion of environmental sound pressure levels into plant sound power levels and vice versa shall be carried out in accordance with EEMUA 140 (using either minimal or significant screening curves) or in accordance with a national standard agreed by the Company.

10.2 Hearing Conservation (Work Area Noise)

The "Work Area" is defined as any position not less than 1m from equipment surfaces accessible to personnel, or any position where a worker's ear may be exposed to noise in the normal course of his duty. It includes any platform, walk-way or ladder.

10.2.1 Absolute limit

The sound pressure level anywhere in the work area shall not exceed 115 dB(A) in any situation, including emergencies such as blowing of safety/relief valves.

10.2.2 Work area limit

The sound pressure level in the work area shall not exceed 85 dB(A).

10.2.3 Restricted area/restricted area limit

Restricted areas are those work areas in the plant where it is not reasonably practicable to reduce the noise level below the work area limit. The absolute limit of 115 dB(A) remains valid in such areas.

If it is unavoidable that the work area limit will be exceeded around particular equipment, action shall be taken to limit the area involved as far as possible; this may include the erection of an acoustic enclosure. It is accepted that areas inside acoustic enclosures around such equipment are restricted areas.

Written permission shall be obtained from the Company's authorities to designate an area as a restricted area. The permission may include a maximum allowable sound pressure level for the area under consideration. Such a restricted area limit may be between 85 and 115 dB(A). However, attempts shall be made to reduce the level below 90 dB(A).

Permanent warning signs to indicate the mandatory use of ear protectors shall be erected at the boundaries of restricted areas. The signs should be of the type given in Appendix A.

10.3 Speech and Work Interference

The following noise limits shall apply in order to reduce speech and work interference from equipment to acceptable proportions.

TABLE 1 - MAXIMUM ALLOWABLE SOUND PRESSURE LEVEL

AREA DESCRIPTION	MAXIMUM ALLOWABLE SOUND PRESSURE LEVEL dB(A)
Areas in workshops and machinery buildings where communication is required Workshops for light maintenance	70
Workshop offices Control rooms, not continuously manned Computer rooms	60
Control rooms, continuously manned Open plan offices Social rooms, changing rooms, wash places and toilets	50
Offices and conference rooms	45

10.4 Accommodation

The sound pressure level shall not exceed 40 dB(A) inside personnel accommodation such as bedrooms, private cabins, etc.

10.5 Additional Restrictions for Narrow-Band or Impulsive Noise

Further restrictions shall apply if the noise contains narrow-band or impulsive components as defined in EEMUA 140 and this shall be taken into account when specifying equipment noise limits, see Clause 11.2.4.

For environmental noise, any narrow-band or impulsive component shall be sufficiently below the broad-band noise from the plant so that it is no longer audible (see Appendix E of EEMUA 140). If this is not possible, the Company's advice shall be obtained.

11. EQUIPMENT NOISE LIMITS

11.1 General

Equipment noise limits shall be derived using the area noise limits and the total available plant sound power level obtained from Clause 11 or any other limits that may be stated in the project specification.

11.2 Maximum Sound Pressure Levels for General Equipment

For equipment where no other limit than the work area limit of 10.1.5 is applicable, equipment sound pressure limits as given in 11.2.1 to 11.2.4 shall apply.

Where more or less (restricted area) stringent area noise limits apply, the equipment limits given below shall be adapted accordingly.

Equipment sound pressure limits shall not be exceeded anywhere at a distance of 1m from the equipment surface.

The equipment noise limits shall be given in an overall dB(A) value or, where considered more appropriate, the corresponding octave band spectrum may be specified instead.

11.2.1 Equipment emitting continuous noise

The maximum value for the equipment noise limit (sound pressure level) shall be 85 dB (A).

If equipment consists of components, e.g. a driver and a driven part, the above limit applied to each component separately will not ensure that the assembled equipment can give the work area limit. For such equipment more stringent limits shall be specified on data/requisition sheets for the separate components. The permissible noise limit component shall be based on acoustic calculations. As a guidance the following can be used:

- a reduction of 3 dB(A) shall be made for each item of a 2-component train
- a reduction of 5 dB(A) for each item of a 3-component train.

A further reduction of the equipment noise limit shall be made when several equipment items or trains are to be mounted close together, i.e. when the distance between equipment surfaces is less than the largest equipment dimension, or when equipment are located in a reverberant area. The equipment noise limit shall be based on calculations.

11.2.2 Equipment emitting intermittent or fluctuating noise

Where the equipment emits an intermittent or fluctuating noise (e.g. depressuring, boiler blowdown, sump pump), the equivalent continuous sound level, Leq, over the most noisy consecutive 8-hour period shall not exceed the equipment limits specified in 11.2.1. The maximum level shall not be more than 10 dB(A) higher than the limit for continuous noise.

For intermittent noise, the equivalents of 85 dB(A) over 8 hours are as follows, provided that no significant noise (i.e. above 75 dB(A)) is emitted for the remaining time in the 8-hour period.

TABLE 2 - T.L.V. (THRESHOLD LIMIT VALUE)

WITH EQUIPMENT ACTUALLY OPERATING	MAXIMUM SOUND PRESSURE LEVEL WITH EQUIPMENT OPERATING
8 hours	85 dB(A)
4 hours	88 dB(A)
2 hours	91 dB(A)
1 hour	94 dB(A)

Where the equipment emits noise fluctuating in a more complicated manner, the equivalent continuous sound level shall be calculated according to the method given in EEMUA 140, Paragraph 3.1.6.

11.2.3 Equipment located outside the work area

The maximum allowable sound pressure level at 1 m from the equipment for equipment located outside the work area may be higher than the limits given in 11.2.1 and 11.2.2. At positions which are inaccessible for personnel, such as may be the case for vent stacks and certain control valves, the allowable increase shall be:

20 * log(×) dB(A) for point sources (e.g. vent openings)
10 * log(×) dB(A) for line sources (e.g. piping)

Where × is the shortest distance from the equipment under consideration to the nearest work area, expressed in meters. For valves, the distance should be taken from directly connected piping to the nearest work area.

11.2.4 Additional restrictions for narrow-band or impulsive noise

Further restrictions shall apply when the noise of an equipment item contains narrow-band and/or impulsive components, as defined in EEMUA 140. The equipment noise limit shall be reduced by 5 dB(A) for such equipment.

11.3 Maximum Sound Pressure Levels for Specific Equipment

11.3.1 Valves for control and depressuring

For each control valve and its associated pipe work the requirements of 11.2.1 to 11.2.4 apply. This also holds for low-rate depressuring valves.

Control valve noise shall be determined for three operating conditions, viz. minimum, normal and maximum throughput. Noise limits shall not be exceeded for any of the three conditions.

11.3.2 Safety/relief and emergency depressuring valves

The noise from safety/relief valves and high-rate depressuring valves (and their piping) which blow under emergency conditions only, shall not exceed the absolute limit in any work area.

The party which sizes safety/relief and emergency depressurizing valves shall also be responsible for the calculation of their noise levels, according to a method to be approved by the Company. The calculations however shall be confirmed by the Supplier.

If it is not possible to remain within the absolute limit for safety/relief or emergency depressuring valves they should be considered as follows:

a) positioned well away from the work area, so that personnel shall not have access to their immediate vicinity. In this case the maximum allowable sound pressure level, Lp, 1 m away from the valve and/or piping shall be calculated using the following equations:

Lp = 115 + 20 * log(×) dB(A) for point sources (e.g. relief valves),

and

Lp = 115 + 10 * log(×) dB(A) for line sources (e.g. pipeline)

where (×) is the shortest distance in meters between the source and the nearest work area;

b) provided with a screen that shall deflect noise away from the nearest work area;

Notes:

1) The above procedures will allow safety/relief valves and their piping to emit noise above the limits of 115 dB(A) at 1 m distance. The corresponding high levels of vibrational energy in the piping, which could cause acoustic fatigue, shall be taken into account in the design of the piping system.

2) The limit of 115 dB(A) may need to be reduced to meet the requirements of environmental noise. Repositioning and shielding shall then not be allowed.

3) Connected pipe work can also radiate excessive noise. Care shall be taken that these noise sources are taken into account.

c) fitted with silencers or acoustic insulation; proposals shall be submitted to the Company's authorities for approval.

11.3.3 Piping

Noise emitting from piping is of major importance in plant noise control and shall be subject to the same restrictions as Equipment General, see 11.2. Such noise usually has its origin in equipment such as a valve or compressor. The noise shall be controlled by selecting low noise equipment (by design) or, when this is not reasonably practicable, by incorporating in-line silencers or acoustic insulation. Guidance into the assessment and reduction of noise emitting from piping by the use of acoustic insulation is given in Shell Standard Code No. DEP 31.46.00.31-Gen. The use of in-line silencers in the suction line of compressors requires approval from the Company's relevant authorities.

11.3.4 Vents

All vents incorporated in the design to meet operational requirements shall be subject to the same restrictions as Equipment-General, see 11.2. Vents intended for emergency use only shall be subject to the same requirements as safety/relief valves, see 11.3.2; where necessary, "vent" or "blow-down" silencers shall be incorporated in the design.

Notes:

1) An acceptable method of calculating vent noise is given in API RP 521.

2) A characteristic difference between vent silencers and blow-down silencers is in the pressure drop. This is as low as possible in the former, whereas in the latter it is a significant proportion of the system pressure. For venting purposes both types should be considered and the most economical type chosen.

11.3.5 Flares

Elevated flares shall not exceed the work area limit (10.2.2) at the perimeter of the sterile area (of at least 60 m from the flare base) when operating at flow rates up to 15% of maximum flaring capacity.

Ground flares shall not exceed the work area limit outside the windscreen or louver wall.

If the plant to which the flare is allocated is subject to environmental noise requirements, the application of low noise flares shall be evaluated even if the flare is to be used for emergency conditions only.

Note:

Flares used operationally shall be taken into account when assigning sound power levels, see 11.4.

11.4 Maximum Sound Power Level for Equipment

When an environmental noise limit is specified in terms of sound power level, the sound power limit for individual equipment shall be determined such that the sum of the levels of all equipment does not exceed the total limit.

The allocation to individual equipment items in an early stage of a project can best be performed using vendor data, data bases, and experience taking into account type, size and speed of equipment.

Unless otherwise specified, equipment emitting intermittent or fluctuating noise shall not cause the environmental limit to be exceeded at any time (i.e. the equivalent noise level concept, see 11.2.2, does not apply).

11.5 Coherence of Noise Limits

The equipment noise limits of 11.2 and 11.3 are sufficient only to ensure that in the completed plant the work area limit will not be exceeded. Where other noise limits also apply, it shall be investigated whether they will be met.

For the purpose of this investigation, the sound power levels of individual equipment should be estimated. Sound power levels are either derived according to Clause 11.4 or are calculated from equipment sound pressure levels, assuming that the requirements of 11.2 and 11.3 will just be met. Where actual sound power levels or sound pressure levels are known they should be used instead. The sound power levels of individual equipment and their location thus form the basis of a calculation of noise levels in the plant. Calculations shall be carried out in accordance with EEMUA 140 or in accordance with a national standard agreed by the Company. Screening effects of large buildings and tanks shall be taken into account where relevant.

Noise levels inside buildings or shelters shall be calculated, taking into account both the noise from equipment in the building and the noise from outside. Calculation of the attenuation of noise from outside to within a building shall be based on standard acoustic principles.

Where an environmental noise limit is specified in terms of sound power it will be sufficient, for this purpose, to add up the sound power levels of individual equipment in order to arrive at a total sound power level per plant or composing part, see 11.4.

If the results of the investigation indicate that one or more of the limits will be exceeded, the equipment concerned should be reconsidered and be replaced by equipment emitting less noise or, if this is not reasonably practicable, be treated with noise control measures such as insulation or acoustic enclosure.

The extent of noise control measures to be taken shall be considered against the severity of the requirements.

11.6 Data/Requisition Sheets

Equipment noise limitation sheets shall be prepared for all relevant items of equipment or an equipment train, if such a train will be provided by a single supplier, specifying the limits as given in 11.2, 11.3 and 11.4. If the components of a train will be provided by different suppliers, separate equipment noise limitation sheets shall be prepared.

The model sheet of Shell data/requisition (DEP 31.10.00.94-General), entitled "Equipment Noise Limitation" shall be used to specify either a maximum sound pressure level at any location 1 m from the equipment surface or a maximum sound power level, or both.

Note:

The maxima for sound pressure level and sound power level need not be related or equivalent since they may originate from different general limits, i.e. the sound pressure limit may originate from the "work area" noise limit and the sound power limit from the "environmental" limit.

It shall be ensured that the supplier is made aware of the obligation to state noise guarantees for the equipment to be provided, for any of the conditions of operation for which the equipment may be expected to be used.

The equipment noise limitation sheet shall be returned with the tender, with its guarantee section completed by the supplier to give the following information:

a) Unsilenced sound pressure and sound power dB(A) levels in octave bands and overall value of the equipment.

b) Sound pressure and sound power dB(A) levels in octave bands and overall value of the equipment together with details of any silencing measures that may be necessary to meet the specified noise limits.

c) If the specified limits cannot be met, the minimum attainable sound pressure and sound power dB(A) levels in octave bands and overall value shall be given.

Additionally the following information shall be given where applicable:

d) Completed data/requisition sheets of any silencers and/or acoustic enclosures, if the tender comprises such silencing equipment. Data/requisition sheets should be based on Shell Standard Code Nos.: DEP 31.10.00.95-Gen., and DEP 31.10.00.96-Gen.

All noise levels quoted shall have an upper tolerance of +0 dB.

Note:

If guarantees have been provided in some other way, specification of noise limits on individual data/requisition sheets is not required. For example, where a supplier provides all the pumps or motors in a project, a list of guaranteed noise levels and spectra per item will be acceptable.

11.7 Equipment Selection

It shall be ensured that suppliers have provided in their tenders all the information required in accordance with 11.6.

Bid comparison shall be made including the cost of all the options required to meet the specified noise limits. Where a choice can be made of equipment of low noise emission by design and equipment with "path-treatment", the estimated extra cost in operation and maintenance that may result from path treatment should be capitalized and taken into account in the ultimate selection. Generally, preference shall be given to equipment of low noise emission by design.

For equipment emitting fluctuating or intermittent noise, temporary excursions above the equipment noise limit may be permissible, see 11.2.2 and 11.4. If such excursions can be avoided by selecting a less noisy and otherwise acceptable alternative then this shall be preferred. Where a higher extra expenditure would seem justified, the Company shall be consulted.

12. SILENCING EQUIPMENT

Silencers shall comply with EEMUA 161 and the appropriate codes and standards for mechanical design. The design of silencers shall ensure that any internal parts that may inadvertently break loose do not partly or completely block the silencer outlet or damage downstream equipment (e.g. compressors).

Acoustic enclosures may be either of the "close fitting" or "walk-in" (large) type. Large enclosures shall be designed in such a way that operating/maintenance personnel can conduct their work without being hampered in their movements.

Large enclosures shall also be subdivided in such a way that personnel servicing the equipment during partial shutdown are not exposed to excessive noise generated by other equipment that may also be in the enclosure. This can be achieved for example by a separating wall between two independent trains of equipment.

Silencers and/or acoustic enclosures may be included in the tenders for noisy process equipment, see 11.6. When the Supplier has been selected, details of such silencing equipment shall be agreed upon between the Supplier and the Company. The Company may choose to order silencing equipment separately from the process equipment.

Noise emission of certain silencing equipment (e.g. silencers on vent stacks, acoustic insulation on pipes) is not always the responsibility of any particular equipment supplied. It shall be ensured that such silencing equipment is incorporated in the design and that the relevant data/requisition sheets are prepared.

It shall be ensured that sound-absorbing materials or constructions are incorporated in the design of potentially reverberant spaces. The minimum absorption coefficient, averaged over walls and ceiling, shall be 0.2 for frequencies above 200 Hz.

For some equipment, calculations or measurements may indicate that the noise limits will be exceeded, but with a margin of uncertainty extending down to levels below the limit (i.e. there is a possibility that the limits may be met). For such equipment the application of noise control measures shall not be postponed until actual noise levels have been obtained after start-up, unless specifically agreed with the Company.

Silencers to suppress commissioning noise only may be of a movable type.

Silencers to reduce noise in transient operations such as start-up, shutdown, etc., shall be permanent.

13. PROJECT CONTROL

13.1 Information for the Noise Control Authorities

For the provision of the required information within the Company's office, a list of documents that should be made available is given in Appendix B.

13.2 Detailed Engineering Phase Reports

Where environmental noise limits or a plant sound power limit are specified, a report shall be prepared to show how sound power levels are allocated to various equipment items. The report, with figures based on manufacturer's information, experience or data bases, serves to set equipment noise limits and to anticipate noise abatement measures. The report shall be submitted to the Company for approval before data/requisition sheets are released for tendering.

When a preliminary noise allocation report has been prepared by the relevant Company's authorities as part of the project definition document, a re-issue shall be submitted incorporating the Contractor's assessment.

In any event a report shall be prepared for approval by the Company after the major part of the equipment selection has taken place. The report shall give sufficient data and calculations to demonstrate to the satisfaction of the Company that the acoustic design of the plant will meet the requirements.

The model format given in Appendix C can be used for the report.

In both reports (13.2 above) due attention shall be given to the prediction of piping noise.

Note:

13.2 refers to action item Nos. A.15 and A.16 in the Table 3 Clause 14.

13.3 Noise Test Runs

The Contractor shall decide which equipment shall have a "noise" test run at the Supplier's works and inform the Company's officials accordingly.

Note:

Where acceptance of individual equipment items is conditional on satisfactory conclusion of noise test runs at the Supplier's works, the test run shall reflect the in-situ arrangement and a suitable test procedure shall be agreed between the Contractor and the Company.

13.4 Acceptance Test

Responsibility of the Contractor for meeting the specified noise limits will not end until measurement and evaluation by an independent acoustic consultant have shown that limits are not exceeded. Contracting out to this independent consultant shall form part of the Contractor's scope of work.

The test includes preparation of an in-plant noise contour plot, showing contours of 75 dB(A) and higher, with incremental steps of 5 dB(A).

Where a sound power limit applies to the project, a suitable test procedure shall be agreed between Contractor and Company.

13.5 Remedial Action

Corrective action shall be taken if actual sound levels or levels calculated from measurements made in the acceptance test exceed the specified limit. The corrective measures shall have the Company's approval.

14. SUMMARY OF ACTION ITEMS AND ALLOCATION OF RESPONSIBILITY

The Action Items defined in this Standard are summarized below:

Note:

The Action Items below are not in the chronological order in which they may occur in a project.

TABLE 3 - SUMMARY OF ACTION ITEMS AND ALLOCATION OF RESPONSIBILITY

ACTION ITEM No.	TASK DESCRIPTION	REF. SECTION	RESPONSIBLE PARTY	
			COMPANY	CONTRACTOR
A1	Investigate local regulations for in-plant noise	10.1	× [1)]	
A2	State local in-plant limits in project specification if more stringent	10.1.1	× [1)]	
A3	Investigate local regulations on environmental noise and discuss with authorities	10.1.2	× [1)]	
A4	Consider environmental noise aspect (where no regulations exist)	10.1.2	×	
A5	Incorporate sound power level in project specification	10.1.2	× [1)]	
A6	Obtain Company's permission for restricted areas	10.1.6		×
A7	Erect earmuff signs	11.1.6		×
A8	Specify equipment noise limits, including additional restrictions	11 11.2.4		× ×
A9	Determine pipe noise, assess insulation and silencer requirements	11.3.3		×
A10	Determine need for vent silencers	11.3.4		×
A11	Evaluate need for low-noise flare	11.3.5		×
A12	Obtain noise limitation sheet with guaranteed power/pressure level from supplier, including silencers/enclosures	11.7		×
A13	Select least noisy equipment	11.7	×	×
A14	Agree on details of silencers/enclosures	12	×	×
A15	Submit report on allocation of sound power level	13.2		×
A16	Submit noise control report	13.2		×
A17	Decide which equipment shall have a "noise" test run	13.3		×
A18	Contract independent acoustic consultant for survey	13.4		×
A19	Take corrective action where required	13.5		×

[1)] On request this information shall be verified by Contractor.

15. ACOUSTIC DESIGN

This section deals with acoustic aspect and is intended for noise control engineer, responsible for the acoustic designs of the plant.

15.1 Acoustical Insulation for Pipes, Valves and Flanges

The noise radiated by the wall of the pipe is usually generated by equipment connected to the pipe, such as compressor, pumps, valves, or ejectors. These noise sources may cause long section of pipe to radiate noise because noise will travel in the pipe with little reduction. The noise radiation may be reduced by acoustic insulation.

Three classes of acoustic insulation are considered, denoted as A, B and C. Calculations shall be carried out in accordance with DEP-31-46-00-31 GEN.

15.2 General Requirements for Vent Silencers

These requirements shall apply to vent silencers for steam, hydrocarbon vapors and other gases. It does not apply to vents used for particulate or polymerizing materials where special designs may be required to prevent clogging.

The silencer shall be constructed of materials compatible with the fluid being vented and all steel surfaces shall have adequate weather protection. The manufacturer shall provide details of all materials used and of the weather protection applied.

15.3 Acoustical Barrier and Enclosures

The most fundamental approach to noise reduction is to a wall between the sound source and receiver. The wall can take the form of:

1) An enclosure of the noise source (machinery),
2) the enclosure of the receiver (employee),
3) a barrier between the two.

15.3.1 Machine enclosures

The isolation of noise producing machinery by means of acoustical enclosures provides the greatest noise reduction. Noise reductions of 20-30 dBA are common with machine enclosures, and with special isolation treatment, noise reductions above 50 dBA can be achieved. Following factors are the main aspects of engineering enclosure design which should be considered:

1) Design guidelines for acoustical effectiveness,
2) consideration of machine operational requirements,
3) insuring production compatibility,
4) maintaining employee safety and welfare.

15.3.2 Employee enclosure design

In designing employee enclosure, the following important factors should be considered:

1) Location,
2) size,
3) visibility,
4) proximity.

15.3.3 Enclosure types

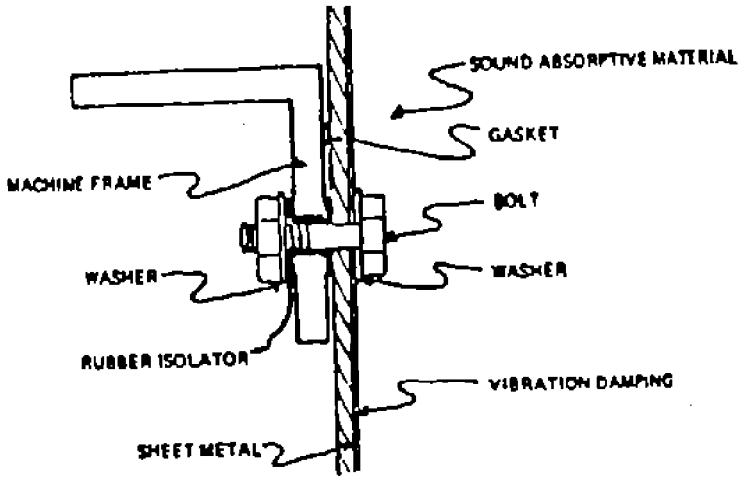
Three design approaches should be considered for machine enclosures, depending upon machine operational requirements and the extent of noise reduction required. These are:

1) Localized enclosure,
2) partial enclosure,
3) complete enclosure.

15.3.3.1 Localized enclosures

In many machines, high noise levels are associated with only localized machine elements. Where isolated noise sources are identified on a machine, it is more feasible to enclose only a small area, rather than the entire machine.

As a general guideline, acoustical enclosure panels should never be attached directly to machine elements which have high vibration levels. Where panels are machine mounted, vibration isolation techniques should be employed as shown in Fig. 1. To insure minimum sound radiation due to panel vibration, damping treatment shall also be applied to machine-mounted enclosures.



TECHNIQUE FOR VIBRATION ISOLATION OF ENCLOSURE PANEL FROM MACHINE FRAME
Fig. 1

15.3.3.2 Partial enclosures

A machine enclosure which has at least one open side or a very large opening should be considered as a partial enclosure.

A partial machine enclosure will provide virtually no noise reduction for an employee working directly at the machine unless it:

a) Interrupts the line-of-sight path between the machine and the operator's hearing zone, or
b) Absorbs sound which is reflected from the machine to the operator by an adjacent wall or ceiling.

15.3.4 Opening in an enclosure

For effectiveness of an acoustical enclosure, openings should be prevented or minimized. Where openings are necessary, such as for ventilation, silencers or "sound traps" can be installed.

15.3.5 Vibration isolation

Vibration is transmitted through the floor to enclosures. The large surface area enclosure panels will become a noise source. This problem can be avoided by the mounting of the machine on vibration isolators. The typical vibration levels of a bolted and isolated blanking press, shown in Table 4, indicate the effectiveness of vibration isolation.

TABLE 4 - LINEAR VIBRATION LEVELS IN DECIBELS RE 1.0 g FOR 250-TON BLANKING PRESS

STRUCTURAL MEASUREMENT LOCATION	PRESS BOLTED	PRESS ISOLATED
Press Leg	+22	+7
Foundation	-3	-30
Floor	-21	-41
Building column	-10	-25

15.3.6 Non-acoustical requirements

In addition to the design of an acoustical enclosure to meet noise reduction objectives, the following additional design requirements should be considered:

1) The enclosure shall be properly ventilated to prevent heat build-up.

2) Operational accessibility shall be provided to meet production requirements.

3) Localized and complete accessibility shall be provided for maintenance.

4) If audible signals are utilized to assess machine performance alternate detection systems shall be installed.

5) Supply systems must be provided to the enclosed machinery to meet energy and process requirements.

6) In-feed and out-feed openings shall be designed which provide noise attenuation consistent with the total enclosure system but which will not obstruct material flow.

7) An internal lighting system shall be installed if the enclosure shadows exterior lighting excessively.

8) Protection shall be provided against employee and vehicular (lift trucks, etc.) damage.

9) Protection shall be provided against operational abuse: moisture, water spray, oil, grease, dirt, erosion by fluid flow, etc.

10) Flame-spread and fire-endurance limits shall be specified for all materials. Firebreak requirements shall be employed on all ducts, pipe runs, and shafts. Smoke or temperature alarms may also be considered for enclosures.

PART 2

16. VIBRATION CONTROL

Acoustical radiation from a vibrating surface is one of the two methods by which noise will radiate. In this Part the radiation of sound from vibration, and the control of vibrational energy through isolation and damping will be discussed.

16.1 Vibration Radiation

Sound is produced by the movement of a vibrating structure which, in turn, sets in to motion the air molecules which are coupled to it.

For any mechanical system vibration and noise must be considered as:

a) vibration energy; and;
b) system response.

System response is dependent upon the following two facts:

1) Vibration response:

a) mass;
b) stiffness;
c) damping.

2) Acoustic radiation efficiency:

a) surface area;
b) critical coincidence frequency.

16.2 Vibration Isolation

To control vibrationally induced noise is to isolate the driving force or the machinery from the adjacent structure. Machinery which has a driving force frequency in the 10-60 Hz range and is rigidly mounted to a building foundation will create a very annoying environment for plant and office employees. Vibration isolators will generally reduce this annoyance.

Vibration isolators can be the spring type, rubber mount, or any other type as illustrated in Fig. 2. The natural frequency of the isolator should be 3 to 10 times lower than the driving force frequency of the machinery.

Referring to Fig. 2, an isolator whose natural frequency is equal to the driving force frequency will act as an amplifier of noise. The natural frequency of an isolator system is calculated as:

$$fn = 3.13 \sqrt{\frac{1}{d}}$$

Where:

fn = Natural frequency of isolator, Hz
d = Isolator's static deflection (units), or,

$$fn = 188 \sqrt{\frac{1}{d}}$$

Where:

fn is in cycles per minute

Transmissibility is defined as:

$$Tr = \frac{1}{(fd/fn)^2 - 1}$$

Where:

Tr = Transmissibility
fd = Driving force frequency

A second requirement of an isolator specification is the damping factor of the isolator, as indicated in Fig 2. Above the "resonance" region of the curve the most efficient vibration isolator is provided by isolators with a low damping factor

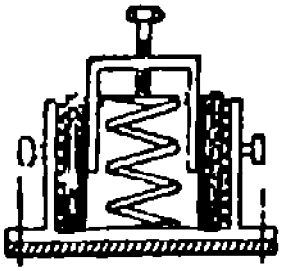
A third specification is the isolator stiffness. The isolator stiffness is defined as:

$$K = \frac{w}{d}$$

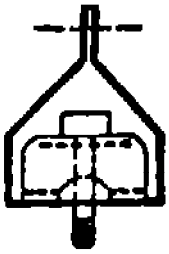
Where:

K = Isolator stiffness, kg/m
w = Weight of machinery, kg
d = Static Deflection, m

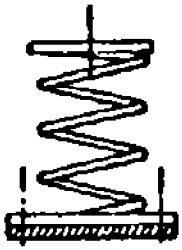
In order to calculate the deflection of the isolator, use manufacturer's data. If typical curve for a spring isolator is shown in Fig. 3. The Fig. 3 indicates the various vibration isolation efficiencies. The vibration isolator manufacturer usually assumes a massive, rigid structure, but in reality machinery can be mounted on a lightweight floor. The efficiency of the isolator on a lightweight floor will be much less than it is mounted on a massive, rigid surface. Thus, higher isolation efficiencies must be used for mountings on lightweight floors.



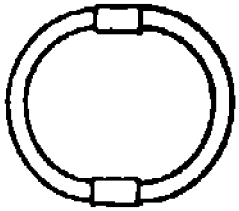
MULTIPLE-PART SPRING



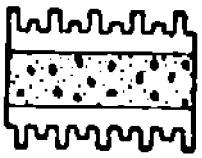
CEILING MOUNT



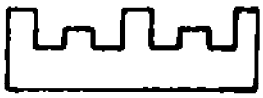
SIMPLE SPRING



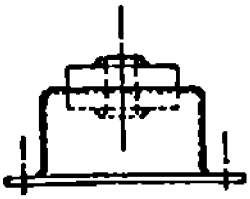
CABLE ISOLATOR



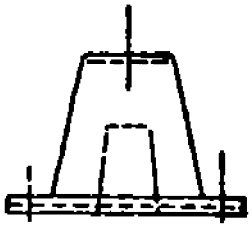
RUBBER PAD



COMPOSITE PAD

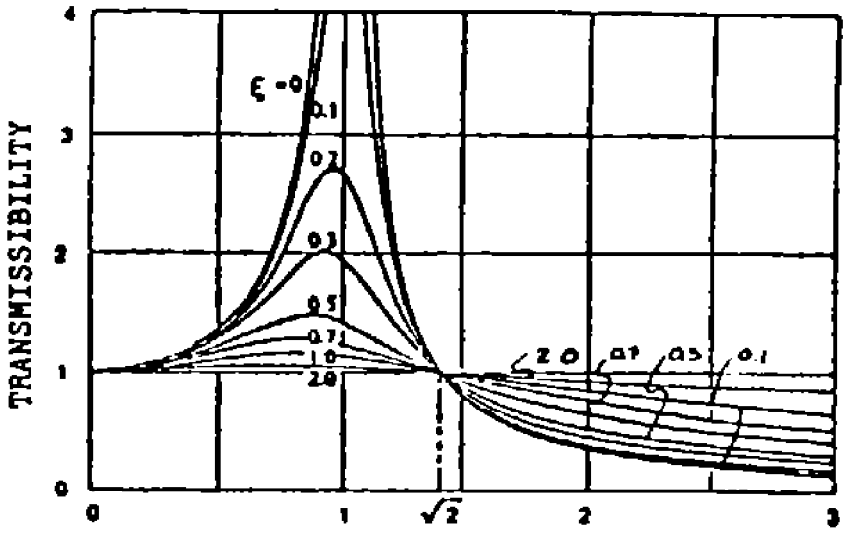


SUSPENDED MOUNT



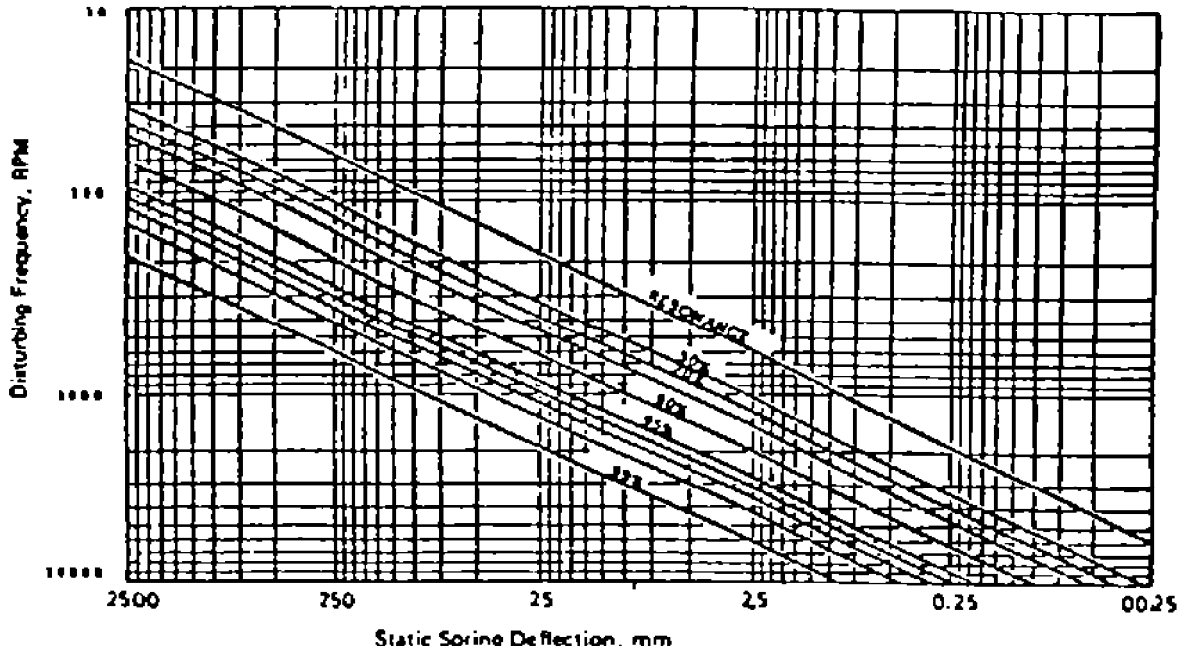
RUBBER MOUNT

CLASSIFICATION OF VIBRATION ACTUATORS
Fig. 2



FORCING FREQUENCY ÷ ISOLATOR NATURAL FREQUENCY

TRANSMISSIBILITY FOR VARIOUS DAMPING FACTORS
Fig. 3



STATIC DEFLECTION CURVE FOR A SPRING ISOLATOR
Fig. 4

16.3 General Vibration Considerations

1) Always specify that rotating machinery be statically and dynamically balanced.

2) Design supporting structures to have no natural frequencies within 30 percent of the operating speed of the machinery.

3) Choose equipment which minimizes vibrational problems. (If a compressor must be located in a critical area, a quieter centrifugal type can be used instead of the noisier reciprocating one).

4) Use vibration isolating mounts as required on large fans, transformers, etc. Use flexible connections to isolated pipes and ductwork.

5) Floor slabs should be heavier and stiffer to support machinery that is a potential vibration source.

6) Weight of accelerated parts should be reduced whenever possible.

7) All moving parts should have smooth finishes.

16.4 Vibration Damping

The physical mechanism of most noise problems is acoustical radiation from vibrating structures, it reduces the noise by means of vibration damping. The term "damping" refers to the design property of materials which converts vibrational energy into heat energy.

16.5 General Equipment Considerations

Consider the following items in designing any equipment for noise reduction:

a) Balance equipment to reduce vibration.

b) Reduce weight of accelerated parts where possible.

c) Reduce accelerations and decelerations of machine parts to the minimum, while still performing the required function.

d) Check that all moving parts have smooth finishes.

e) Reduce mechanical noise where possible.

f) Enclose the sound source.

g) Use acoustical absorption materials such as glass fiber to absorb sound.

h) Reduce impact sound by using soft surfaces.

i) Provide vibration isolators and flexible connectors.

j) Reduce air, liquid, or gas turbulence where possible.

k) Cover any holes in enclosures.

When the noise cannot be treated at the source, either external silencers, enclosures, barriers, or path treatment should be provided.

APPENDICES

APPENDIX A
RESTRICTED AREA WARNING SIGN

The colors for the sign, a white symbol on a blue background, shall be in accordance with BS 5378.

APPENDIX B
DOCUMENTS TO BE SUBMITTED TO COMPANY'S NOISE CONTROL AUTHORITIES

The following documents shall be made available:

- Basis of design,
- project specification,
- plot plan,
- noise allocation report (if applicable),
- noise report,
- noise verification study.

For major projects in the design and engineering phase and the procurement phase, the following documents should be submitted to the noise control authorities if close guidance by the Company is required. The appropriate issue or issues shall be decided by the authorities concerned.

- Equipment summary, project specification.
- Equipment data requisitions for:
  - Heat exchangers (air coolers only),
  - furnaces, burners,
  - mechanical handling equipment,
  - extruders, ejectors,
  - pumps, compressors, including drives,
  - valves,
  - flare and vent stacks,
  - external insulation, sound proofing only,
  - transformers, generators,
  - electric motors,
  - cooling towers,
  - fired steam generators,
  - silencing equipment (silencers, enclosures, screens).
- Data on the acoustic properties of buildings (in special cases only).

APPENDIX C
MODEL FORMAT FOR THE NOISE CONTROL REPORT

The report specified in 9.2 and nominated as Action Item A16 shall be prepared in accordance with the following format:

1) Summary showing to what extent:

- the acoustic design of the plant has been completed;
- guaranteed noise data has been obtained from suppliers;
- the specified noise limits have been met.

2) Specified limits-quote the original requirements and make any comments necessary.

3) Supplier noise data:

- tables of octave band sound power, sound pressure and overall levels of all potentially noisy equipment per plant unit. The origin of the data shall be indicated (guarantee from supplier, estimate from supplier, test data from Contractor, estimate from Contractor, etc.);

- the results of "noise" test runs;

- a list of control valves with a noise level above 80 dB(A) with an indication where low-noise control valves will be applied.

4) Noise control measures:

- a list of silencers and acoustic enclosures;
- the detail and extent of any acoustic insulation;

5) Calculations:

- in-plant noise contour maps, showing contours of 75, 80 and 85 dB(A) and higher where applicable;

- evaluation of the sound power level of the plant, even in the case that no plant sound power limit is required;

- separate evaluation of plant pipe noise;

- calculations of expected noise levels inside buildings and shelters.

6) Restricted areas.

7) Outstanding items.

APPENDIX D
GREEK ALPHABET

A α alpha	a
B β beta	b
Γ γ gamma	g, n
Δ δ delta	d
E ε epsilon	e
Z ζ zeta	z
H η eta	é
Θ θ theta	th
I ι iota	i
K κ kappa	k
Λ λ lambda	l
M μ mu	m
N ν nu	n
Ξ ξ xi	x
O ο omicron	o
Π π pi	p
P ρ rho	r, rh
Σ σ s sigma	s
T τ tau	t
Y υ upsilon	y, u
Φ ϕ phi	ph
X χ chi	ch
Ψ ψ psi	ps
Ω ω omega	ö