MEMORANDUM

TO: DOCKET FOR AES HIGHGROVE PROJECT FILES (06-AFC-2)

FROM: ROBERT WORL, PROJECT MANAGER

SUBJ: PRESENTATION OF INFORMATION AT AUGUST 1, 2007 MR. HERMAN HILKE

DATE: AUGUST 15, 2007

DOCKET
06-AFC-2
DATE AUG 1 5 2007
RECD. AUG 1 6 2007

At the August 1, 2007 Highgrove Project Workshop held in Grand Terrace, CA, Mr. Herman Hilke made a variety of statements, and presented documents upon which his statements were based. These documents are attached to this memorandum.

Appended Documents:

A. An outline of Mr. Hilkes comments and concerns "Peaker Plant Speech"

B. Four (4) Electric Power Research Intstitute Technical Reports:

1. TR-114203: "Building Community Support for Local Renewables and Green Pricing Projects"
2. TR 1006878: "Siting Guide-Site Selection and Evaluation Crieteria for an early site Permit Application". (Nuclear Power TR)
3. TR 1012395: "Blending a Substation into its Environment".
4. TR 1003974. "Siting of Distributed Resources Units: Process and Issues".

C. Three pages of selected plant operator safety information and descriptive information about the "New Madrid Power Plant" and its use of anhydrous ammonia in the selective catalytic reduction system (SCR).

D. An USEPA Chemical Emergency Preparedness and Prevention Office pamphlet: "Hazards of Ammonia Releases at Ammonia Refrigeration Facilities". August 1998 . (This document exclusively refers to Anhydrous Ammonia, no material relevant to aqueous ammonia as proposed for the Highgrove Project.)

E. Natural Gas Processing. A download from Wikipedia, the free encyclopedia. 3 of 4 downloaded pages supplied.

F. "Interpretation of Evaluation Guide" to Solve Low Frequency Noise Problems. 6pps. No date, no publication source listed.

G. Department for Environment, Food and Rural Affairs (Defra). May 2003. Dr. Geoff Leventhall (author). "A Review of Published Research on Low Frequency Noise and its Effects. 7pps.

H. British Medical Journal, 5 February 1994. "Annoyance due to low frequency hums". 3pps.

A. Herman Hilke Peaker Plant Speech

Peaker Plant Speech

From:
Herman Hilkey
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hilkey@pacbell.Net

I. **I know this town**

   A. **Working for a High School for 20 years**

      1. **Prevailing Southwesterly Wind**

II. **Story of the friend's advise on three issues.**

CONTACT EPRI ELEC POWER RESEARCH INSTITUTE

   A. **Ammonia use and Safety**

      1. **Power Plants Prohibit Facial Hair for good gas mask safety**

      2. **Power Plants that use Ammonia always have wind socks**

      3. **Ammonia explosions due to handeling of ammonia are Frequent**

   B. **Natural Gas Varies in Content**

      1. **The content of Natural Gas varies from Pipeline to pipeline and user to user.**

TEMP INVERSION when PLANT IS NEEDED.

      2. **There are 1,100 Natural Gas Generators and there is an explosion aprox one a year.**

   C. **Low Freq Sound**

      1. **Story of Boom Boxes**

         a. **B M J doctors report on Low freq noises**

         b. **Low freq noise travels further than High freq noise**

         c. **Low freq noise can not be filtered out like high freq noise**

         d. **Low freq noise causes health problems**

            (1) **Low freq noise causes secondary vibration of fixtures such as hardware and windows.**

            (2) **This secondary noise can be heard even though the low freq sound can not.**

B. Electric Power Research Institute
Four Technical Reports

Product ID:	TR-114203	Market Segment:	Power Generation
Date Published:	12/14/1999	Document Type:	Technical Report

EPRI

Building Community Support for Local Renewables and Green-Pricing Projects

ELECTRIC POWER RESEARCH INST

Abstract
Building local community support for new renewable generation installations can reduce the time and costs spent planning, developing, and constructing these projects by identifying pitfalls, developing alliances, and gaining stakeholder consensus. If this generation is tied to green-pricing programs, support can translate into an increased subscriber base. This report discusses ways to build such support, using examples from projects that have been developed or are currently in development.

Background

The large-scale development of renewable generation continues to increase in the United States and worldwide. Associated with this development come community issues of planning, siting, constructing, and operating such renewable projects. Companies that have already implemented renewable projects have discovered substantial time and cost benefits from building support for such projects in the community; however, most power producers' experience and knowledge in this area is limited. This report draws from the stories of electric utilities, independent power producers, consultants, community members, and government agencies to illustrate the most successful strategies for building community support for renewable generation projects.

Objective

To identify and describe effective methods for building community support for renewable energy projects that will help power producers design and implement popular, economical renewable generation units.

Approach

EPRI researchers selected renewable energy programs from around the United States that would represent a range of renewable technologies, developers, and communities. Once selected, EPRI researchers interviewed one or more representatives of each project. The EPRI team analyzed the information to identify underlying principles among the projects that would be applicable to future projects and chose six subjects to be case studies. Working from the principles identified, researchers prepared material that power producers can reference to build community support for projects.

Results

This research revealed two key points: many recurring factors appear among renewable generation projects, and involving stakeholders early in the design and planning of these projects can provide invaluable benefits to both the power producer and the community.

Common themes among renewable generation projects can be grouped into five categories:

- Credibility
- Education
- Planning
- Program or Project Support
- Marketing (for green-pricing programs)

EPRI Perspective

The issues discussed in this study include siting, community outreach, tangibility, follow-through, visibility, and economics. Renewable energy project developers can employ the principles elucidated in this work to build community support that translates into shorter planning times, lower costs, and improved community relations. Ignoring community issues can lengthen project schedules, increase costs, limit a renewable energy program's effectiveness, or even potentially prevent an installation from being built.

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Product ID:	1006878	Market Segment:	Nuclear Power
Date Published:	3/21/2002	Document Type:	Technical Report

EPRI

Siting Guide: Site Selection and Evaluation Criteria for an Early Site Permit Application

Abstract
As part of the Early Site Permit (ESP) Demonstration Program, the "Siting Guide: Site Selection and Evaluation Criteria for an Early Site Permit Application" was initially published in March 1993. It served as a roadmap and tool for applicant use in developing detailed siting plans to support an ESP application. This revision has been prepared to update the site selection process and criteria to reflect current regulatory requirements. The updated Guide also addresses the impact of significant changes in business conditions since 1993 because of electric utility deregulation.

Background
Prior to preparing an application for an ESP, applicants must select a site. The site that is selected must be suitable for construction and operation of a standard plant design envelope that encompasses the range of specific designs contemplated for deployment. In addition, since deployment of a nuclear power facility is a major federal action, it is subject to the National Environmental Policy Act (NEPA). Therefore, a full NEPA analysis is conducted by NRC as part of the ESP process in accordance with 10 CFR Part 51. Changes in regulatory requirements resulted in modifying a number of siting criteria as well as introducing additional criteria, notably in the areas of geology/seismology, environmental justice, and cost. Furthermore, the siting process has been expanded to describe how existing nuclear power plant sites, industrial sites (sites with potential legacy contamination), and characterized sites (sites that have been previously studied) would be incorporated into the site selection process.

Objective
o To provide a roadmap and tool for conducting a site selection process for advanced light water reactor (ALWR) designs and, in general, other designs, except for design-specific aspects of the site/facility interface and the application of individual siting criteria.

o To support identification of sites that conform with requirements for a site permit in Subpart A - Early Site Permits and a combined construction and operating license in Subpart C - Combined Operating License of 10 CFR Part 52.

Approach
The "Siting Guide" describes a four-step site selection process involving sequential application of exclusionary, avoidance, and suitability criteria, as well as incorporation of preferences (or weighting factors) that are applied to the suitability criteria. The exclusionary, avoidance, and suitability criteria address the full range of considerations important in nuclear power facility siting. These include health and safety aspects, environmental aspects, socioeconomic and land use aspects, and engineering and cost aspects. The criteria encompass construction, operations, transportation, and accident conditions.

Results
The "Siting Guide" provides an up-to-date framework for the site selection process. Steps 1 and 2 of the siting process are areal in nature; screening of a relatively large region of interest is performed to identify a number of discrete "site-sized" parcels for evaluation as a potential nuclear power facility site. These steps are accomplished using mappable information. Comparing individual sites based on their relative suitability is the focus of steps 3 and 4. This portion of the process begins with the use of mapped and other published information and concludes with detailed information collected through on-site investigations, as necessary. Step 4 culminates in selecting a preferred site for which an ESP application can be submitted.

EPRI

Product ID:	1012395	Market Segment:	Power Delivery
Date Published:	12/12/2006	Document Type:	Tech Update 1-Informal Report

Blending a Substation into its Environment

Volume 2: Utility Experience

Abstract
This report provides information about public acceptance issues as well as technical approaches available to make substations acceptable within their environments. Case studies were used to examine substation acceptance experience from utilities in different countries and areas.

This is the second report in a multi-year effort to build a multi-volume library on Blending a Substation into its Environment. Volume 1 examined available literature, standards, guides, and regulations that affect the blending of a substation into its environment. Volume 1 is titled *Blending a Substation into its Environment – Volume 1. State of the Art Review* and is EPRI Report number 1010599.

The studies focused on the challenges involved with blending or acceptance issues. Techniques used to provide public acceptance solutions were considered in terms of station configurations and designs that were used in order to gain acceptance for a substation within its environment.

Techniques have been illustrated with photographs from the selected stations or with illustrations from similar situations or installations. Analysis was based on characteristics of surroundings that stations had to blend into. These included population density, as well as proximity to residences.

Program
Substations
Keywords
Substation aesthetics
Substation environmental impact
Substation location
Utility experiences
GIS (Gas Insulated Substations)

EPRI

Product ID:	1003974	Market Segment:	Power Generation
Date Published:	12/20/2001	Document Type:	Technical Progress

ALWAYS SUCCESSFULLY

Siting of DR Units: Process and Issues

Abstract
This report identifies distributed resources (DR) siting issues and the process followed by DR installers to complete their projects. It explores areas of the country that pose unique environmental regulations and permitting conditions and discusses other issues that impact DR siting. It provides EPRI members with information necessary to understand the impact of environmental regulations on the siting of DR units.

Background
During the last year, DR units have become more widely commercialized, especially in states where there is a combination of high electric grid prices, ozone nonattainment areas, and constrained grid generation capacity. Siting these DR units is not the same as installing a central station generator. Increasingly, state regulations have been changing so that DR units are not treated as emergency backup generators. As a result, the siting process is no longer obvious and must be carefully planned. To avoid unnecessary delays and costs, it is useful to conduct several tasks in parallel, and it can be cost-effective to obtain specialized expertise.

Objective
To identify DR siting issues and the process followed by DR installers to complete their projects; to identify areas of the country that pose unique environmental regulations and permitting conditions; to discuss other issues that impact DR siting.

Approach
The project team used DR installer experience, manufacturer data, case studies, permitting data, and other resources to explore issues involved in siting DR equipment, the current state-of-the-art of DR technology emission rates, and emissions control technology cost and performance. The team consulted installers, manufacturers, and distributors to prepare a summary of the current siting landscape and contacted state agencies to develop summaries of their permitting process and environmental compliance requirements for DR. The team studied several leading states to illustrate how the DR siting process must be carried out differently by state.

Results
DR siting has generally been a straightforward exercise. However, it can be complicated by a number of local regulations and processes that may delay projects and increase costs. Changing air quality standards, revised permitting procedures, and public hearings that result in adverse rulings can all conspire to require customers or their developer to re-apply for one or more of the required approvals. Additional requirements for emissions control or grid interconnection that go beyond the original DR specifications increase both the project cost and the time to complete the project.

A standard siting process involves performing a site analysis, obtaining all necessary permits, seeking interconnection with the local utility, installing the DR unit, and finally operating and continuously testing the system for compliance with the permits. This report documents a typical siting process and gives the particular tasks that need to be performed. The siting analysis track, permitting process, and interconnection requirements for a DR project are covered in detail. In addition, many siting principles are given to guide those involved with DR to mitigate risks.

EPRI Perspective

DR currently accounts for a small percentage of total power generation, but this is beginning to change with the onset of deregulation in the marketplace. As DR becomes more widespread, compliance with the existing as well as anticipated future public policy actions will greatly assist those seeking to be involved in DR projects. The regulations covering siting, permitting and interconnection of DR systems continue to evolve. However, those planning on implementing DR will find this report to be very helpful in both identifying the pertinent siting issues and in documenting the process used to effectively guide the siting of DR systems. As this report illustrates, the DR siting process can sometimes be complicated; but it can be completed successfully.

Program
2005 Program 101.0 Distributed Energy Resources
History
2004 Program 101.0 Distributed Energy Resources
2003 Program 101.0 Distributed Resources
2002 Program 034.0 Distributed Resources: Information for Business Strategies
Keywords
Sites
Interconnected Power Systems
Environmental Policies
Licensing
Power Generation Planning
Environmental Qualification
Other Keywords
Distributed Resources
Dr
Distributed Generation
Dg
Dr Siting
Dr Regulations
Environmental Assessment
Interconnection
Report
000000000001003974
Note
For further information about EPRI, call the EPRI Customer Assistance Center at (800) 313-3774 or email askepri@epri.com

C. Plant Operator Safety Information-“New Madrid Power Plant”

PROTECTIVE GEAR

C. Anhydrous Ammonia

The New Madrid Power Plant has a Selective Catalyst Reduction (SCR) system on each of two units. These systems use liquid anhydrous ammonia to react with a catalyst to remove NO_x from the flue gas before it is emitted into the atmosphere. The New Madrid Power

- Facial Hair
- Hearing Prot

Plant has the capability to store 480,000 gallons of liquid anhydrous ammonia on site. The New Madrid Power Plant is subject to OSHA's Process Safety Management regulation and EPA's Risk Management Planning regulation. All contractors are required to complete a plant safety orientation at least annually to comply with these regulations

IV. PERSONAL PROTECTIVE EQUIPMENT

A. Head Protection

All contract employees; subcontractors, visitors, and delivery personnel are required to wear protective helmets while on AECI property. These protective helmets shall comply with ANSI Z89.1-1986.

B. Hearing Protection

All contract employees, subcontractors, visitors, and delivery personnel are required to wear appropriate hearing protection to reduce time weighted average exposure levels of noise to within OSHA permissible exposure limits.

C. Eye and Face Protection

All contract employees, subcontractors, visitors, and delivery personnel are required to wear as a minimum; safety eyeglasses with side shields. More specialized eye protection should be required when the work being performed warrants additional protection. All eyewear shall meet ANSI Z87.1-1989 standards.

D. Respiratory Protection

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FACIAL HAIR

Contractors Safety Manual Page 1 of 15 Respiratory protection that conforms to OSHA regulations shall be used when engineering controls are not adequate to protect employee from exposure to air contaminants. No Contact employee may be assigned to wear a negative pressure respirator unless a physician to determine his or her physical ability to wear the respirator has first evaluated Contractors Safety Manual Page 1 of 15 Plant has the capability to store 480,000 gallons of liquid anhydrous ammonia on site. The New Madrid Power Plant is subject to OSHA's Process Safety Management regulation and EPA's Risk Management Planning regulation. All contractors are required to complete a plant safety orientation at least annually to comply with these regulations

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Contractors Safety Manual Page 1 of 15

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D. USEPA-CEPPO Hazards of Ammonia Release

United States Environmental Protection Agency | Office of Solid Waste and Emergency Response (5104) | EPA 550-F-98-017 August 1998 www.epa.gov/ceppo

EPA CEPPO

HAZARDS OF AMMONIA RELEASES AT AMMONIA REFRIGERATION FACILITIES

The Environmental Protection Agency (EPA) is issuing this *Alert* as part of its ongoing effort to protect human health and the environment. EPA is striving to learn the causes and contributing factors associated with chemical accidents and to prevent their recurrence. Major chemical accidents cannot be prevented solely through command and control regulatory requirements, but by understanding the fundamental root causes, widely disseminating the lessons learned, and integrating these lessons learned into safe operations. EPA will publish *Alerts* to increase awareness of possible hazards. It is important that personnel who operate refrigeration systems, managers of facilities, SERCs, LEPCs, emergency responders and others review this information and take appropriate steps to minimize risk.

Chemical Safety ALERT

PROBLEM

Anhydrous ammonia is used as a refrigerant in mechanical compression systems at a large number of industrial facilities. Ammonia is a toxic gas under ambient conditions. Many parts of a refrigeration system contain ammonia liquefied under pressure. Releases of ammonia have the potential for harmful effects on workers and the public; if the ammonia is under pressure, larger quantities may be released rapidly into the air. Also, some explosions have been attributed to releases of ammonia contaminated with lubricating oil. This *Alert* further discusses these potential hazards and the steps that can be taken to minimize risks. This *Alert* should be reviewed by personnel who operate and maintain refrigeration systems, managers of facilities, and emergency responders (e.g., haz mat teams).

ACCIDENTS

A number of accidental releases of ammonia have occurred from refrigeration facilities in the past. Causes of these releases include plant upsets, leading to the lifting of relief valves; leaks in rotating seals; pipeline failures; vehicular traffic hitting pipes, valves, and evaporators; and failures during ammonia delivery, such as hose leaks. Some of these releases have killed and injured workers, caused injuries off site, or resulted in evacuations. The following describes several recent incidents in more detail.

A specific incident demonstrates the need for mechanical protection to protect refrigeration equipment from impact. In a 1992 incident at a meat packing plant, a forklift struck and ruptured a pipe carrying ammonia for refrigeration. Workers were evacuated when the leak was detected. A short time later, an explosion occurred that caused extensive damage, including large holes in two sides of the building. The forklift was believed to be the source of ignition. In this incident, physical barriers would have provided mechanical protection to the refrigeration system and prevented a release.

Another incident highlights the need for an adequate preventive maintenance program and scheduling. In a 1996 incident in a produce cold storage facility, oil pressure got low over a long weekend in an older ammonia refrigeration system. The low oil pressure cutout switch failed and the compressor tore itself apart, resulting in a significant ammonia release. The periodic testing of the low oil pressure cutout switch against a known standard would have prevented this incident.

Two other incidents illustrate the potential for serious effects from accidental releases from ammonia refrigeration systems, although the causes of these releases were not reported. In a 1986 incident in a packing plant slaughterhouse, a refrigeration line ruptured, releasing ammonia. Eight workers were critically injured, suffering respiratory burns from ammonia inhalation, and 17 others were less severely hurt. A 1989 ammonia release in a frozen pizza plant led to the evacuation of nearly all of the 6,500 residents of the town where the plant was located. The release started when an end cap of a 16-inch suction line of the ammonia refrigeration system was knocked off. Up to 45,000 pounds of ammonia was released, forming a cloud 24 city blocks long. About 50 area residents were taken to hospitals, where they were treated with oxygen and released, while dozens of others were treated with oxygen at evacuation centers.

HAZARD AWARENESS

Ammonia is used widely and in large quantities for a variety of purposes. More than 80% of ammonia produced is used for agricultural purposes; less than two percent is used for refrigeration. Use of ammonia is generally safe provided appropriate maintenance and operating controls are exercised. It is important to recognize, however, that ammonia is toxic and can be a hazard to human health. It may be harmful if inhaled at high concentrations. The Occupational Safety and Health Administration (OSHA) Permissible Exposure Level (PEL) is 50 parts per million (ppm), 8-hour time-weighted average. Effects of inhalation of ammonia range from irritation to severe respiratory injuries, with possible fatality at higher concentrations. The National Institute of Occupational Safety and Health (NIOSH) has established an Immediately Dangerous to Life and Health (IDLH) level of 300 ppm for the purposes of respirator selection. Ammonia is corrosive and can burn the skin and eyes. Liquefied ammonia can cause frostbite.

The American Industrial Hygiene Association (AIHA) has developed Emergency Response Planning Guidelines (ERPGs) for a number of substances to assist in planning for catastrophic releases to the community. The ERPG-2 represents the concentration below which it is believed nearly all individuals could be exposed for up to one hour without irreversible or serious health effects. The ERPG-2 for ammonia is 200 ppm. EPA has adopted the ERPG-2 as the toxic endpoint for ammonia for the offsite consequence analysis required by the Risk Management Program (RMP) Rule under section 112(r) of the Clean Air Act.

In refrigeration systems, ammonia is liquefied under pressure. Liquid ammonia that is accidentally released may aerosolize (i.e., small liquid droplets may be released along with ammonia gas) and behave as a dense gas, even though it is normally lighter than air (i.e., it may travel along the ground instead of immediately rising into the air). This behavior may increase the potential for exposure of workers and the public.

Although pure ammonia vapors are not flammable at concentrations of less than 16%, they may be a fire and explosion hazard at concentrations between 16 and 25%. Mixtures involving ammonia contaminated with lubricating oil from the system, however, may have a much broader explosive range. A study conducted to determine the influence of oil on the flammability limits of ammonia found that oil reduced the lower flammability limit as low as 8%, depending on the type and concentration of oil (Fenton, et al., 1995).

An important property of ammonia is its pungent odor. Odor threshold varies with the individual but ammonia can be usually detected at concentrations in the range of about 5 ppm to 50 ppm. Concentrations above about 100 ppm are uncomfortable to most people; concentrations in the range of 300 to 500 ppm will cause people to leave the area immediately.

HAZARD REDUCTION

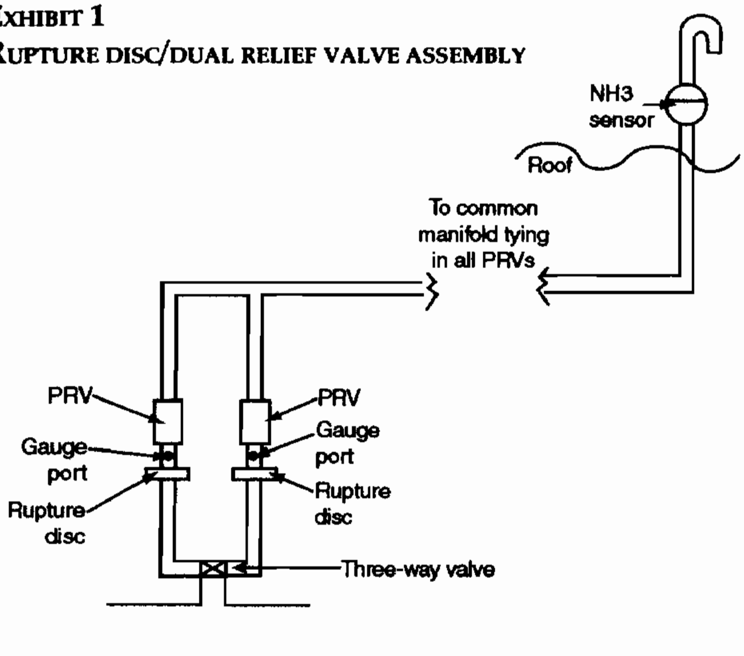
The Chemical Accident Prevention Group of EPA's Region III (Pennsylvania, Maryland, Virginia, West Virginia, Delaware, and the District of Columbia) has been evaluating facilities in Region III with ammonia refrigeration systems to gather information on safety practices and technologies and to share its knowledge with these facilities. Region III has conducted more than 120 audits from 1995 to the present of both large and small facilities using ammonia for refrigeration. To share their findings from the audits, including both the deficiencies observed and the actions that facilities are taking to increase safety, Region III has made presentations to the Refrigerating Engineers and Technicians Association (RETA). This *Alert* is intended to communicate these findings to a wider audience.

Ammonia refrigeration facilities should be aware of the potential hazards of ammonia releases and of the steps that can be taken to prevent such releases. They should be prepared to respond appropriately if releases do occur. Here are steps that ammonia refrigeration facilities could take to prevent releases and reduce the severity of releases that do occur include:

- Establish training programs to ensure that the ammonia refrigeration system is operated and maintained by knowledgeable personnel.
- Consider using a spring-loaded ball valve (dead-man valve) in conjunction with the oil drain valve on all oil out pots (used to collect oil that leaks through seals) as an "emergency stop valve."
- Develop written standard operating procedures for removing oil from the oil out pots. Consider developing an in-house checklist to guide mechanics through the procedure.
- Remove refrigeration oil from the refrigeration system on a regular basis. Never remove oil directly from the refrigeration system without pumping down and properly isolating that component.
- Provide barriers to protect refrigeration equipment, i.e., lines, valves, and refrigeration coils, from impact in areas where forklifts are used. Consider starting a forklift driver training program.
- Develop and maintain a written preventive maintenance program and schedule based on the manufacturer's recommendations for all of the refrigeration equipment. The preventive maintenance program should include, but not be limited to:
  a) compressors
  b) pumps
  c) evaporators
  d) condensers
  e) control valves
  f) all electrical safety(s), including
    1) high pressure cutouts
    2) high temperature cutouts
    3) low pressure cutouts
    4) low temperature cutouts
    5) low oil pressure cutouts
  g) ammonia detectors
  h) emergency response equipment, including,
    1) air monitoring equipment
    2) self-contained breathing apparatus (SCBA)
    3) level A suit
    4) air- purifying respirators
- Perform vibration testing on compressors. Document and analyze results for trends.
- Maintain a leak-free ammonia refrigeration system. Investigate all reports of an ammonia odor and repair all leaks immediately. Leak test all piping, valves, seals, flanges, etc., at least four times a year. Some methods which can be used for leak testing are sulfur sticks, litmus paper, or a portable monitor equipped with a flexible probe.
- Consider installing ammonia detectors in areas where a substantial leak could occur or if the facility is not manned 24 hours/day. The ammonia detectors should be monitored by a local alarm company or tied into a call-down system. Ensure that the ammonia detectors are calibrated regularly against a known standard. Check the operation of ammonia sensors and alarms regularly.
- Replace pressure relief valves (PRVs) on a five-year schedule; document replacement dates by stamping the replacement date onto each unit's tag.
- Replace single PRVs with dual relief valves. A dual relief valve installation consists of one three-way dual shut-off valve with two pressure safety relief valves.
- For large systems with many PRVs, consider using the arrangement shown in Exhibit 1 for detecting leakage. This arrangement includes installation of a rupture disc upstream of each PRV with a gauge port or transducer in between the disc and PRV and installation of an

ammonia sensor in the PRV common manifold. In case of leakage from a PRV, the sensor would set off an alarm. A check of either the pressure gauge or transducer signal would permit easy identification of which PRV has popped.

EXHIBIT 1
RUPTURE DISC/DUAL RELIEF VALVE ASSEMBLY



- Consider installing a low water level probe with an alarm in the water sump for the evaporative condenser(s) to warn of water supply failure.

- Ensure that the ammonia refrigeration system is routinely monitored. Consider using a daily engine room log, recording process parameters (e.g., temperature and pressure levels) and reviewing the log on a regular basis. Consider having the chief engineer and the refrigeration technician sign the daily engine room log. In designing new systems or retrofitting existing systems, consider the use of computer controls to monitor the process parameters.

- Keep an accurate record of the amount of ammonia that is purchased for the initial charge to the refrigeration system(s) and the amount that is replaced. Consider keeping a record of the amount of lubricating oil added to the system and removed from the system.

- Ensure that good housekeeping procedures are followed in the compressor rooms.

- Ensure that refrigeration system lines and valves are adequately identified (e.g., by color coding or labeling) by using an in-house system.

- Properly post ammonia placards (i.e. NFPA 704 NH_3 diamond) and warning signs in areas where ammonia is being used as a refrigerant or being stored (for example, compressor room doors). Properly identify the chemicals within the piping system(s); label all process piping, i.e. piping containing ammonia, as "AMMONIA." Label must use black letters with yellow background. (This requirement is not the same as the in-house color coding system.)

- Periodically inspect all ammonia refrigeration piping for failed insulation/vapor barrier, rust, and corrosion. Inspect any ammonia refrigeration piping underneath any failed insulation systems for rust and corrosion. Replace all deteriorated refrigeration piping as needed. Protect all un-insulated refrigeration piping from rust and/or corrosion by cleaning, priming, and painting with an appropriate coating.

- Carry out regular inspections of emergency equipment and keep respirators, including air-purifying and self-contained breathing apparatus (SCBA), and other equipment in good shape; ensure that personnel are trained in proper use of this equipment. For SCBA, it is important to ensure that air is bone dry. For air-purifying respirators, replace cartridges as needed and check expiration dates.

- Consider using the compressor room ammonia detector to control the ventilation fans.

- Identify the king valve and other emergency isolation valves with a large placard so that they can easily be identified by emergency responders, in case of an emergency. These valves should be clearly indicated on the piping and instrumentation diagrams (P&IDs) and/or process flow diagrams.

- Establish emergency shutdown procedures and instructions on what to do during and after a power failure.

- Establish written emergency procedures and instructions on what to do in the event of an ammonia release.

- Mount a compressor room ventilation fan manual switch outside of the compressor room and identify it with a placard for use in an emergency. Good practice would be to have ventilation switches located outside and inside of each door to the compressor room.

- Mount windsocks in appropriate places and incorporate their use into the facility emergency response plan. In addition to the emergency response plan, consider developing additional materials (posters, signs, etc.) to provide useful information to employees and emergency responders in case of an emergency.

- Keep piping and instrumentation diagrams (P&IDs), process flow diagrams, ladder diagrams, or single lines up-to-date and incorporate them into training programs for operators.

- Stage a realistic emergency response spill exercise with the local fire company.

References

Fenton, D.L., K.S. Chapman, R.D. Kelley, and A.S. Khan. 1995. Operating Characteristics of a flare/ oxidizer for the disposal of ammonia from and industrial refrigeration facility. ASHRAE Transactions, 101 (2), pp. 463-475. Atlanta, GA: American Society of Heating, Refrigeration, and Air-Conditioning Engineers.

INFORMATION RESOURCES

General References

The Alaska DEC fact sheet on preventing accidental releases of anhydrous ammonia is available at: http://es.inel.gov/techinfo/facts/alaska/ak-fs03.html.

◆

CEPPO has prepared a general advisory on ammonia (OSWER 91-008.2 Series 8 No. 2), available at: http://www.epa.gov/ceppo/acc-his.html.

Statutes and Regulations

The following are a list of federal statutes and regulations related to process safety, accident prevention, emergency planning, and release reporting.

EPA

Clean Air Act (CAA)

- General Duty Clause [Section 112(r) of the Act]- Facilities have a general duty to prevent and mitigate accidental releases of extremely hazardous substances, including ammonia.

- Risk Management Program (RMP) Rule [40 CFR 68]- Facilities that have anhydrous ammonia in quantities greater than 10,000 pounds are required to develop a hazard assessment, a prevention program, and an emergency response program. EPA has developed a model guidance to assist ammonia refrigeration facilities comply with the RMP rule.

Emergency Planning and Community Right-to-Know (EPCRA)

- Emergency Planning [40 CFR Part 355] - Facilities that have ammonia at or above 500 pounds must report to their LEPC and SERC and comply with certain requirements for emergency planning.

- Emergency Release Notification [40 CFR Part 355]- Facilities that release100 pounds or more of ammonia must immediately report the release to the LEPC and the SERC.

- Hazardous Chemical Reporting [40 CFR Part 370]- Facilities that have ammonia at or above 500 pounds must submit a MSDS to their LEPC, SERC, and local fire department and comply with the Tier I/ Tier II inventory reporting requirements.

- Toxic Chemicals Release Inventory [40 CFR Part 372] - Manufacturing businesses with ten or more employees that manufacture, process, or otherwise use ammonia above an applicable threshold must file annually a Toxic Chemical Release form with EPA and the state.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

- Hazardous Substance Release Reporting [40 CFR Part 302]- Facilities must report to the National Response Center (NRC) any environmental release of ammonia which exceeds 100 pounds. A release may trigger a response by EPA, or by one or more Federal or State emergency response authorities.

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OSHA

- *Process Safety Management (PSM)* Standard [29 CFR 1910] Ammonia (anhydrous) is listed as a highly hazardous substance. Facilities that have ammonia in quantities at or above the threshold quantity of 10,000 pounds are subject to a number of requirements for management of hazards, including performing a process hazards analysis and maintaining mechanical integrity of equipment.
- *Hazard Communication* [29 CFR 1910.1200] - Requires that the potential hazards of toxic and hazardous chemicals be evaluated and that employers transmit this information to their employees.

For additional information, contact OSHA Public Information at (202) 219- 8151.

Web site: http://www.osha.gov

Codes and Standards

There are a number of American National Standards Institute (ANSI) Standards available for refrigeration systems. Some examples are given below.

ANSI/ASHRAE Standard 15-1994 - Safety Code for Mechanical Refrigeration

Available for purchase from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) International Headquarters,
1791 Tullie Circle, NE, Atlanta, GA 30329-2305.
Customer service: 1-800-527- 4723

ANSI/IIAR 2-1992 - Equipment, Design, and Installation of Ammonia Mechanical Refrigeration Systems

Available from the International Institute of Ammonia Refrigeration (IIAR)
1200 19th Street, NW
Suite 300
Washington, DC 22036-2422
(202) 857-1110

Web site: http://www.iiar.org

ISO 5149-1993 - Mechanical Refrigerating Systems Used for Cooling and Heating -- Safety Requirements

Available from the American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
(212) 642-4900

Web site: http://www.ansi.org

FOR MORE INFORMATION...

CONTACT THE EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW HOTLINE

(800) 424-9346 OR (703) 412-9810
TDD (800) 553-7672

MONDAY-FRIDAY, 9 AM TO 6 PM, EASTERN TIME

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VISIT THE CEPPO HOME PAGE ON THE WORLD WIDE WEB AT:
HTTP://WWW.EPA.GOV/CEPPO/

E. Natural Gas Processing
(Wikipedia download)

1100 Nat Gas Gen. Diff STD's
1 EXP per year.

Natural gas processing

From Wikipedia, the free encyclopedia

A natural gas processing plant

Natural gas processing plants, or fractionators, are used to purify the raw natural gas extracted from underground gas fields and brought up to the surface by gas wells. The processed natural gas, used as fuel by residential, commercial and industial consumers, is almost pure methane and is very much different from the raw natural gas.

Raw natural gas typically consists primarily of methane (CH_4), the shortest and lightest hydrocarbon molecule. It also contains varying amounts of:

- Heavier gaseous hydrocarbons: ethane (C_2H_6), propane (C_3H_8), normal butane (n-C_4H_{10}), isobutane (i-C_4H_{10}), pentanes and even higher molecular weight hydrocarbons. When processed and purified into finished by-products, all of these are collectively referred to NGL (**Natural Gas Liquids**).
- Acid gases: carbon dioxide (CO_2), hydrogen sulfide (H_2S) and mercaptans such as methanethiol (CH_3SH) and ethanethiol (C_2H_5SH).
- Other gases: nitrogen (N_2) and helium (He).
- Water: water vapor and liquid water.
- Liquid hydrocarbons: perhaps some natural gas condensate (also referred to as *casinghead gasoline* or *natural gasoline*) and/or crude oil.
- Mercury: very small amounts of mercury primarily in elementary form, but chlorides and other species are possibly present.[1]

The raw natural gas must be purified to meet the quality standards specified by the major pipeline transmission and distribution companies. Those quality standards vary from pipeline to pipeline and are usually a function of a pipeline system's design and the markets that it serves. In general, the standards specify that the natural gas:

- Be within a specific range of heating value (caloric value). For example, in the United States, it should be about 1,035 ± 5% Btu per cubic foot of gas at 1 atmosphere and 60 °F (41 MJ ± 5% per cubic metre of gas at 1 atmosphere and 0 °C).
- Be delivered at or above a specified hydrocarbon dew point temperature (below which some of the hydrocarbons in the gas might condense at pipeline pressure forming liquid slugs which could damage the pipeline).
- Be free of particulate solids and liquid water to prevent erosion, corrosion or other damage to the pipeline.
- Be dehydrated of water vapor sufficiently to prevent the formation of methane hydrates within the gas processing plant or subsequently within the sales gas transmission pipeline.[2][3]
- Contain no more than trace amounts of components such as hydrogen sulfide, carbon dioxide, mercaptans, nitrogen, and water vapor.
- Maintain mercury at less than detectable limits (approximately 0.001 ppb by volume) primarily to avoid damaging equipment in the gas processing plant or the pipeline transmission system from mercury amalgamation and embrittlement of aluminum and other metals.[1][4][5]

Contents

Types of raw natural gas wells

Raw natural gas comes primarily from any one of three types of wells: crude oil wells, gas wells, and condensate wells.

Natural gas that comes from crude oil wells is typically termed *associated gas*. This gas can exist separate from the crude oil in the underground formation, or dissolved in the crude oil.

Natural gas from gas wells and from condensate wells, in which there is little or no crude oil, is termed *non-associated gas*. Gas wells typically produce only raw natural gas, while condensate wells produce raw natural gas along with a very low density liquid hydrocarbon called *natural gas condensate* (sometimes also called *natural gasoline* or simply *condensate*).

Raw natural gas can also come from methane deposits in the pores of coal seams. Such gas is referred to as *coalbed gas* and it is also called *sweet gas* because it is relatively free of hydrogen sulfide.

Description of a natural gas processing plant

There are a great many ways in which to configure the various unit processes used in the processing of raw natural gas. The block flow diagram below is a generalized, typical configuration for the processing of raw natural gas from non-associated gas wells. It shows how raw natural gas is processed into sales gas pipelined to the end user markets.[6][7][8][9][10] It also shows how processing of the raw natural gas yields these byproducts:

- Natural gas condensate
- Sulfur
- Ethane
- Natural gas liquids (NGL): propane, butanes and C_5+ (which is the commonly used term for pentanes plus higher molecular weight hydrocarbons)

Raw natural gas is commonly collected from a group of adjacent wells and is first processed at that collection point for removal of free liquid water and natural gas condensate. The condensate is usually then transported to an oil refinery and the water is disposed of as wastewater.

The raw gas is then pipelined to a gas processing plant where the initial purification is usually the removal of acid gases (hydrogen sulfide and carbon dioxide). There a many processes that are available for that purpose as shown in the flow diagram, but amine treating is the most widely used process. In the last ten years, a new process based on the use of polymeric membranes to dehydrate and separate the carbon dioxide and hydrogen sulfide from the natural gas stream is gaining acceptance.

The acid gases removed by amine treating are then routed into a sulfur recovery unit which converts the hydrogen sulfide in the acid gas into elemental sulfur. There are a number of processes available for that conversion, but the Claus process is by far the one usually selected. The residual gas from the Claus process is commonly called *tail gas* and that gas is then processed in a tail gas treating unit (TGTU) to recover and recycle residual sulfur-containing compounds back into the Claus unit. Again, as shown in the flow diagram, there are a number of processes available for treating the Claus unit tail gas. The final residual gas from the TGTU is incinerated. Thus, the carbon dioxide in the raw natural gas ends up in the incinerator flue gas stack.

The next step in the gas processing plant is to remove water vapor from the gas using the either regenerable absorption in liquid triethylene glycol (TEG)[3] or a Pressure Swing Adsorption (PSA) unit which is regenerable adsorption using a solid adsorbent.[11] Another newer process using membranes may also be considered.

Mercury is then removed by using adsorption processes (as shown in the flow diagram) such as activated carbon or regenerable molecular sieves.[1]

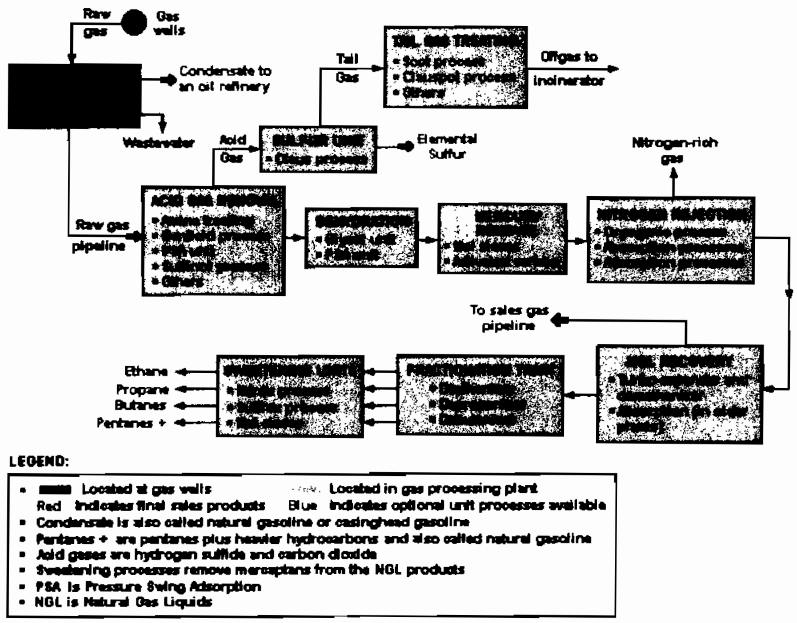
Nitrogen is next removed and rejected using one of the three processes indicated on the flow diagram:

- Cryogenic process[12] using low temperature distillation. This process can be modified to also recover helium, if desired.
- Absorption process[13] using lean oil or a special solvent[14] as the absorbent.
- Adsorption process using activated carbon or molecular sieves as the adsorbent. This process may have limited applicability because it is said to incur the loss of butanes and heaver hydrocarbons.

The next step is to recover of the natural gas liquids (NGL) for which most large, modern gas processing plants use another cryogenic low temperature distillation process involving expansion of the gas through a turbo-expander followed by distillation in a demethanizing fractionating column.[15][16] Some gas processing plants use lean oil absorption process[13] rather than the cryogenic turbo-expander process.

The residue gas from the NGL recovery section is the final, purified sales gas which is pipelined to the end-user markets.

The recovered NGL stream is processes through a fractionation train consisting of three distillation towers in series: a dethanizer, a depropanizer and a debutanizer. The overhead product from the deethanizer is ethane and the bottoms are fed to the depropanizer. The overhead product from the depropanizer is propane and the bottoms are fed to the debutanizer. The overhead product from the debutanizer is a mixture of normal and iso-butane, and the bottoms product is a C_5+ mixture. The recovered streams of propane, butanes and C_5+ are each "sweetened" in a Merox process unit to convert undesirable mercaptans into disulfides and, along with the recovered ethane, are the final NGL by-products from the gas processing plant.



External links

- Natural Gas Processing Principals and Technology (http://www.schulich.ucalgary.ca/Chemical/class_notes/ench607/mainmenu.pdf) (an extensive and detailed course text by Dr. A.H. Younger, University of Calgary, Alberta, Canada).
- Processing Natural Gas (http://www.naturalgas.org/naturalgas/processing_ng.asp) a website maintained by the Natural Gas Supply Association.
- Natural Gas Processing (http://www.epa.gov/ttn/chief/ap42/ch05/final/c05s03.pdf) (part of the US EPA's AP-42 publication)
- Natural Gas Processing Plants (http://primis.phmsa.dot.gov/comm/FactSheets/FSNaturalGasProcessingPlants.htm) (a US Department of Transportation website)

References

1. ^ a b c *Mercury Removal from Natural Gas and Liquids* (http://www.uop.com/objects/87MercuryRemoval.pdf) UOP website page
2. ^ Dehydration of Natural Gas (http://www.ipt.ntnu.no/~jsg/undervisning/naturgass/parlaktuna/Chap7.pdf) by Prof. Jon Steiner Gudmundsson, Norwegian University of Science and Technology
3. ^ a b Glycol Dehydration (http://www.processgroup.com.au/Technologies/GasProcessing/GlycolDehyrdation/tabid/84/Default.aspx) (includes a flow diagram)
4. ^ *Desulfurization of and Mercury Removal From Natural Gas* (http://www.tigg.com/ACTIVATED-CARBON/desulfurization.html) by Bourke, M.J. and Mazzoni, A.F., Laurance Reid Gas Conditioning Conference, Norman, Oklahoma, March 1989.
5. ^ Using Gas Geochemistry to Assess Mercury Risk (http://www.gaschem.com/mercur.html), OilTracers, 2006
6. ^ *Natural Gas Processing: The Crucial Link Between Natural Gas Production and Its Transportation to Market* (http://www.eia.doe.gov/pub/oil_gas/natural_gas/feature_articles/2006/ngprocess/ngprocess.pdf)
7. ^ *Example Gas Plant* (http://www.uop.com/gasprocessing/6070.html)
8. ^ *From Purification to Liquefaction Gas Processing* (http://www.axens.net/upload/presentations/fichier/axens_gpagcc_2004v2.pdf)
9. ^ *Feed-Gas Treatment Design for the Pearl GTL Project* (http://www.spe.org/specma/binary/files/5804785Syn10682.pdf)
10. ^ *Benefits of integrating NGL extraction and LNG liquefaction* (http://lnglicensing.conocophillips.com/NR/rdonlyres/B78B6727-E5F4-4505-B9C3-96CC94D7B30D/7357/AICHELNGNGLIntegrationPaper.pdf)
11. ^ Molecular Sieves (http://www.uop.com/objects/96%20MolecularSieves.pdf) (includes a flow diagram of a PSA unit)
12. ^ *Gas Processes 2002*, Hydrocarbon Processing, pages 84-86, May 2002 (schematic flow diagrams and descriptions of the Nitrogen Rejection and Nitrogen Removal processes)
13. ^ a b *Market-Driven Evolution of Gas Processing Technologies for NGLs* (http://www.aet.com/gtip1.htm) Advanced Extraction Technology Inc. website page
14. ^ AET Process Nitrogen Rejection Unit (http://www.aet.com/aetnrubig.pdf) Advanced Extraction Technology Inc. website page
15. ^ *Cryogenic Turbo-Expander Process* (http://www.aet.com/turbo.htm) Advanced Extraction Technology Inc. website page
16. ^ *Gas Processes 2002*, Hydrocarbon Processing, pages 83-84, May 2002 (schematic flow diagrams and descriptions of the NGL-Pro and NGL Recovery processes)

Categories: Chemical engineering | Chemical processes | Natural gas | Unit processes

F. Interpretation of Evaluation Guide: Low Frequency Noise Problems

SECONDARY VIBRATI

"Interpretation of Evaluation Guide" to Solve Low Frequency Noise Problems

1. Scope

Local government frequently receive complaints about low frequency noise from stationary sources at plants, workshops, stores and facilities installed in residential areas. These sources emit low frequency noise in a relatively stationary sound pressure level. Test labs have accumulated data through experiments using almost steady and constant low frequency sound. They have not yet obtained enough research data of low frequency noise which occurs singly or for a short period.

This Evaluation Guide is not applicable to low frequency noise from sources on highways which do not always emit the noise but where the noise from these sources is irregular and varies widely depending on the time and situation, or the noise from transient and intermittent sources such as airplanes and railways, and explosive noise from such sources as blasting, explosion and high-speed trains entering a tunnel. The Evaluation Guide will be limited at the moment to being applicable to those sources which are stationary or temporarily not moving, and which emit low frequency noise consistently for a certain period.

2. Reference Values to Counter Complaints about Low frequency Noise

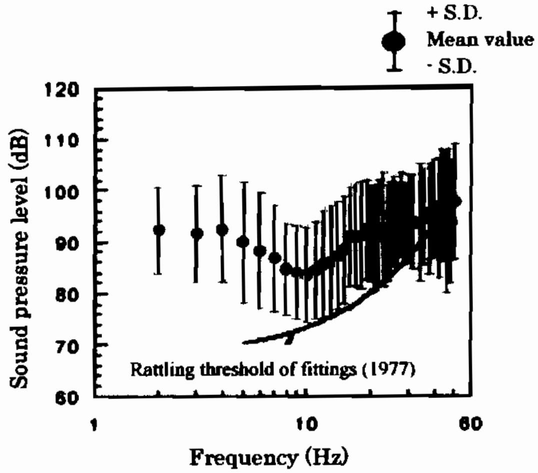
The Guide provides reference values to identify whether complaints are ascribable to low frequency noise or not, because of differences in response to the low frequency noise between fittings and persons. These reference values are categorized into those for complaints of rattling and those for complaints of mental and physical discomfort.

2.1 Reference Values for Complaints of Rattling

(1) Thresholds of Low Frequency Noise to Rattle Fittings

The threshold of low frequency noise for rattle in fittings is the minimum sound pressure level at which fittings start rattling. The result of steady low frequency noise testing of fittings indicates that the minimum sound pressure to initiate rattling varies with the type of fittings and ranges between 30 and 40 dB (see Figure.4.3.2 in "Examination of Low frequency Noise Countermeasures (interim report)" issued in July 2003[1]: following Figure.3[2]). The "mean value - standard deviation" of the minimum sound pressure level to initiate rattling in fittings generally coincides with the previously obtained "threshold of rattle in fittings" (see Figure. d-5 in "the Measurement Manual for Low Frequency Noise"[3]: following Figure.4[4]).

There are differences in characteristics between low frequency noise thresholds at which fittings start rattling and at which persons sense the noise. People can sense low frequency noise at a higher sound pressure level, while fittings tend to start rattling at a lower sound pressure level than people sense at a frequency below 20 Hz.



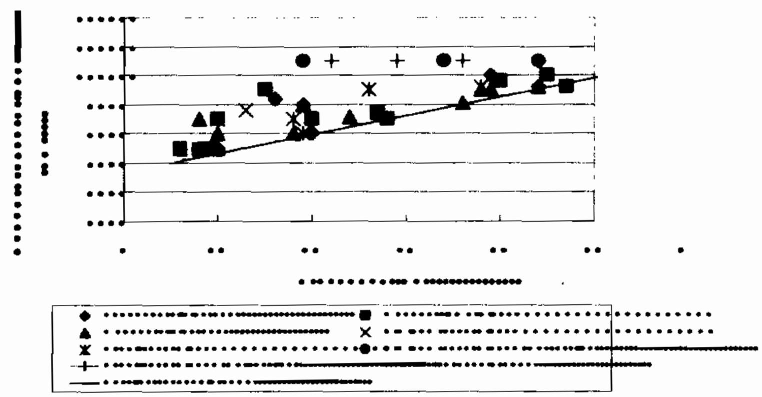


Fig.3 Minimun sound pressure level of rattling. (63samples; 2002[2])

Fig.4 Minimun sound pressure level of rattling. (15samples; 1977[4])

(2) Interpretation of Reference Values for Complaints of Rattling

There are complaints of rattling such as quivering and rattling of fittings caused by low frequency noise. Each fitting has its own characteristic frequency. When the frequency of low frequency noise from outside and the characteristic frequency synchronize, the fittings tend to rattle at a low sound pressure level. This means the "mean value - standard deviation" correspond to complaints better than mean values of low frequency ranges.

The results of the national survey of low frequency noise problems since 2000 also indicate complaints of rattling at the sound pressure level of around the "threshold of rattle in fittings" as calculated through experiments in a test lab. It is generally concluded that complaints of rattling can be reasonably assessed by these values.

Taking data accumulated so far into consideration in addition to the above, the "thresholds of rattles" were employed as reference values for complaints of rattling from low frequency noise.

2.2 Reference Values for Complaints of Mental and Physical Discomfort

(1) Results of Evaluation of Threshold and Mental and Physical Complaints

It is said that the complainants are sensitive. To confirm this belief, the Ministry tested the minimum sensing threshold (hearing threshold) by comparing complainants with an adult control group as test subjects in 2003. The test results did not indicate that complainants are sensitive. Although it was probably partly the cause that there were rather aged complainants who participated in the test to obtain data; the average values of their hearing threshold were higher than those of the average adults (in short, the complainants were not sensitive)(following Figure.5).

In 2003, the Ministry also examined the tolerable level (acceptable limit) when the test complainants and average adults control group were exposed to low frequency noise in a room (a low frequency pressure chamber assumed as in living room or bedroom). The test was based on the assumption that test subjects would prefer a calm and peaceful living environment. According to the test results, many average adults felt the noise at a higher tolerable sound pressure level than the hearing threshold by a few decibels to a dozen decibels. In contrast, many complainants felt the level approximate to the hearing threshold tolerable. The result demonstrated the tendency for the frequency characteristics of the tolerable level for the complainants to be at around the reference values for mental and physical discomfort which were obtained from ten percentile curve of the tolerable level of average adults control groups in the bedroom (following Figure.6).

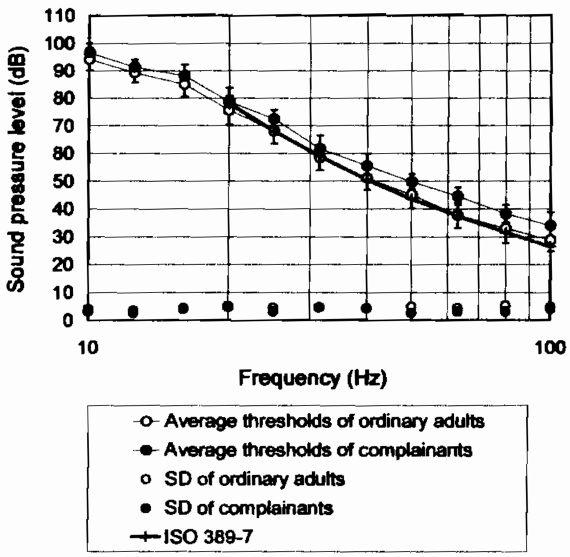


Figure.5 Average hearing thresholds of ordinary adults and complainants[5]

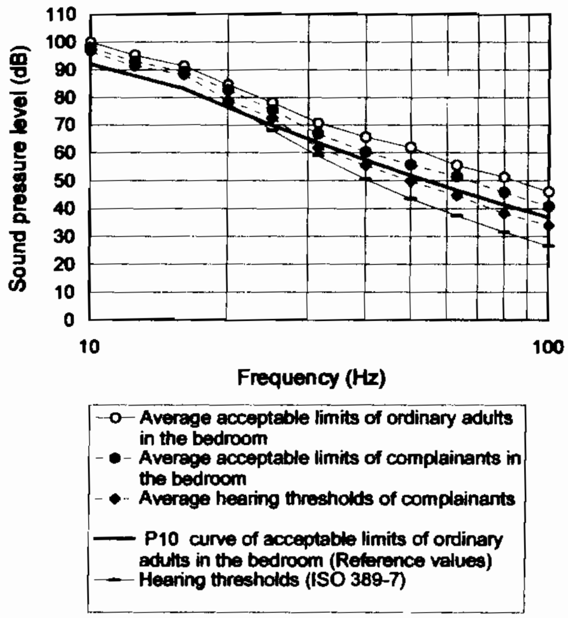


Figure.6 Tolerable levels (acceptable limits) of ordinary adults and complainants in the bedroom[6,7]

(2) Interpretation of Reference Values for Complaints of Mental and Physical Discomfort

Most complainants felt low frequency noise in a room. Taking this fact into consideration, the measurement values obtained in the room were employed as reference values. In addition, considering significant individual differences in sensing the low frequency noise, the sound pressure level which the large proportion of the test subjects felt tolerable was defined as a reference value.

The past field measurement data were compared with the reference values. In the case where complaints corresponded to the period of operation of a source, most data indicated that the sound pressure level exceeded the reference values at some frequencies. In the case where there was no source but complaints, and there could be causes other than the low frequency noise, most data about complaints were lower than the reference values at every frequency. In short, it was concluded that the reference values reasonably correlated with most complaints corresponding to operation of the source. Incidentally, there is a slight possibility that complainants would complain about the noise at a lower sound pressure level.

According to the results of the past surveys, tremendously significant infrasound seldom occurred in ordinary living environments. Focusing on mental and physical discomfort caused by infrasound, the Ministry added the evaluation using the G-weighted sound pressure level. The reference values at the G-weighted sound pressure level were calculated based on the tolerable level in the bedroom. Incidentally, low frequency noise is assessed basically at the 1/3 octave band sound pressure level. It is not recommended to evaluate low frequency noise only by the G-weighted sound pressure level.

3. Measurement

3.1 Measurement Methods

As a rule, measurement methods for low frequency noise were carried out in accordance with the "Measurement Manual for Low frequency Noise (October 2000)"(in Japanese) and "Guidance" to counter low frequency noise problems.

3.2 Measurement Position

(1) Measurement Position for Complaints of Rattling

The test results of low frequency noise to rattle fittings are sorted by the incident sound pressure level to the fittings; therefore, the measurement was performed outside of the building. A desirable outdoor measurement position is 3.5 meters or more away from complainant's building, considering any influence from reflection from the surrounding buildings to measure low frequency noise in general living conditions. In cases of complaints of rattling, the low frequency noise would be measured one or two meters away from complainant's building such as residences, etc.

(2) Measurement Position for Complaints of Mental and Physical Discomfort

This measurement is designed to identify the characteristics of low frequencies which are the subject of complaints by measuring the noise at the position in the room where complainants most frequently feel low frequency noise and discomfort. The measurement position was defined as the position where people feel the noise most, because standing waves occur at a certain frequency in a room and the sound pressure level of noise varies according to the location of the room.

In addition, it is generally effective if the above measurement data are compared with measurements taken at the position in the room where the complainant does not feel low frequency noise or discomfort.

3.3 Measurement Value

With regard to the measurement value of low frequency noise, test results as a base for reference values are already classified by frequency. Thus, the sound pressure level is measured in the 1/3 octave band. In addition, the G-weighted sound pressure level is employed for the evaluation of mental and physical discomfort caused by infrasound, as specified with respect to the weighting for the evaluation of infrasound below 20 Hz in ISO-7196.

3.4 Frequency Range for Measurement

The frequency range for measurement is the center frequency of 1 Hz to 80 Hz in the one-third octave band according to the "Measurement Manual for Low frequency Noise"(in Japanese).

3.5 Calculation Method for Measurement Results

This Guide covers low frequency noise with a narrow fluctuation range of the sound pressure near sources. In spite of there being little fluctuation in the sound pressure level at the source, the fluctuation range might increase due to several factors in process of transmission. In this sense, the Guide provides how to calculate the results with an unstable sound pressure level of low frequency noise.

In the case where the sound pressure level of the low frequency noise fluctuates with wind, the noise will be measured at positions with less influence from wind where, in other words, the sound pressure level seldom fluctuates. Then, the sound pressure level of power average is used.

The fluctuation range of the sound pressure level is determined by reading indications of a low frequency sound level meter or a level recorder. In this measurement, with regard to the weighing characteristic of the low frequency level meter, the flat-weighting is used for frequency analysis and the G-weighting for calculating the G-weighted sound pressure level (If the low frequency meter does not have a G-weighting function, flat-weighing may be used).

4. Evaluation Methods

4.1 Evaluation Methods for Complaints of Rattling

In the case of a rattle in fittings, the causes are different from the case where every fitting in a house or in a room rattles to the case where only a specific fitting rattles. In the latter case, low frequency noise is a possibility.

If the sound pressure level of measurements in the 1/3 octave band is higher than or equal to the reference values shown in Table 1 at either of frequencies, it is concluded that low frequency noise may cause such rattle.

If the sound pressure level of measurements in the 1/3 octave band is below the reference values at any frequencies, and if there is no correlation between operation of the source and the rattle in fittings, a cause of the rattle could be factors other than low frequency noise, such as ground vibration. If every fitting in a house or a room quivers, ground vibration is likely.

Incidentally, the G-weighted sound pressure level is not used for the evaluation of complaints of rattling.

4.2 Evaluation Methods for Complaints of Mental and Physical Discomfort

In past evaluation of complaints of mental and physical discomfort caused by low frequency noise, only the G-weighted sound pressure level used to be measured and the result of 100 dB or less used to be determined as no problem. The G-weighted sound pressure level is an evaluation index used to evaluate the influence of infrasound of 20 Hz or less, so it cannot evaluate low frequency noise in the audible range up to 80 Hz. For the evaluation of complaints of mental and physical discomfort due to low frequency noise, it is crucial to both the G-weighted sound pressure level and the 1/3 octave band sound pressure level.

If the G-weighted sound pressure level is higher than or equal to the reference values, people may sense a infrasound and may make a complaint. The G-weighted sound pressure level, however, seldom increases to the reference values or higher in general living conditions. Next, if the sound pressure level of measurements in the 1/3 octave band is higher than or equal to the reference values as shown in Table 2 at either of frequencies, people may perceive low frequency noise and may make a complaint. If the G-weighted sound pressure level is less than the reference values, and the sound pressure level of measurements in the 1/3 octave band is smaller than the reference values at any or all frequencies, the low frequency noise is seldom problematic. In the latter case, a noise of 100 Hz or more or other factors such as ground vibration, rather than low frequency noise, may cause complaints.

If there is no relation between changes in low frequency noise and the response of complainants, it is concluded that complaints of mental and physical discomfort may be caused by the noise from 100 Hz to 200 Hz outside of the frequency range initially measured, ground vibration or factors other than low frequency noise (factors directly related to the complainant, such as tinnitus, etc.)

References

[1] Kenji Kamigawara, Yasuo Tokita,Shinji Yamada and Hiroaki Ochiai, Community responses to low frequency noise and administrative actions in Japan, Proceeding of INTERNOISE 2003, 221-1226(2003).

[2] Hiroaki Ochiai and Koichi Taya, " On the threshold low frequency sound pressure level generating rattling doors or windows ."(In Japanese), Journal of INCE-J, Vol.26, No.2, 120-128(2002).

[3] Hiroaki Ochiai. The state of the art of the infra and low frequency noise problem in Japan, Proceeding of INTERNOISE 2001, 1495-1498 (2001).

[4] Yasuo Tokita and Kazuo Shimizu, "Proposal on the low frequency noise meter", Proceedings on low frequency noise and hearing, 227-234(1980).

[5] Yukio Inukai and Shinji Yamada, "Thresholds, psychometric functions and detection ratios below thresholds of low frequency noise in ordinary adults and complainants", Proceedings of Low Frequency 2004, Maastricht, The Netherlands, 129-138(2004).

[6] Kamigawara, K., Yue, J., Saito, T. and Hirano, T. "Publication of Handbook to Deal with Low Frequency Noise (2004)", Proceedings of Low Frequency 2004, Maastricht, The Netherlands, 157-161 (2004).

[7] Yukio Inukai, Shinji Yamada, Hiroaki Ochiai and Yasuo Tokita, "Acceptable limits and their percentiles for low frequency noise in ordinary adults and complainants", Proceedings of Low Frequency 2004, Maastricht, The Netherlands, 117-127(2004).

G. Review: Low Frequency Noise Effects

A Review of Published Research on Low Frequency Noise and its Effects

Report for Defra by Dr Geoff Leventhall

Assisted by Dr Peter Pelmear and Dr Stephen Benton

May 2003

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1. Preamble

Low frequency noise causes extreme distress to a number of people who are sensitive to its effects. Such sensitivity may be a result of heightened sensory response within the whole or part of the auditory range or may be acquired. The noise levels are often low, occurring in the region of the hearing threshold, where there are considerable individual differences. There is still much to be done to gain a fuller understanding of low level, low frequency noise, its effects, assessment and management. Survey papers of low frequency noise and its occurrence include (Backteman et al., 1983a; Backteman et al., 1983b; Backteman et al., 1984a; Backteman et al., 1984b; Berglund et al., 1996; Broner, 1978a; Hood and Leventhall, 1971).

Historically, early work on low frequency noise and its subjective effects was stimulated by the American space programme, a source of very high levels of low frequency noise. The launch vehicles produce their maximum noise energy in the low frequency region. Furthermore, as the vehicle accelerates, the crew compartment is subjected to boundary layer turbulence noise for about two minutes after lift-off. Experiments were carried out, in low frequency noise chambers, on short term subjective tolerance to bands of noise at very high levels of 140 to 150dB in the frequency range up to 100Hz It was concluded that the subjects, who were experienced in noise exposure and wearing ear protection, could tolerate both broadband and discrete frequency noise in the range 1Hz to 100Hz at sound pressure levels up to 150dB. Later work suggests that, for 24 hour exposure, levels of 120-130dB are tolerable below 20Hz. These limits were set to prevent direct physiological damage (Mohr et al., 1965; von Gierke and Nixon, 1976; Westin, 1975). It is not

suggested that the exposure was pleasant, or even subjectively acceptable, for anybody except those who might have had a personal interest in the noise.
The levels used in the experiments are considerably higher than the exposure levels of people in their homes, arising from environmental, traffic, industrial and other sources.
The early American work was published in the mid 1960's and created no great sensation, but a few years later infrasound entered upon its "mythological" phase, echoes of which still occur. Infrasound . the "silent sound" - was blamed for many misfortunes for which another explanation had not yet been found (e.g., brain tumours, cot deaths, road accidents). A selection of some press headlines from the early years is:

- *The Silent Sound Menaces Drivers - Daily Mirror, 19th October 1969*
- *Does Infrasound Make Drivers Drunk - New Scientist, 16th March 1972*
- *Brain Tumours 'caused by noise' - The Times, 29th September 1973*
- *Crowd Control by Light and Sound - The Guardian, 3rd October 1973*
- *Danger in Unheard Car Sounds - The Observer, 21st April 1974*
- *The Silent Killer All Around Us - Evening News, 25th May 1974*
- *Noise is the Invisible Danger - Care on the Road (ROSPA) August 1974*

Blatantly incorrect claims were made in the book 'Supernature' by Lyall Watson, first published in 1973 as 'A natural history of the supernatural' and which had large sales as a paperback. For example, it stated that, in an experiment with infrasonic generators, all the windows were broken within a half mile of the test site and further, that two infrasonic generators "focused on a point even five miles away produce a resonance that can knock a building down as effectively as a major earthquake".
Those who were investigating low frequency noise problems at this time were often asked "It's dangerous, isn't it?" Public concern over infrasound was one of the stimuli for a growth in complaints about low frequency noise during the 1970's and 1980's and may still have lingering effects.
However, infrasound has long been a respected area of study in meteorology, where the frequencies range from as low as one cycle in 1000 seconds up to a few cycles per second. Large arrays of infrasound microphones detect low frequencies originating in atmospheric effects, meteorites, supersonic aircraft, explosions etc. There is also a worldwide system of about 60 infrasound arrays, which are part of the monitoring for the Nuclear Test Ban Treaty.
It is a big step from the American endurance exposures and the exaggerated effects of infrasound to the very real low frequency noise difficulties faced in a number of environmental noise problems, where low frequency noise occurs at low levels, often in the region of an individual's hearing threshold. The noise, typically classed as "not a Statutory Nuisance", causes immense suffering to those who are unfortunate to be sensitive to low frequency noise and who plead for recognition of their circumstances.
The World Health Organization is one of the bodies which recognizes the special place of low frequency noise as an environmental problem. Its publication on Community Noise (Berglund et al., 2000) makes a number of references to low frequency noise, some of which are as follows:

• *" It should be noted that low frequency noise, for example, from ventilation systems can disturb rest and sleep even at low sound levels"*
• *"For noise with a large proportion of low frequency sounds a still lower guideline* (than 30dBA) *is recommended"*
• *" When prominent low frequency components are present, noise measures based on A-weighting are inappropriate"*
• *"Since A-weighting underestimates the sound pressure level of noise with low frequency components, a better assessment of health effects would be to use C-weighting"*
• *"It should be noted that a large proportion of low frequency components in a noise may increase considerably the adverse effects on health"*
• *"The evidence on low frequency noise is sufficiently strong to warrant immediate concern"*
This present study considers some properties of low frequency sounds, their perception, effects on people and the criteria which have been developed for assessment of their effects. Proposals are made for further research, to help to solve the continuing problems of low frequency environmental noise.

2.7.1 Propagation. Similar factors influence the propagation of low frequency noise
to those which influence infrasound. However, because of the higher frequencies, air and other attenuations are greater for low frequency noise than for infrasound and more is known about them. Typical air attenuations at 20oC and 70% relative humidity are:
9
63Hz - 0.1dB/km
125Hz - 0.35dB/km
250Hz - 1.1dB/km
which shows very low attenuation at 63Hz.
In addition to these there is reduction of 6dB per doubling of distance due to spreading out of the wave and any reduction which might occur due to absorption over the ground or by shielding. It is seen that air attenuations are a small contributor to losses at low frequencies but, since attenuation increase rapidly as frequency rises, air attenuation can be a main contributor at much higher frequencies in the kilohertz range. As a result, noise which has travelled over long distances is normally biased towards the low frequencies.

2.7.2 Control. Low frequency noise and infrasound are steps along the same physical process of wave propagation, so that similar considerations apply to their control, although the shorter wavelengths of low frequency noise make control easier. Thus, a massive single partition, or a complex multiple partition, is needed to stop low frequency noise, with results which improve as the frequency increases. But most walls in buildings are deficient in the low frequency region, so that noise transmission between rooms, and from outside to inside, is a problem. Absorption of low frequency noise requires thick material, such that most sound absorbing linings.

5.6 The "cognitive itch". It has been suggested by Sargent (Sargent, 1996) that subjects could become sensitive to a noise, possibly developing an ongoing "memory" of it. We have all experienced certain "catchy" tunes repeating in the head . the "cognitive itch" (Kellaris, 2001). The main characteristics of such tunes are repetition, simplicity and incongruity, all of which hold the attention. In particular, repetition causes an automatic pattern echo in the brain. The "cognitive itch" metaphor arises since, in the same way that one scratches an itch, the cognitive itch demands attention through internal repetition of its sounds. It is related to endomusia, a syndrome in which melodies are recalled in the head, possibly to an obsessive extent .

A similar effect to the cognitive itch may be relevant to some of the low frequency noise problems, in which exposure has developed a memory of the noise.

15

Yamada and colleagues (Yamada, 1980) reported male and female thresholds separately, measured in a pressure chamber at third octave frequencies from 8Hz to 63Hz. For his subjects, women were about 3dB more sensitive than men except at the lowest two frequencies, 8Hz and 10Hz. It was also found that individual differences are large, one male subject having a threshold which was 15dB more sensitive than the average.

It is clear that the audiogram is not a smooth curve and that there are pronounced individual differences. Low frequency audiograms of complainants have shown that some hum complainants have low frequency hearing which is more sensitive than the average threshold, whilst others are less sensitive (Walford, 1978; Walford, 1983), as would be expected in any population of subjects. Thus, complainants do not necessarily have enhanced hearing acuity at low frequencies.

4.3 Loudness at low frequencies. Loudness is also a .quasi-objective. measurement, although, as with the threshold, its determination depends on the subject.s responses. Loudness is measured against the loudness of a tone at 1000Hz. Experimentally, the subject adjusts the level of the sound under investigation until it sounds equally loud to the 1000Hz reference tone. This is the way in which the equal loudness contours of ISO 226:1987, shown in Figure 8 were developed. It is also possible to use an intermediate frequency, F2, first comparing F2 with the 1000Hz reference and then the test tone, F3, with F2, in order to compare F3 with 1000Hz. For example, 50Hz might be compared directly with 1000Hz, but lower frequencies compared directly with 50Hz and indirectly with 1000Hz. The unit of loudness is the "phon", which is the level of a 1000Hz tone that has the same loudness as the test tone when the tones are presented as plane waves, with the subject facing the direction of the waves.

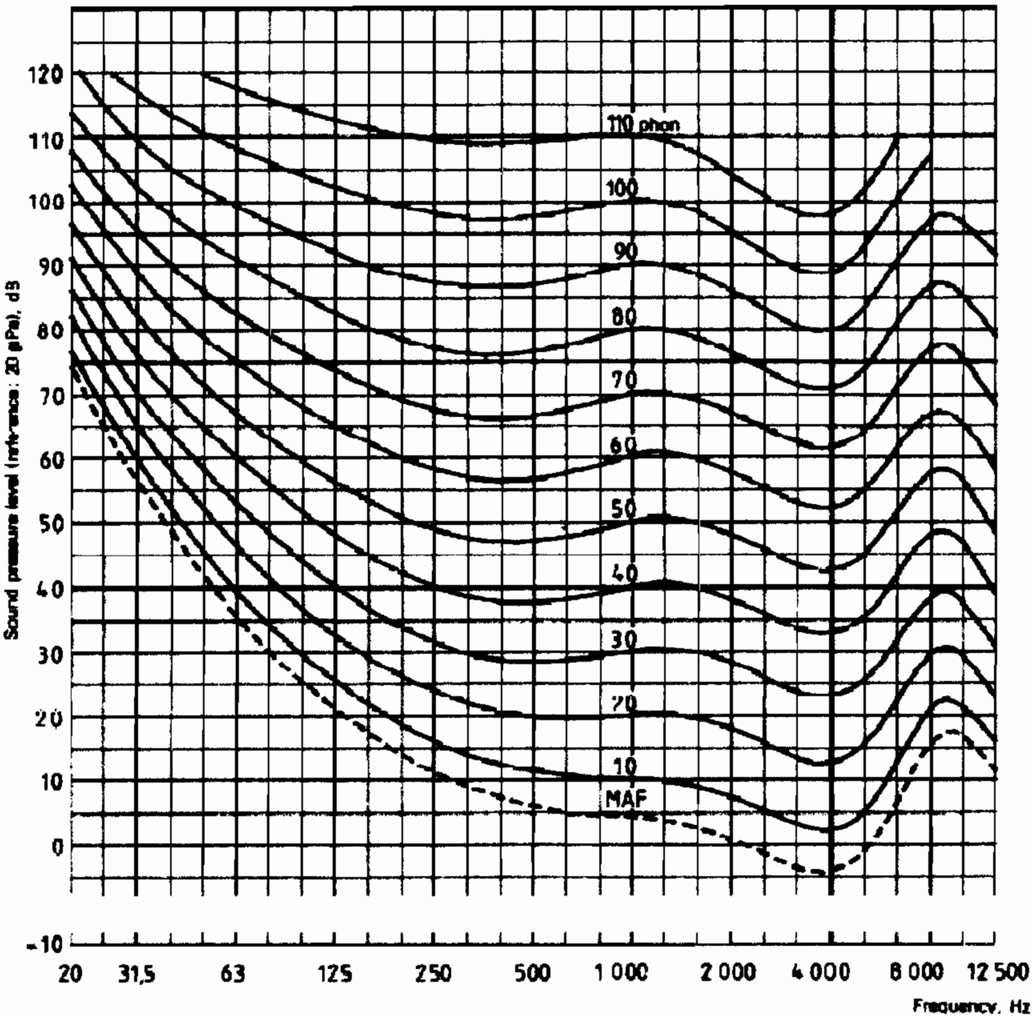

Figure 8. Equal loudness contours (ISO 226).

8. Annoyance

8.1 The meaning of annoyance. Annoyance has roots in a complex of responses,
which are moderated by personal and social characteristics of the listeners. (Belojevic and Jokovljevic, 2001; Benton and Leventhall, 1982; Fields, 1993; Grime, 2000; Guski, 1999; Guski et al., 1999; Kalveram, 2000; Kalveram et al., 1999; Stallen, 1999).

For example, Guski (1999) proposes that noise annoyance is partly due to acoustic factors and partly due to personal and social moderating variables, which are shown in Table 3. Noise annoyance in the home is considered as a long-term negative evaluation of living conditions, dependent on past disturbances and current attitudes and expectations. Annoyance brings feelings of disturbance, aggravation, dissatisfaction, concern, bother, displeasure, harassment, irritation, nuisance, vexation, exasperation, discomfort, uneasiness, distress, hate etc, some of which combine to produce

the adverse reaction.
Personal Moderators Social Moderators
Sensitivity to noise Evaluation of the source
Anxiety about the source Suspicion of source controllers
Personal evaluation of the source History of noise exposure
Coping capacity with respect to noise Expectations
Table 3. Noise Annoyance Moderators.

Figure 13, modified from Guski (1999) in order to emphasise the central nature of the personal factors, summarises the interactions. The interpretation of Figure 13 is as follows. The noise load causes activity interference (e.g. to communication, recreation, sleep), together with vegetative reactions (e.g. blood pressure changes, defensive reactions). Activity interference develops into annoyance and disturbance. Prolonged vegetative reactions may lead to effects on health. Personal factors feed into the outer boxes of Figure 13, moderating the complainant's complex of responses. The social factors moderate how the complainant interacts with external authorities in attempting to deal with the annoyance. Social factors may also interact with health effects, as some social classes may more readily seek medical assistance. The personal and social moderating factors are so variable that Grime (2000) questions the feasibility of a national noise policy.

8.2.5 Unpleasantness. The "unpleasantness" of low frequency noise has also been
estimated (Inukai et al., 2000; Nakamura and Inukai, 1998). Nakamura and Inukai used a stimulus sound of a pure tone in 20 conditions from 3Hz to 40Hz and pressure levels from 70dB to125dB, with evaluation by 17 subjects. There were four main subjective factors in response to low frequency noise: auditory perception, pressure on the eardrum, perception through the chest and more general feeling of vibration. (In actual problems in the field, a fifth factor is the failure of assessment methods, which intensifies other responses). Analysis of the responses showed that auditory perception was the controlling factor.

16. Validation of the Methods

Piorr and Wietlake (1990) used a night reference curve identical to DIN 45680 up to 63Hz. They reported that 90% of complainants were satisfied with the implementation of the limits. Subsequently, Piorr and Wietlake's night criterion was applied to investigations in the UK (Rushforth et al., 2002) and found to be a "reasonably good predictor of annoyance".
Laboratory measurements using recordings of actual noises (Poulsen, 2002; Poulsen and Mortensen, 2002) have been used to compare the effectiveness of proposed national assessment methods for low frequency noise limits. The noise examples are shown in Table 12.
No. Name Description Tones, characteristics
1 Traffic Road traffic noise from a
highway

None . broadband,
continuous
2 Drop forge Isolated blows from a drop forge
transmitted through the ground
None . deep, impulsive
sound
3 Gas turbine Gas motor in a power plant
25 Hz, continuous
4 Fast ferry High speed ferry; pulsating tonal
noise
57 Hz, pass-by
6 Generator Generator 75 Hz, continuous

5 Steel factory Distant noise from a steel rolling
plant
62 Hz, continuous
6 Generator Generator 75 Hz, continuous
7 Cooling Cooling compressor (48 Hz, 95 Hz) 98 Hz,
continuous
8 Discotheque Music, transmitted through a
building
None, fluctuating, loud
drums

Table 12. Comparison of test noises.

Noise no. 1 is from a busy six-lane highway and it is almost continuous. Noise no. 2 consists of a series of very deep, rumbling single blows from a drop forge.

3 Gas turbine Gas motor in a CHP plant
25 Hz, continuous

Noises 3, 4, 5, and 6 each have one tonal component. Noise no. 7 has three tones but two of them are at a low level, and noise no. 8 has a characteristic rhythmical pulsating sound. The noises were selected to represent typical low frequency noise known to cause complaints. All noises had a clear low frequency character.

H. British Medical Journal: Annoyance due to low frequency hums

BMJ helping doctors make better decisions
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Annoyance due to low frequency hums

Hums - low frequency noises - cause much annoyance and may have other non-auditory effects on health. The issue is one of the most enigmatic factors in the assessment and control of environmental noise.

Over the past 20 years both scientific and lay publications have repeatedly drawn attention to mysterious hums, for which there often seems to be no explanation.[1,2] Universities, government departments, research establishments, and industrial and public companies have all been concerned,[3,4] as have learned societies, charities, and sufferers' associations. [5,6] What are these hums, and why are there no clear explanations?

Audible sound is in the frequency range 20-20 000 Hz. "Infrasound" is inaudible sound in the frequency range 1-20 Hz - and if it is sufficiently intense it is sensed rather than heard. "Low frequency sound" is audible sound in the range 20-150 Hz. Hums seem to be perceived in the range 1-150 Hz, in which physical measurement is difficult.

Hums are associated with noise problems that cannot be routinely solved by acoustic consultants or environmental health officers. Typically, in around a tenth of cases no clear cause can be found - and this results in an element of mystery and much conjecture.[7] Hums are often linked with the supply of utilities, waste pipes, ionisation and electromagnetic radiation equipment, industrial plants, and pumping and combustion machinery. Common descriptions include "an incessant hum," "like an airplane stuck in the sky," "feels like a tremendous surge of energy," and "continuous throbbing day and night."

Someone investigating an elusive hum should pay close attention to the following considerations. Firstly, many cases can be solved by a competent acoustic engineer using sensitive equipment that measures and analyses sound to a standard above that normally expected in routine investigations. The engineer may also eliminate wrongly suspected causes. All this depends on the hum being perceived when the engineer is on site - often not the case - and account being taken of such features as meteorological and propagation effects, ground and structural vibrations, and masking effects of other background noises.

Attention should also be paid to physiological causes. Tinnitus commonly (but by no means always) accompanies hearing loss and is not caused by any environmental agent. People with normal hearing may also suffer tinnitus. The sounds are commonly described as hissing, ringing, clattering, and humming in the ears. Tinnitus becomes more apparent in quiet surroundings and is more likely to be noticed by someone resting or in bed, and when the ears are occluded. Tinnitus is not frequency specific and consequently does not always manifest itself by a low frequency sound.

Tinnitus often has no known cause, and its confirmation requires comprehensive audiological investigation. After its diagnosis a course of rehabilitation is often recommended, for little can be done to alleviate the symptom - fortunately not life threatening - which the patient has to learn to live with.

Sometimes, then, the cause of an annoying hum can be related to tinnitus, particularly if there is a sole complainant and other close family and neighbours cannot hear the noise - though some persistence is often necessary to get the complainant to acknowledge the explanation.[8] An important variant of tinnitus should be suspected when descriptions such as incessant hum, energy surges, and continuous throbbing are used, and when the complainant's behaviour changes. When extreme measures are adopted such as attempting physically to escape from the noise by temporarily moving location or altering sleeping habits, and when the complainant is greatly upset by a noise that no one else has heard, a brain tumour should be suspected and neurological investigations begun.

Increased sensitivity in hearing at low frequencies may account for some people being more able than others to detect quiet but nevertheless annoying hums.[9] Laboratory investigations of the fine structure of hearing at frequencies below 150 Hz have so far proved inconclusive, and the special facilities needed to reproduce frequencies down to 20 Hz have limited research to a few specialist institutes. The suggestions that ionisation and electromagnetic radiation may also induce sensations of hearing in some people need further evaluation.

What conclusions can be drawn about these elusive hums? They are perceived by enough people to be an important source of annoyance, and when the problem is unresolved substantial stress may be caused.[10] In theory, if the correct but complex measurements are undertaken by an acoustic engineer then specific sources ought to be either identified or excluded. If this procedure fails then consultant neuroaudiological investigations ought to be carried out to exclude a physiological cause. If these time consuming and expensive procedures fail it is usually very difficult to come up with an explanation despite there being little doubt about the distress being caused. No doubt further research will be carried out, but probably each case will prove to be as different and as individual as the complainants themselves.

C G Rice

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1. Broner N. The effects of low frequency noise on people - a review. *Journal of Sound and Vibration* 1978;58:483-500.

2. Fox B. Low-frequency "hum" may penetrate the environment. *New Scientist* 1989;124:27.

3. Department of the Environment Noise Review Working Party. Low frequency noise. London: HMSO, 1990:27.

4. Howell K. A review of low frequency noise investigations by British Gas. *Journal of Low Frequency Noise and Vibration* 1993;12:45-66.

5. Discussion at end of 3rd international conference on low frequency noise and vibration, London. *Journal of Low Frequency Noise and Vibration* 1985;4:168-80.

6. Griggs E. The Low Frequency Noise Sufferers Association. *Journal of Low Frequency Noise and Vibration* 1990;9:149-55.

7. Tempest W. A survey of low frequency noise complaints received by local authorities in the United Kingdom. *Journal of Low Frequency Noise and Vibration* 1989;8:45-9.

8. Walford RE. A classification of environmental "hums" and low- frequency tinnitus. *Journal of Low Frequency Noise and Vibration* 1983;2:60-80.

9. Frost FP. An investigation into the microstructure of the low frequency auditory threshold and of the loudness function on the near threshold region. *Journal of Low Frequency Noise and Vibration* 1987;6:34-9.

10. Benton S, Leventhall HG. The role of background stressors in the formation of annoyance and stress responses. Proceedings of the 7th international meeting on low frequency noise and vibration, Edinburgh, April 1993. Brentwood: Multiscience, 1993:5-14.