The influence of low frequency and infrasonic noise on man

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It is quite obvious that noise at low frequencies (20 to 200 Hz) and infrasound (below 20 Hz) will be an important part of the total noise levels generated by the proposed LNG tankers. Not only do the ships emit considerable amounts of acoustic power at these frequencies, the propagation loss of ship noise at these low frequencies is very low.

During the last 10 to 15 years, several effects of low frequency and infrasonic noise on human beings have been demonstrated, ranging from slight annoyance at low sound pressure levels to severe physiological effects at very high levels. The effects on humans cannot be directly applied to marine mammals such as whales and seals, especially not for specific frequencies and sound pressure levels. However, it is important to be aware of these potential effects and to evaluate them in relation to marine mammals. The present paper does not provide such an evaluation but does present a short summary of the effects on human beings, without going into details about frequencies and levels.

The most well-known effects are those on the hearing capability of humans. Among these effects are masking of "wanted" sound (Alford et al. 1966, Connor and Yeowart 1974, Doroshenko and Palgov 1975, Yeowart 1973), for example vocal communication, which is the subject of several other contributions to this workshop. Other effects are disturbance of the hair cells in the inner ear which causes temporary or permanent hearing impairment (Alford et al. 1966; Coles and Guignard 1965; Doroshenko and Palgov 1975; Hood, Kyriakides and Leventhall 1971; Lidström and Liszka
1976; Nixon 1973), pain from overloading of the middle ear (Cole et al 1965; Davis et al 1953; Evans 1976) and, at very high levels, rupture of the tympanic membrane (Johnson 1973 for data from a chinchilla). Also, disturbance of the vestibular system may result in balance disturbance and nystagmus (Alford et al 1966; Bazarov, Doroshenko and Palgov 1977; Bryan, Evans and Tempest 1972; Cole et al 1965; Davis et al 1953; Evans and Tempest 1972; Hood, Kyriakides and Leventhall 1971; Okai et al 1980; Yeowart 1971; on animals: Gierke, Parker and Reschke 1970 and Gierke and Parker 1971). These effects are probably induced by liquid flow through the small endolymphatic duct between the cochlea and the vestibularis.

Because of resonances in the lungs, stomach and other compressible parts of the body, unpleasant and possibly dangerous tissue vibrations may also result from low frequency sound. The Helmholtz resonator effect created by the lungs and throat may cause disturbances of respiration (Alford et al 1966; Barthelemy et al 1971; Cole et al 1965; Evans 1976; Grognot 1969; Okai et al 1980) which at very high pressure levels has even caused cessation of breathing in a dog; the dog did not die because the sound itself provided sufficient air exchange in the lungs (Johnson 1973).

Although it is generally believed that human hearing has a limiting frequency of 16 to 20 Hz, this is, in fact, not true. The human ear is able to detect sounds with frequencies at least down to 1 to 2 Hz (Békésy 1960; Bryan, Tempest and Yeowart 1967; Bryan, Tempest and Yeowart 1969; Collins, Robinson and Whittle 1972; Evans and Yeowart 1974; Franke and Dancer 1980; Gierke and Johnson 1974; Guttmann and Julesz 1963; Okai et al 1980; Rubak 1980; Yeowart 1971; Yeowart 1976). For these infrasonic frequencies, the hearing threshold level is higher than for the normal hearing range (Figure 1).

An important feature of infrasound is that it only needs to be slightly above the hearing threshold level to be subjectively loud and annoying (Bryan 1976; Bryan and Tempest 1979; Gordon and Vasudevan 1977; Leventhall 1980; Tempest 1973; Yamada et al 1980). This annoyance may be the source of some effects on task performance (Evans and Tempest 1972; Hood, Kyriakides and Leventhall 1971; Kyriakides and Leventhall 1977; Landström
1980; Møller 1980) and some stress-like physiological effects observed in humans experiencing infrasound exposure, such as changes in blood pressure, heart rate, EEG and production of certain hormones (Alford et al 1966; Barthelemy et al; 1971; Borredon and Nathie 1973; Cole et al 1965; Edge and Mayes 1966; Grognot 1969; Ising 1980; Landström 1980; Lidström and Liszka 1976; Okai et al 1980).

Only in a few countries do maximum limits on infrasonic exposure exist (Arbetarskyddsstyrelsen 1978; Arbeidtilsynet 1979; Brüel 1980; Gierke 1977). In the writer's opinion, the most reasonable limits on infrasonic exposure are those guidelines recommended in the United States (Gierke 1977). They provide two sets of limits (Figure 2). Limit A is intended to prevent direct physiological effects and is applicable for exposure times below 1 minute. Limit B is intended to prevent annoyance effects and is applicable for exposure times above 100 minutes. For exposure times between 1 and 100 minutes, an interpolation procedure is given. Limits are recommended for pure tone exposure but it is not stated how broadband noise should be measured. A possible solution would be measurements in the 1/3 or 1/1 octave bands.

Recommended limits for underwater exposure of marine mammals to low frequency and infrasound are completely uncertain. There are several reasons for not using the same limits as for human beings. However, these limits are the only ones available. Figure 3 illustrates the expected 1/1 octave sound pressure levels at two different distances from an LNG carrier cruising at a speed of 4 kt in heavy ice. The reader is free to make his own comparison of Figures 2 and 3.

REFERENCES


Yeowart, N. S. 1971. Low frequency threshold effects. IN: British Acoustical Society Meeting on Infrasound, 26th November 1971, University of Salford.


Figure 1. Hearing threshold level of the human ear stimulated by pure sinusoidal tones. The solid line is a standardized curve (ISO - 226), while the dotted line is based on data from Evans and Yeowart (1974).
Figure 2. Recommended maximum limits for human exposure to pure tones (Gierke 1977)
Figure 3. Expected 1/1 octave sound pressure levels in two distances from the ship cruising at a speed of 4 knots in heavy ice. Figures are based on the source levels agreed upon at the workshop: (a) broadband noise of the spectral density being flat at a level of 189 dB re 1 µPa Hz$^{1/2}$ below 50 Hz and above this decreasing 20 dB per decade; plus (b) pure tones at 8.6 Hz and harmonics of that, the first three being 201 dB each, and from the fourth decreasing 5 dB per harmonic.