Airborne Ultrasound: Measurement and Possible Adverse Effects

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Food and Drug Administration

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Airborne Ultrasound: Measurement and Possible Adverse Effects

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Standardization of Protection
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FOREWORD

The Bureau of Radiological Health develops and carries out a national program to control unnecessary human exposure to potentially hazardous ionizing and nonionizing radiations and to ensure the safe, efficacious use of such radiations. The Bureau publishes the results of its work in scientific journals and in its own technical reports.

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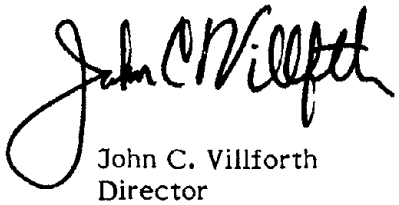

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PREFACE

The Division of Electronic Products (DEP) of the Bureau of Radiological Health, Food and Drug Administration, conducts a program of scientific and technical evaluation of radiation-emitting electronic products as part of the FDA's effort to implement the Radiation Control for Health and Safety Act of 1968, PL90-602.

Products emitting airborne ultrasound are increasingly used in consumer and industrial applications. It has been reported that certain individuals can experience pain or irritation from airborne ultrasound. As greater numbers of people are exposed to this form of energy, an assessment of possible biological hazards becomes important.

This report reviews the bioeffects research literature and various proposed exposure-limiting criteria. Measurement techniques for airborne ultrasound are discussed and typical output levels from intrusion alarms and other devices producing this acoustic radiation are compared with these criteria.

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ABSTRACT

Herman, B.A. and D. Powell. Airborne Ultrasound: Measurement and Possible Adverse Effects. HHS Publication (FDA) 81-8163 (May 1981).

A literature study was undertaken to investigate research efforts concerning possible adverse effects of airborne ultrasound on humans. Findings of this research, as well as proposed exposure-limiting criteria are presented. Measurement techniques for airborne ultrasound are reviewed and the results of output measurements of devices producing this acoustic radiation are discussed.

AIRBORNE ULTRASOUND: MEASUREMENT AND POSSIBLE ADVERSE EFFECTS

INTRODUCTION

Ultrasound energy in the range of 16 kHz to 100 kHz is used in a variety of consumer and industrial applications, although most are below 50 kHz. For consumer devices the intended transmitting medium is usually air while industrial processes usually use liquid or solid materials as propagating media. In the latter situation there typically is attendant acoustic energy radiated into the surrounding atmosphere.

APPLICATIONS

Currently marketed consumer products using airborne ultrasound include intrusion alarms, television remote controls, rodent and pest repellers, automatic door openers, dog repellers and guidance devices for sightless people.

Industrial applications involving ultrasound include cleaning and degreasing, drilling, welding plastics and metals, emulsifying, homogenizing and vaporizing liquids. These devices produce airborne ultrasound only as stray radiation. Of course, several of the consumer type devices (intrusion alarms, pest repellers) are also found in industrial situations and vice versa.

MEASUREMENT

Quantitative measurement of both audible acoustic and ultrasound intensity is usually given in terms of sound pressure level (SPL). A logarithmic scale is used and relative SPL's are given in terms of dB (decibels) with respect to a reference level (SPL_r). The equation used to compare SPL's is:

$$dB = 20 \log (SPL/SPL_r)$$

The standard reference level usually used is 20 micropascals (μPa), where 1 pascal equals 1 newton per square meter. This reference pressure corresponds approximately to the weakest sounds a human being can hear (in the audible range obviously), which is 10^{-12} watts per square meter.

Occasionally, relative levels are given directly in terms of intensity (I) units (power per unit area). These also are in dB and the governing equation is:

$$dB = 10 \log (I/I_r)$$

where I_r is the standard reference intensity (usually 10^{-12} watts per square meter).

These equations, both in dB, are internally consistent because the intensity at a particular position is proportional to the square of the SPL at that position. Thus:

$$dB = 10 \log (I/I_r) = 10 \log (SPL/SPL_r)^2 = 20 \log (SPL/SPL_r)$$

A 6 dB difference in SPL or intensity corresponds to a doubling of the sound pressure level or to a quadrupling of intensity level.

The 20 μPa reference level given above, chosen for being barely audible, is also used in the ultrasound range even though ultrasound is usually defined as acoustic energy beyond the frequency range of human hearing. In fact, there is some ambiguity in this definition, since the upper frequency hearing limit can vary greatly with each individual. Some people (usually women or young children) can perceive sound at 20 kHz, but most adults' upper limit is less than 18 kHz. High frequency hearing capability decreases with age. These facts have relevance when discussing biological effects, since some researchers (2,5) believe it is primarily the extremely high audible frequency components that affect human beings.

Ultrasound is rapidly attenuated in air. For example, at 40 kHz a beam of ultrasound loses approximately 0.5 dB per foot. This attenuation decreases with a lowering of the acoustic frequency. Design of devices utilizing airborne ultrasound must take this absorption factor into account, and this can have relevance to possible hazards to human beings within the radiation field of such devices. This is described in more detail in another section.

INSTRUMENTATION

The actual determination of dB levels at various positions in an airborne ultrasound field can be made with any of several commercially available systems. These usually include a capacitor microphone sensing element, flat in frequency response within the range of interest and signal processing circuitry. Typically, this circuitry includes a set of third-octave filters so that the additive SPL within any particular third-octave frequency range is shown on the meter. Thus a spectrum of SPL as a function of frequency (to third-octave resolution) can be obtained by 'stepping through' the filter set. The specific instrumentation used by BRH in its survey of devices producing airborne ultrasound is discussed in the Appendix.

Measurements are made this way, rather than by using the standard A, B, or C weighting schemes associated with audible acoustic radiation for several reasons. These curves-- A, B, and C--designed to approximate the frequency response of the human ear at low, medium and high intensities, respectively, fall off rapidly within the region of interest for airborne ultrasound, and are defined with large allowed tolerances at these frequencies (+ 3, - 6 dB). Therefore, instruments designated to these tolerances are not very accurate. Also, biological effects seem to arise from "single frequency" components (1); i.e., the additive SPL's over a broad frequency range may not be important, but rather the individual levels in narrow bandwidths. Studies correlating the A, B, or C curves with biological effects in the audible range have dealt primarily with hearing loss at frequencies below 8 kHz. (No standard currently exists that describes 'normal' hearing above 8 kHz.)

AUDITORY AND NONAUDITORY PHYSIOLOGICAL EFFECTS

When airborne ultrasound impinges on human skin, less than 1 percent is absorbed, the remainder being reflected. The ear, however, is an efficient coupler of acoustic energy from air into the human body. Therefore, investigators looking at the biological effects of this energy have tended to concentrate on hearing-related impairments.

Some early investigations, however, did deal with internal and skin heating by airborne ultrasound. It was found that levels of approximately 152 dB are required to kill rats and guinea pigs via body temperature increase. Parrack (2), extrapolating to human beings, calculated a uniform airborne ultrasound level of more than 180 dB as a lethal whole body exposure. This level is many thousands of times greater than that produced by any known product. Immersing a portion of a body in a fluid through which ultrasound is propagating

could, of course, heat that portion much more efficiently than airborne exposure, since there is less reflection at a water-skin interface than at an air-skin interface.

Reports of both a drop (and increase) of blood sugar levels have been reported, as well as changes in the electrolyte balance of nervous tissue (3), but neither frequency nor sound pressure levels were given. These findings have not been confirmed by other researchers such as Grigor'eva (4), who found no significant physiological changes using 110 dB, 20 kHz ultrasound for a 1-hour exposure time.

Studies of industrial workers exposed to levels of ultrasound at approximately 120 dB failed to find either temporary or permanent losses of hearing (5). However, temporary threshold shifts (TTS) were noted in the hearing of subjects used in experiments conducted by Parrack (2). He noted TTS at subharmonics of discrete test frequencies in the range of 17 kHz to 37 kHz in subjects exposed for approximately 5 minutes to 150 dB airborne aoustic energy. These shifts were attributed to nonlinear distortion of the eardrum, which produces audible sound within the ear. It has long been assumed by investigators that a temporary threshold shift is a sufficient condition, if continued over an extended period of time, for a permanent threshold shift in hearing.

SUBJECTIVE EFFECTS

Effects reported by workers near ultrasound producing devices include fatigue, headaches, tinnitus, nausea, irritability, and a 'fullness' in the ear. Researchers have corroborated these symptoms (in an industrial setting) and lumped them under the general term "subjective." At the same time, these studies tend to indicate that it is primarily the high frequency, barely audible components of the acoustic energy that are responsible for these effects.

For example, Acton and Carson (5) investigated a situation where several women, working in a factory near a bank of ultrasonic cleaners, complained of "subjective" effects (fatigue, headaches, nausea, tinnitus). These symptoms were also experienced by several objective observers. Audiometric examinations showed that only those workers with normal hearing at the upper end (12 kHz) of the tested range (all women) were affected. Furthermore, cleaners producing high levels ($\simeq$ 90 dB) at 16 kHz, but without intense radiation at 20 kHz and 25 kHz, caused the same symptoms as did devices radiating at high levels within all three of these third octave bands. Two of the workers involved were also tested in the laboratory, using the output from a Galton whistle. Complaints of "subjective" effects were forthcoming when acoustic levels were 78 dB at 16 kHz (third-octave band centered at 16 kHz) but radiation of 100 dB at 20 kHz and 25 kHz failed to cause any effects.

No in-depth study is available concerning adverse responses to consumer products emitting airborne utrasound. There is anecdotal information, however, usually involving intrusion alarms or pest repellers. Young people and females, who in general have better high frequency hearing response, seem to be the most affected. This tends to reinforce the theory that audible high frequency components are the major causative factor.

PROPOSED EXPOSURE LIMITS

Criteria limiting human exposure to airborne ultrasound have been suggested by several sources.

In England, a voluntary standard developed by W.I. Acton (6,7) allows sound pressure levels to 75 dB within third-octave bands centered on frequencies up to 20 kHz (over a working day). Permitted levels are 110 dB in third-octave bands centered on 25 kHz and above. Acton's rationale for extending the 75 dB limit to the 20 kHz third-octave band is

that the lower half of this band is in the audible frequency range of a few people. This approach extends the usable frequency range of the ISO (International Organization for Standardization) "Noise Rating Curve Number 85" (proposed as a criterion for hearing damage by audible acoustic energy). Acton's proposal is listed in the World Health Organization report of June 6, 1977. Parrack, in the United States, proposed exposure limits to the ANSI (American National Standards Institute) Working Group S3-W40. These limits were set at 80 dB per third-octave up to 16 kHz (center frequency) range, 105 dB for the 20 kHz third-octave band, 110 dB for the 25 kHz third-octave band and 115 dB for higher frequencies (10). These limits are for approximately 8 hours per day, 5 days a week. The American Conference of Governmental Industrial Hygienists (ACGIH) also recommends Parrack's criteria (12).

Grigor'eva of the Soviet Union proposed an allowed level of 120 dB for exposure to ultrasound noise above 20 kHz, 90 dB within the third-octave band centered at 16 kHz and 12.5 kHz, and 85 dB for the third-octave band centered at 10 kHz (9). No exposure duration or qualifications as to band width above 20 kHz were given, however. Therefore, the proposed criteria are somewhat ambiguous. The only official American standard limiting exposure to ultrasonic energy is the United States Air Force Regulation 161-35. This document requires ear protection whenever SPL's exceed 85 dB per third-octave, within the frequency range of 12.5 kHz to 40 kHz (8). These criteria (above 25 kHz) seem extremely conservative when compared with the other proposals. The Canadian Department of National Welfare has recommended allowed levels of 80 dB from 6.3 kHz to 20 kHz (center frequency of third-octave bands) and 110 dB beyond 20 kHz centered third-octave bands (13). Table 1 compares the criteria given above.

Table 1. Proposed exposure limits

Midfrequency of third-octave band (kHz)	SPL levels within third-octave band (in dB reference 20 micropascals)				
	Acton	Parrack	Grigor'eva	U.S. Air Force	Canada
8	75	80	80	-- [a]	80
10	75	80	85	-- [a]	80
12.5	75	80	90	85	80
16	75	80	90	85	80
20	75	105	120[b]	85	80
25	110	110	120[b]	85	110
31.5	110	115	120[b]	85	110
40	-- [a]	115	120[b]	85	110
50	-- [a]	115	120[b]	-- [a]	110

[a]No criteria given for these third-octave bands
[b]120 dB is allowed additive value over all frequencies beyond 20 kHz

DISCUSSION

The range and number of products emitting airborne ultrasound are constantly growing. Studies to date tend to indicate that the audible high frequency sound often associated with these emissions is primarily responsible for any adverse effects encountered. These effects include hearing damage and "subjective" symptoms. A comprehensive review of relevant research is given by Michael (1).

Several researchers, notably Acton in England and Parrack in the United States, have proposed exposure limits for airborne ultrasound. Their allowed levels are reasonably similar throughout the frequency range dealt with. Acton's criteria, although having no legal or official status, have been widely adopted in England.

It should be noted that relatively few biological effect studies involving airborne ultrasound have been undertaken, when compared to research utilizing other radiaton modalities: x rays, microwaves, clinical ultrasound, and so forth. A question not sufficiently explored is whether levels high enough to cause "subjective" effects can promote adverse physiological changes over a long time period, such as changes in the cardiac or nervous systems. Questions as to whether unusual frequency spectra or time variation of the ultrasound intensity (pulse versus continuous radiation) are important factors are still left unanswered.

Studies designed to monitor exposure or long term dose and correlate it with "subjective" effects encounter several problems. In an industrial setting, the presence of organic vapors, wideband noise sources, and a generally stressful environment often obscure an easy correlation between bioeffects and acoustic levels. These last two factors may also be present in office and home situations. Furthermore, the symptoms classified as "subjective" are easily created psychosomatically, and can be greatly dependent on an individual's specific frame of mind.

Specific measurement problems also arise. When using sound pressure level meters (exposure type measurement) placement is critical, since pivoting the microphone by a few degrees or displacing it a few centimeters may cause as much as a 5 dB variation in reading. Unless the ultrasonic field is mapped in some detail, the highest levels can be overlooked since the acoustic radiation may be highly directional at these frequencies.

Cumulative exposure effects characterized by the concept of total dose may also be an important factor, as it is in the low audible region. To date, however, there is no biological effects hypothesis upon which to base criteria or recommendations, and no portable dosimeter capable of good response up to 40 kHz.

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APPENDIX: AIRBORNE ULTRASOUND SURVEY SUMMARY

INTRODUCTION

During 1978 and 1979, a limited survey of intrusion alarms and selected other devices producing airborne ultrasound was undertaken. Nine installations utilizing intrusion alarms were visited, including four department stores, a government credit union, a private home, a small store, a large government office complex and the manufacturing plant of a company producing these devices. In some locations more than one unit was tested.

In addition, the output levels produced by an ultrasonic cleaner located at a large university were determined. This was also done for a portable ultrasound dog repeller, purchased by the Bureau of Radiological Health and tested in-house. These will be discussed at the end of the Appendix.

EQUIPMENT

The measuring devices used were all manufactured by B & K Instruments (Bruel & Kjaer Precision Instruments, 5111 W. 164th Street, Cleveland, Ohio 44142) and included a 2209 sound level meter, 4149 microphone (1/2 inch), 1616 third-octave filter set, and a 4220 calibration pistonphone. The frequency range of the sound level meter, in conjunction with the microphone and filter set is from 20 Hz (third-octave centered at 20 Hz) to 40 kHz (third-octave centered at 40 kHz). The pistonphone produces a pure 250 Hz tone at 124 dB and was used to calibrate the system each day measurements were made. Overall system operation was within ± 3 dB over the entire range of interest.

SURVEY TECHNIQUE

One position at which measurements were made was chosen to be that which gave the highest sound levels while still within an area likely to be occupied by people. (Levels as high as 140 dB were measured near the surface of some of the radiating transducers.) Sites where workers would remain for long periods of time, such as a desk chair, were also monitored. A rough mapping of SPL's usually was also accomplished. For the manufacturing plant survey, three intrusion alarms (different models) were chosen at random and tested in an anechoic chamber.

The detecting microphone was mounted on a tripod support and placed approximately at ear level. The sound pressure level as a function of frequency in third-octave steps centered at 6.3 kHz to 40 kHz, as well as linear and "A"-weighted readings were then determined.

In addition to the questions incorporated in the survey form (Fig. 1, a and b), inquiries as to the use of and reaction to the ultrasound devices were made of employees working near the alarms.

RESULTS

Table 2 summarizes the major survey results involving ultrasound intrusion alarms. At least four different manufacturers' devices were seen and are designated A, B, C, or D. In some cases the manufacturer could not be determined (because of repackaging by a subsequent distributor) and those are denoted with a question mark.

Table 2. Intrusion alarm results

Facility No.	Type	Manufacturer	Can ultrasound be turned off?	All frequencies Max dB	All frequencies 1/3 octave	Below 25 kHz Max dB	Below 25 kHz 1/3 octave
1	Government office	A	Yes[a]	86	25	61.5	20
2	Factory	A	No	87	25	58	20
	(3 models tested)	A	No	90.5	25	65	20
		A	No	79	25	55	20
3	Department store	B	Yes	89	25	63.5	20
4	Small store	?	No	91.3	40	41	20
5	Department store	C	Yes	63	20	63	20
6	Department store	C	Yes	81	20	81	20
	(2 units tested)	C	Yes	81	20	81	20
7	Department store	?	No	86	20	86	20
8	Credit union	?	No	93	20	93	20
9	Private home	D	Yes	85	40	35	20

[a]Normally "No" but modified to do so

In four cases the ultrasound power could not be turned off by the user, even when the alarm system (bells, sirens, etc.) was not engaged. Two devices allowed the ultrasound to be switched off, but in only one instance had this been done during working hours. Therefore, four units (manufacturing plant excepted) were radiating ultrasonic energy 24 hours per day. The intrusion alarm in the large government office complex normally radiated all the time, but a cut-off switch had been installed onsite. The device found in the private home produced ultrasound only in "detect" mode, i.e., when the alarm system was engaged, thus avoiding unnecessary exposure. (Underwriters Laboratory has stated that they will attempt to incorporate such a provision in their next specification for intrusion alarms (11).

The maximum SPL's and corresponding frequency bands are shown for all frequencies and for those below the 25 kHz third-octave band. This was done to correlate the measured levels with the exposure criteria developed by Acton, which allows 75 dB per third-octave up to the 20 kHz centered band and 110 dB above this frequency. (All intrusion alarms tested radiated substantial energy in only one third-octave band.) Three installations (Nos. 6, 7, and 8) exceeded those levels allowed by Acton.

One of the three (No. 7) located over an escalator, was audible and extremely irritating to the surveyor, though no one else was available for questioning. Another (No. 8) installed in a credit union office was audible to three people (all women) but only for brief periods of the day. No one made any direct correlation between "subjective" effects and the sound, but one woman often experienced headaches after work. A male worker reported that someone was speaking to him when suddenly the speaker cupped his hands over both ears, stated that the high pitched noise was too annoying, and requested that the conversation be moved elsewhere. A few other instances of complaints from patrons were also recalled. No instances of complaints or "subjective" effects were remembered at installation number 6.

The only other instance of anyone complaining of "subjective" effects occurred at the government office complex. A female employee complained that her heart began beating arrythmically when she entered the immediate vicinity of the intrusion alarm. These symptoms supposedly disappeared after a cut-off switch was installed and ultrasound ceased being transmitted during working hours. These symptoms remain unconfirmed. Also, the surveyors experienced no "subjective" effects during testing.

It was mentioned previously that the absorption of ultrasound in air increases as the frequency increases. This could mean that intrusion alarms operating at higher frequencies would have to radiate at greater SPL's to operate properly. Thus, even if higher frequency ultrasound would produce fewer "subjective" effects, the increase of power necessary could mitigate this positive aspect. The devices surveyed by BRH, however, showed no such pattern of greater SPL for higher frequencies. This could indicate that the intrusion alarms radiating ultrasound at lower frequencies could still operate effectively at considerably lower output powers.

ULTRASONIC LABORATORY CLEANER

BRH measured the output levels produced by a 6-kilowatt ultrasound cleaner used to degrease high vacuum components. The device was located at a large university research facility. The laboratory's safety officer, who requested the survey, informed us that personnel using the cleaner often experienced headaches, chest pressure, throat constriction, irritabiity, and tension.

With the cleaner operating as usual, levels at positions where personnel might be were over 80 dB from 6.3 kHz to 20 kHz (third-octave bands), over 70 dB at 25 kHz and 31.5 kHz, and 90 dB at 40 kHz. Forty kilohertz is the nominal operating frequency of the cleaner's energizing transducers, and the high level broadband radiation was probably caused by cavitation within the device's liquid bath.

This typical broadband sonic radiation produced by ultrasonic cleaners makes it difficult to correlate the subjective effects to specific frequency components. Levels encountered are not only above those suggested for high frequency components, but exceed criteria published by the Occupational Safety and Health Administration in 1971 (Standard for Occupational Exposure to Noise (29, CFR 1910.95)). We were informed several months later that the problems encountered were eliminated by surrounding the cleaning tank with foam insulation.

ULTRASONIC DOG REPELLER

BRH purchased a device that was claimed to be an ultrasonic dog repeller, inaudible to humans. Five feet away from and in front of the device, measured levels were 81 dB at 12.5 kHz, 108 dB at 16 kHz and 96 dB at 20 kHz. Levels in all other frequency bands were below 75 dB. Beyond 5 feet, SPL's fell off approximately as an inverse square field (6 dB per doubling of distance). Subjective reaction of laboratory personnel to the acoustic radiation varied from no perception or no symptoms at all, to expressions of severe discomfort 40 feet from the source, in another room.

This device is activated by a spring-loaded switch, automatically shutting itself off when finger pressure is released. Thus, it is unlikely that any long-term exposure to a human being would result from use of this device. The high SPL's produced from 12.5 kHz to 20 kHz (center frequencies for third-octave bands) again make correlation of "subjective" effects to specific frequency components difficult.

AIRBORNE ULTRASOUND SURVEY Date_____

Installation #_____ *** DO NOT RECORD BUSINESS NAME OR LOCATION !!! ***

Type of business (e.g., bank, store, etc.)_____

Type of unit surveyed (use, make, model)_____

_____

INSTRUMENTATION

DEVICE	TYPE	MODEL #	SERIAL #
Sound level meter			
Microphone			
Filters			
Calibrator			

Date of last calibration_____

METEOROLOGICAL DATA

Barometric Pressure_____

Temperature_____

Rel. Humidity_____

TYPE OF SOUND (check one)

Transient____ Tones____

Steady____ Impulse____

ROOM DESCRIPTION

Walls_____

_____

Floor_____

_____

Ceiling_____

_____

MISCELLANEOUS

Mic. distance off floor:

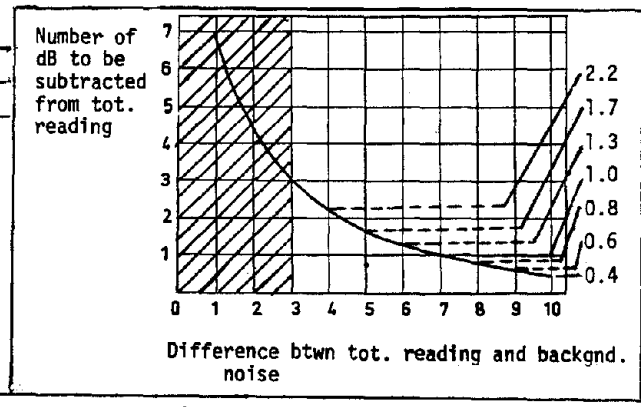
_____

Transmitter dist. off floor:

_____

Dist. from transmtr to mic:

_____



Sketch of site (to scale)-include walls, meter & unit

REMARKS

QUESTIONS

1. Can power to transmitter be turned off?_____
2. Is the switch easily accessible?_____
3. Between what hours is the device left on?_____
4. How old is the device?_____

Surveyor's signature_____

Figure 1a. Airborne Ultrasound Survey Form, Page 1

All dB values referenced to 0.0002 microbars

Position		I Background noise / II Total reading / III Corrected total											
	kHz	6.3	8	10	12.5	16	20	25	31.5	40	50	dBA	Lin
(1) I	dB												
(1) II	dB												
(1) III	dB												
(2) I	dB												
(2) II	dB												
(2) III	dB												
(3) I	dB												
(3) II	dB												
(3) III	dB												
(4) I	dB												
(4) II	dB												
(4) III	dB												
(5) I	dB												
(5) II	dB												
(5) III	dB												
(6) I	dB												
(6) II	dB												
(6) III	dB												
(7) I	dB												
(7) II	dB												
(7) III	dB												

REMARKS

Figure 1b. Airborne Ultrasound Survey Form, Page 2

*U.S. GOVERNMENT PRINTING OFFICE: 1981-0-341-177/37

FDA 80-8116 Chest X-Ray Screening Practices: An Annotated Bibliography (GPO 017-015-00167-9, $3.50) (PB 80-183890, mf only).

FDA 80-8117 X Radiation and the Human Fetus - A Bibliography (PB 80-157712, $20.00).

FDA 80-8118 A Word of Caution on Tanning Booths (brochure).

FDA 80-8119 Measurements of Emission Levels During Microwave and Shortwave Diathermy Treatments (GPO 017-015-00168-7, $1.75) (PB 80-194772, mf only).

FDA 80-8120 Microwave Oven Radiation (brochure) (supersedes FDA 79-8058).

FDA 80-8121 Laser Light Shows Safety - Who's Responsible? (brochure).

FDA 80-8122 Microwave Hazard Instruments: An Evaluation of the Narda 8100, Holaday HI-1500, and Simpson 380M (PB 80-227820, $6.50).

FDA 80-8124 Optimization of Chest Radiography - Proceedings of a Symposium Held in Madison, Wisconsin, April 30-May 2, 1979 (GPO 017-015-00176-8, $7.50) (PB 80-208317, mf only).

FDA 80-8125 Research Into the Biological Effects of Ionizing Radiation in The Bureau of Radiological Health (GPO 017-015-00172-5, $4.00) (PB 80-217268, mf only).

FDA 80-8126 Symposium on Biological Effects, Imaging Techniques, and Dosimetry of Ionizing Radiations (July 1980) (GPO 017-015-00175-0, $8.00) (PB 81-112351, mf only).

FDA 80-8128 The Selection of Patients for X-ray Examinations: The Pelvimetry Examination (GPO 017-015-00174-1, $2.00) (PB 81-113490, mf only).

FDA 80-8129 Possible Genetic Damage from Diagnostic X Irradiation: A Review (PB 81-101743, $6.50).

FDA 80-8130 Nationwide Survey of Cobalt-60 Teletherapy: Final Report (PB 81-101784, $9.50).

FDA 80-8131 Vignettes of Early Radiation Workers: A Videotape Series (flyer).

FDA 80-8135 Hazards from Broken Mercury Vapor and Metal Halide Lamps (Notice of Alert) (pamphlet).

FDA 81-8027 Directory of Personnel Responsible for Radiological Health Programs (supersedes FDA 80-8027, March 1980).

FDA 81-8033 Bureau of Radiological Health Publications Index (supersedes FDA 79-8033) (PB 81-156192, $18.50).

FDA 81-8034 Report of State and Local Radiological Health Programs, Fiscal Year 1979 (PB 81-167678, $6.50).

FDA 81-8042 CSU-FDA Collaborative Radiological Health Laboratory Annual Report 1979.

FDA 81-8070 Bureau of Radiological Health Publications Subject Index (supersedes FDA 80-8070, May 1980) (PB 81-149478, $5.00).

FDA 81-8136 Optical Radiation Emissions from Selected Sources: Part I - Quartz Halogen and Fluorescent Lamps (GPO 017-015-00177-6, $6.50) (PB 81-139693, mf only).

FDA 81-8139 Quality Assurance in Diagnostic Ultrasound - A Manual for the Clinical User (GPO 017-015-00179-2, $4.00) (PB 81-139727, mf only).

FDA 81-8141 Quality Assurance in Diagnostic Radiology and Nuclear Medicine - The Obvious Decision (PB 81-164477, $14.00).

FDA 81-8142 Use of Photographic Film to Estimate Exposure Near the Three Mile Island Nuclear Power Station.

FDA 81-8146 Radiographic Film Processing Quality Assurance: A Self-Teaching Workbook (GPO 017-015-00180-6. $4.00) (PB 81-163974, mf only).

FDA 81-8147 Quality Assurance in Diagnostic Radiology: A Guide for State Program Implementation (PB 81-175747, $9.50).

FDA 81-8150 The Correlated Lecture Laboratory Series in Diagnostic Radiological Physics (GPO 017-015-00184-9, $4.50).

FDA 81-8151 A Feasibility Study of the Biological Effects of Fallout on People in Utah, Nevada, and Arizona.

FDA 81-8152 Annual Report of the Division of Biological Effects, Bureau of Radiological Health - Fiscal Year 1979.

FDA 81-8155 A Practitioner's Guide to the Diagnostic X-Ray Equipment Standard (GPO 017-015-00185-7, $1.25).