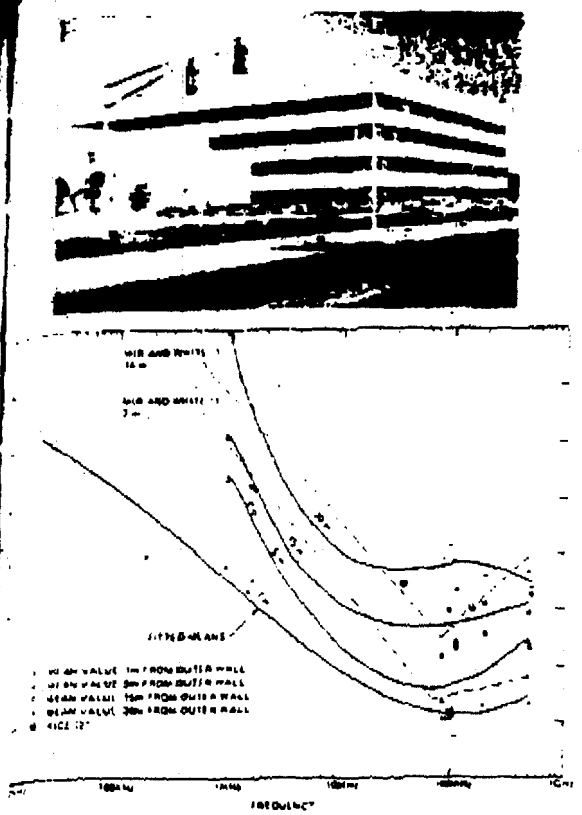


Fig. 9. Electric-field attenuation, four-story office building (Building No. 5).

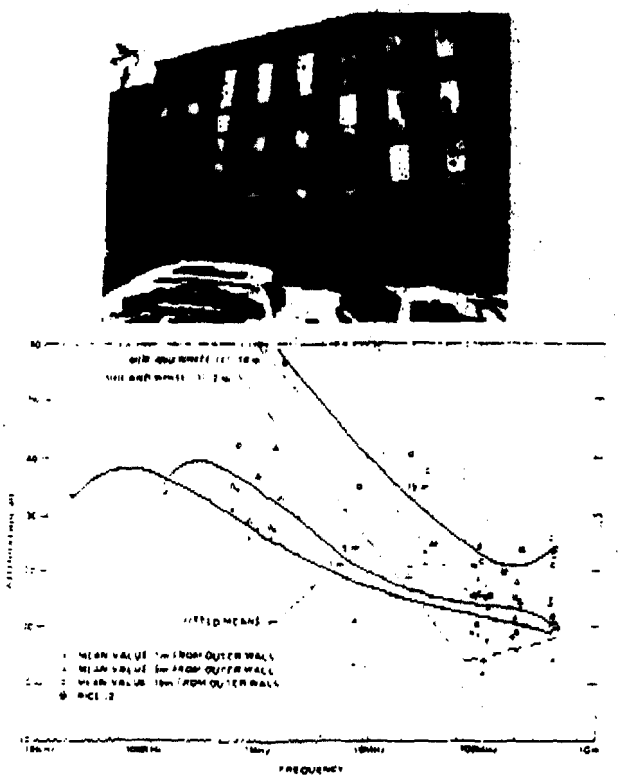


Fig. 11. Electric-field attenuation, four-story office building (Building No. 6).

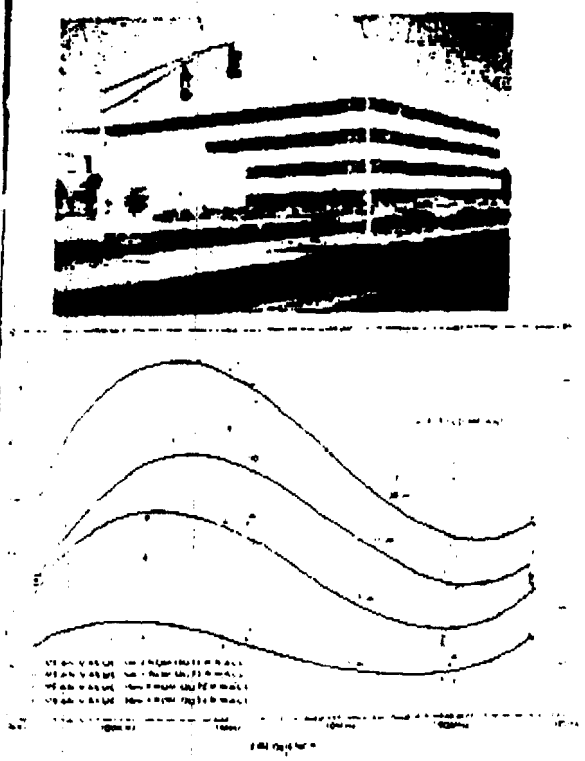


Fig. 10. Magnetic-field attenuation, four-story office building (Building No. 5).

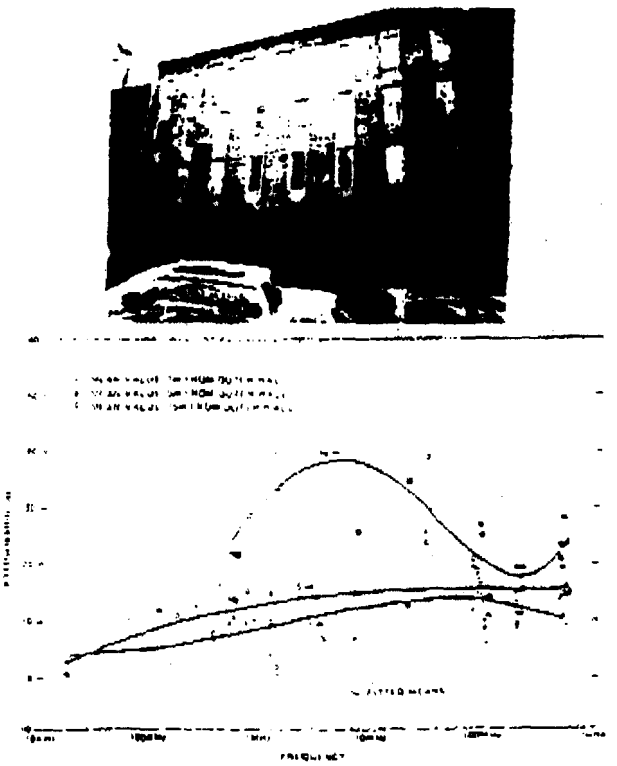
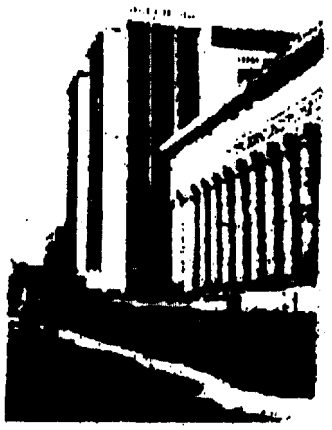


Fig. 12. Magnetic-field attenuation, four-story office building (Building No. 6).



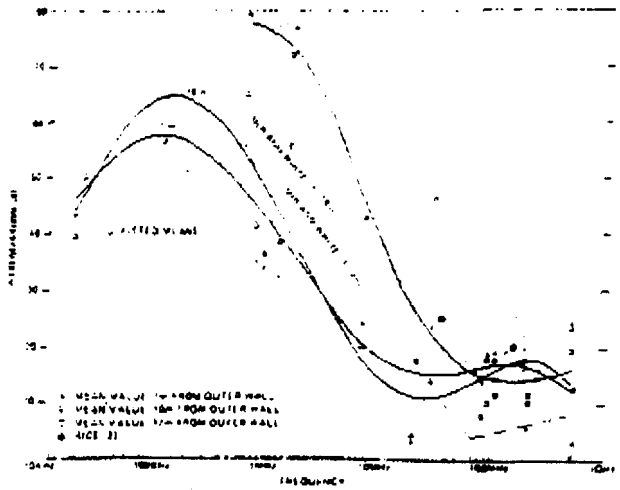


Fig. 13. Electric-field attenuation, twenty-story office building (Building No. 7).

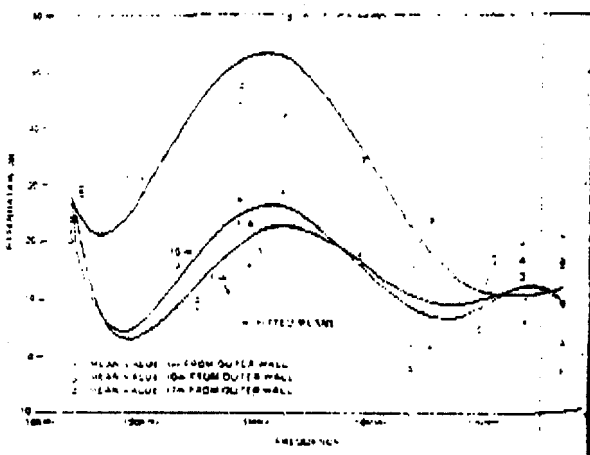


Fig. 14. Magnetic-field attenuation, twenty-story office building (Building No. 7).

RESULTS AND DISCUSSION

The E- and H-field building-attenuation results for the seven buildings are given in Figs. 1–14. The graphs for Buildings 1–4 (Figs. 1–8) show the measured data points and mean value at each frequency, each measured data point corresponding to a different location within the building at that frequency. Because of the large number of measured data points, only mean values, at various distances from the outer walls, are plotted for Buildings 5–7 (Figs. 9–14).

The distribution of the building-attenuation data was assumed to be log-normal. Attenuation versus frequency curves were plotted from a computer-generated fifth-order polynomial fit of the means (except for Building 5, where a third-order fit was used because of the sparsity of data).

The measured data revealed only a weak relationship between building attenuation and polarization. While the polarization of the exterior fields was very pronounced (predominantly vertical in the HF band and horizontal in the VHF and UHF bands), the interior fields were more randomly polarized due to reflections and scattering. For this reason, polarization was removed as a parameter above 7 MHz by computing building attenuation, at a particular frequency and at a particular location within the building, as the difference in decibels of the maximum averaged outside component (horizontal or vertical) and the maximum inside component (horizontal or vertical).

Buildings 1 and 2, single-family detached residences, exhibited similar electric-field and magnetic-field attenuations. Building 1, which had the least metal of all the buildings sampled, had a maximum mean-electric-field attenuation of approximately 38 dB at 50 kHz, decreasing monotonically to zero at 500 MHz. The mean magnetic-field attenuation for the building was zero over most of the frequency range, increasing to approximately 4 dB at 200 MHz.

Building 2, a single-family residence with partial aluminum siding, had a mean magnetic-field attenuation which varied between zero and 6 dB from 20 kHz to 350 MHz, increasing to 13 dB at 500 MHz. The mean-electric-field attenuation for Building 2, which peaked at 31 dB at 50 kHz, was less than 10 dB from 1 MHz to 400 MHz, and increased to 14 dB at 500 MHz.

Statistical wave impedances for the fields inside Buildings 1 and 2 can be derived from the mean electric-field and magnetic-field building attenuation curves in Figs. 1–4 (using straight-

approximations to the curves and assuming the wave impedance of the outside fields to be $120\pi\ \Omega$). Defining the inside wave impedance Z_w as the ratio of the electric-field and magnetic-field magnitudes, the following approximation is found for Building 1:

$$Z_w \doteq 120\pi \frac{f_{MHz}}{150}, \qquad 100\ \text{kHz} \leq f_{MHz} \leq 150\ \text{MHz}$$

where f_{MHz} is the frequency in megahertz.

Similarly, for Building 2

$$Z_w \doteq \begin{cases} 120\pi \dfrac{f_{MHz}}{2}, & 50\ \text{kHz} \leq f < 1\ \text{MHz} \\ \dfrac{120\pi}{2}, & 1\ \text{MHz} \leq f \leq 200\ \text{MHz}. \end{cases}$$

While quite different in form, these expressions reveal that, at the lower end of the spectrum, the wave impedance inside the buildings is less than the intrinsic impedance of free space and decreases with decreasing frequency (at least down to 50 or 100 kHz).

Buildings 3 and 4, while both single-story concrete-block structures, exhibit distinctly different attenuation characteristics. The mean electric and magnetic attenuation curves for Building 3 (Figs. 5 and 6) closely resemble those of Building 2, a single-family detached residence, while the curves for Building 4 (Figs. 7 and 8) are similar to the curves of the multistory office buildings at distances 5 m or greater from the outer walls (see Figs. 9–14). (Measurements in Building 4 were made at distances of 2, 10, 30, and 50 m from the outer walls. However, in contrast with the multistory office buildings, no correlation between attenuation and distance from the outer walls was found for this building.) The average electric-field attenuation for a variety of small- and medium-size buildings measured by Snider [3] at 180 MHz and 750 MHz is also plotted in Figs. 5 and 7 for comparison. Agreement at 180 MHz is excellent, while at 750 MHz Snider's results are slightly lower than our extrapolated mean curves.

Mean electric-field and magnetic-field attenuations at various distances from the outer walls of the three multistory office buildings (5–7) are given in Figs. 9–14. The curves for Building 5 (Figs. 9 and 10) show a proportionate increase in attenuation as the distance into the building increases, which is consistent with the relative homogeneity of the interior construction, i.e., doubling the distance from an outer wall approximately doubles the number of steel wall partitions (scattering surfaces) between the receiving antenna and the outer wall.

The curves for Building 6 (Figs. 11 and 12) show a small increase in attenuation from 1 to 5 m from the outer wall, and a substantially larger increase in attenuation from 5 to 15 m. Similarly, below 70 MHz, the curves for Building 7 (Figs. 13 and 14) show little difference in attenuation between 1 and 10 m, but a large increase in attenuation from 10 to 17 m. This phenomenon is not readily explainable in terms of building construction and may merely be the result of a limited statistical sample size. Above approximately 70 MHz, the attenuation in Building 7 is independent of distance. This result is indicative of a waveguide-above-cutoff propagation mode in the interior of this relatively uncluttered building.

The mean-electric-field attenuation curves obtained by Mir and White in steel-frame office buildings are plotted in Figs. 9, 11, and 13 for comparison with the multistory office building results presented herein. Rice's results at 35 MHz and 150 MHz for large multistory office buildings are also shown. Our measurements at the greater distances into the buildings (15 to 30 m) are in general agreement with the results of Rice, and with Mir and White's 14-m curve. However, below approximately 30 MHz, our mean-electric-field attenuation curves for locations closer to the outer walls (1 to 10 m) are consistently lower than Mir and White's 2-m curve.

The measured data for the three multistory buildings did not reveal an increase in field strength within the buildings with increasing floor levels. This absence of a noticeable height-gain trend could be due to the construction of these buildings (corrugated steel floors) or it could have been masked by other variables. Rice [2] and Deitz [5] show a definite increase in signal strength with increasing floor levels.

The average standard deviation of the fields inside Building 5, a four-story office building, was 9.2 dB (with a range from 0.5 to 19 dB). Snider reported standard deviations of 9 and 8.5 dB at 180 and 750 MHz, respectively, while Rice reported standard deviations of 14 and 9 dB at 35 and 150 MHz. The standard deviations measured by Mir and White were 5 to 6 dB at 2 m from the outer wall, and 10 to 15 dB at 14m from the outer wall.

The average standard deviation of the fields outside Building 5, which were measured at five different locations, was 1.55 dB below 1.6 MHz and 4.47 dB above 83 MHz.

Examination of the data in Figs. 1–14 leads to the following general observations. First, there is evidence of a peak in electric-field building attenuation in the frequency range from 50 kHz to 100 kHz. (See Figs. 1, 3, 7, 11, and 13.) A similar apparent peak in magnetic-field attenuation occurs in the range between 500 kHz and 20 MHz. (See Figs. 4, 6, 8, 10, 12, and 14). There is a null in both electric-field and magnetic-field attenuations between 50 MHz and 300 MHz (confirming the existence of the electric-field-attenuation null found by Mir and White at 70 MHz).

Above 10 to 20 MHz, the electric-field and magnetic-field building attenuations are practically identical. Below 10 MHz, the electric-field attenuation is greater than the magnetic-field attenuation, and the difference increases with decreasing frequency (at least down to the 50-kHz to 100-kHz region where the electric-field attenuation peak occurs). Stated another way, below 10 to 20 MHz, the wave impedance inside the buildings is less than $120\pi\ \Omega$ and decreases with decreasing frequency down to 50 or 100 kHz.

It is also interesting to note that the expected attenuation (for both electric and magnetic fields) at locations just inside the walls of some multistory steel-frame office buildings does not differ greatly from the attenuation in single-family detached residences. This is illustrated by comparing Figs. 1–4 with the 1-m curves in Figs. 9–12.

E 9B

OT REPORT 76-98

THE ATTENUATION OF UHF RADIO SIGNALS BY HOUSES

P.I. WELLS
P.V. TRYON

U.S. DEPARTMENT OF COMMERCE
Elliot L. Richardson, Secretary

Betsy Ancker-Johnson, Ph. D.
Assistant Secretary for Science and Technology

OFFICE OF TELECOMMUNICATIONS
John M. Richardson, Acting Director

August 1976

PREFACE

The building attenuation measurement program presented in this report was supported by the Lewis Research Center of the National Aeronautics and Space Administration (NASA), Cleveland, Ohio. The technical monitor for this program was Mr. Richard C. Braley.

The opinions expressed in this report are those of the authors and should not be construed as representing policies and doctrines of NASA.

TABLE OF CONTENTS

	Page
PREFACE	iii
LIST OF FIGURES	vi
LIST OF TABLES	viii
ABSTRACT	1
1. INTRODUCTION	1
2. EXPERIMENT DESIGN	2
2.1. Experiment Parameters	3
2.1.1. Frequency Selection	3
2.1.2. Structure Type Selection	4
2.1.3. Climatic Region Selection	4
2.1.4. Elevation Angle to the Signal Source	6
2.2. ATS-6 Signal Source	8
2.3. Data Collection Guidelines	10
2.3.1. Sampling the Radio Field	10
3. BUILDING ATTENUATION MEASUREMENTS	11
3.1. Experiment Instrumentation	12
3.2. Measurement Procedures	20
4. ANALYSIS OF THE BUILDING ATTENUATION DATA	22
4.1. Description of the Data	23
4.2. Statistical Analysis of Repeat Measurements	24
4.3. Statistical Analysis of the Factors Affecting Attenuation	27
4.4. Discussion of Isolated High Attenuation Cases	31
4.5. Statistical Analysis of Outside Signal Strength Measurements	36
4.6. Analysis of the Effect of the Elevation Angle	38
5. HOUSING CHARACTERISTICS	41
6. CONCLUSIONS	43
7. ACKNOWLEDGEMENTS	47
8. REFERENCES	48
APPENDIX. DESCRIPTION OF THE HOUSES MEASURED	49

THE ATTENUATION OF UHF RADIO SIGNALS BY HOUSES

P.I. Wells* and P.V. Tryon**

This paper presents the results of a measurement program which was conducted to determine the attenuation of UHF radio signals penetrating to the inside of a typical house. This program is part of a study to determine the feasibility of using direct satellite communication to disseminate disaster warning messages. The measurements were made in a manner to determine the building attenuation as a function of frequency, construction type, climate, and the elevation angle to the signal source.

Attenuation measurements were made in five cities, Boulder, Colorado; Duluth, Minnesota; Kansas City, Missouri; Little Rock, Arkansas; and Houston, Texas. The measurements were made at three frequencies, 860 MHz, 1550 MHz, and 2569 MHz, using the ATS-6 geosynchronous satellite as a signal source. Most measurements were made on two principal house types, wood frame with a wood outside surface and a wood frame brick veneer outside surface.

A brief description of the measurement program and an analysis of the measurement results are presented.

Key words: building attenuation, ultra-high frequency, direct satellite communication, disaster warning

1. INTRODUCTION

The measurement program discussed in this paper is one part of a broader study to assess the feasibility of using a geosynchronous satellite for direct broadcast of warnings of impending natural disaster, such as tornadoes, floods, etc. The feasibility study is being conducted by the National Aeronautics and Space Administration (NASA). The purpose of this measurement

*The author is with the Institute for Telecommunication Sciences, Office of Telecommunications, U.S. Department of Commerce, Boulder, Colorado 80302.

**The author is with the Statistical Engineering Laboratory, National Bureau of Standards, U.S. Department of Commerce, Boulder, Colorado 80302.

program was to study the additional attenuation of ultra-high frequency (UHF) radio signals penetrating to the inside of a typical house.

Building attenuation measurements were made at three frequencies in the UHF band, 860 MHz, 1550 MHz, and 2569 MHz, using the Applications Technology Satellite No. 6 (ATS-6) as a signal source. Measurements were made between October 1974 and June 1975 on several typical wood frame, wood siding and wood frame, brick veneer houses in each of five geographical locations. Measurements were also made on two houses during the period the ATS-6 was being moved from its geostationary position of 94°W longitude to a new position over East Africa.

The measurements were made by sampling the signal level at sixteen locations outside the house, then sampling the signal level at sixteen locations in each of two rooms in the house. Due to satellite scheduling constraints, measurements were not made at all three frequencies on all houses. The data samples were then compared using statistical techniques to determine the average attenuation and the standard deviation of the data samples.

The design of this experiment is described in a previous report by P.I. Wells, et al., An experiment design for the measurement of building attenuation (Office of Telecommunications Technical Memorandum 75-199, of limited distribution). The basic experiment approach described in that report was followed during the measurement program. There were, however, a number of changes made, particularly in the statistical techniques used for the analysis of the measured data. A brief discussion of the experiment design and measurement techniques are presented in this report for completeness.

2. EXPERIMENT DESIGN

This experiment was designed to determine the building attenuation of radio signals as a function of building construction type, frequency, climate, and the elevation angle

4.3. Statistical Analysis of the Factors Affecting Attenuation

Each of the 203 measurements is classified according to city (5), frequency (4), construction type of building (5), and type of insulation used in building (7). Each room was also classified according to effective window surface area (6 groups) and degree of exposure (9 groups); i.e., classified by degree of sheltering by other parts of the building. The roof conditions of the building were also the basis for classification. Snow (3 levels) and rain (3 levels) were considered.

In the analysis of these data, the statistical technique of analysis of variance was used. The purpose of the analysis was to determine the relative contribution of each of the eight factors listed above to the overall variability of the measured building attenuation data. Thus, the initial analysis design is an 8-factor analysis of variance (ANOVA). However, it is badly unbalanced with many combinations of factor levels missing due to practical reasons ranging from budget limitations to the uncooperativeness of mother nature and the fact that construction and insulation types are somewhat unique to different climate areas.

Analysis of the data was made possible by RUMMAGE, a general linear model computer package written by Del Scott of the Pennsylvania State University and implemented at the National Bureau of Standards in Boulder, Colorado, by Janet R. Donaldson of the NBS Statistical Engineering Laboratory. RUMMAGE, which is capable of analyzing such unbalanced designs, is a modified form of the MAD package (Bryce, 1975).

Initial analysis of all the data and all eight factors showed that all factors except room aperture, snow and rain had statistically significant effect on building attenuation. It should not be concluded, however, that rain or snow on a roof do not have an effect since the number of measurements with anything but dry roofs were very small. As always, failure to reject a null hypothesis of no effect can only be interpreted

as an indication of insufficient evidence and not that the hypothesis is true.

The adjusted R^2 for the eight factor linear model was 0.73. That is, 73% of the observed variability in the attenuation measurements is explained by the 8-factor linear model. The residual standard deviation of the measured attenuations about the fitted model was 2.4 dB. This is the combined effect of the variability of the measurements and the variability of individual buildings. Since it is only slightly larger than the 1.5 dB standard deviation estimated for the variability of the measurements, we conclude that this model represents this set of data rather well.

Because of the numerous missing factor level combinations, analysis of all data to obtain quantitative estimates of the effect of each factor is impossible. A subset of the data was selected by omitting data from building and insulation types that were isolated cases. These are considered separately. Retained in the data set were only two building types (wood siding and brick veneer) and two insulation types (blown in ceiling and ceiling and walls no metal). Room exposure was reclassified to two groups (one or more exposed walls and no exposed walls). This is consistent with the conduct of the experiment since, of the two rooms per house, one in each group was generally chosen. The factor "city" cannot be used in the model since it is highly confounded with insulation type. In interpreting the results, it must be kept in mind that insulation type is generally specific to a given area. For example, blown in ceiling insulation and none in the walls applies only to Boulder. We had only one of this type of insulation in any other climate area.

Analysis of the subset of 147 data points using the reduced 4 factor ANOVA model [Frequency (4 levels), Construction Type (2 levels), Insulation Type (2 levels), and Room Position (2 levels)] shows that all but room position are statistically significant (at the 0.05 level of significance). However,

this factor was retained in the model and the effect estimated since, with the finer classification, it was shown to be significant. The estimated effects are given in table 4.3.

Table 4.3. Estimated Effects*

Average		6.30 dB
Frequency 2569		1.16
1550		.39
860 V		-1.69
860 H		.14
Construction	Wood siding	- .58
	Brick veneer	.58
Insulation	Blown in ceiling	- .80
	Ceiling and walls	.80
Room Position	Exposed walls	- .30
	No exposed walls	.30

*The standard deviations of the estimated effects are not given individually by RUMMAGE, but confidence intervals for the difference of effects for each factor are given in figure 4.1.

Table 4.3 can be interpreted in the following way. The average attenuation is 6.3 dB. A frequency of 2569 MHz results in 1.16-0.39=0.77 dB more attenuation than a frequency of 1550 MHz and wood houses result in 1.16 dB less attenuation than brick veneer. Confidence intervals for all such differences are given in figure 4.1. The predicted attenuation for a room having any combination of levels can be obtained by summing the effects. For example, the predicted attenuation into an unexposed room in a brick veneer house with insulation in the ceiling and walls at 2569 MHZ is 9.14 dB. The standard deviation of this predicted value is 0.23 dB. The predicted attenuation for the opposite extreme condition is 2.93 dB with a standard deviation of 0.27 dB.

The residual standard deviation for this model is 3 dB, which is consistent with the 2.4 dB for the full model. The

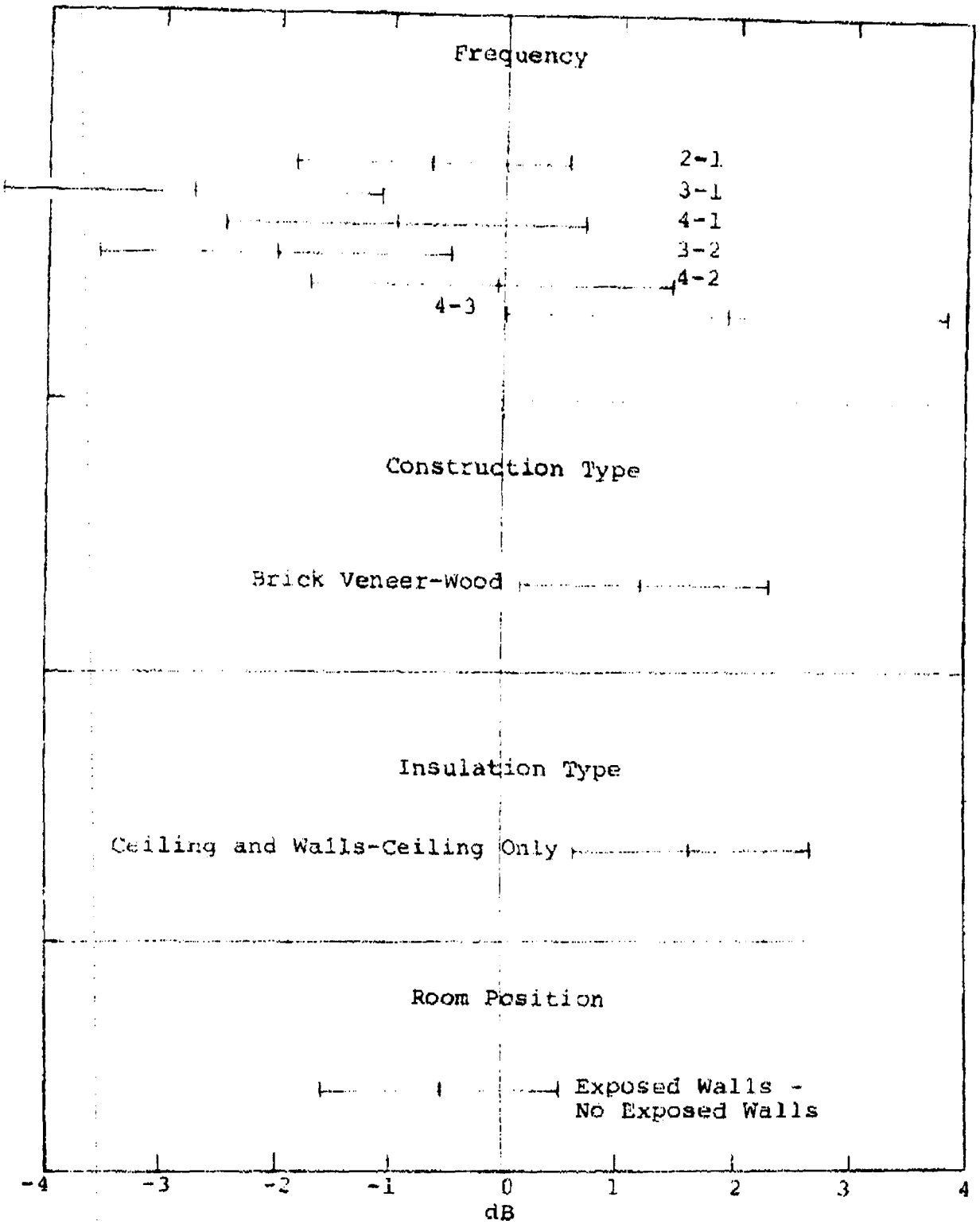


Figure 4.1. 95% confidence intervals with 140 degrees of freedom of the pairwise differences of the means.

interpretation that should be placed on it is that measurements on individual buildings of any one type will vary with a standard deviation of 3 dB. The variation is due both to random measurement error as well as to the variability of the buildings. For example, the predicted attenuations for the worst case building above was 9.14 ± 0.46 dB (± 2 standard deviations). To account for the variability among buildings, we might add $\pm 2 \times 3$ dB to cover roughly 95% of all buildings of this type, implying that an attenuation of $9.14+2[(0.46)^2+(6)^2]^{1/2}=15.2$ dB should be allowed for.

An alternative analysis might be the following. The $(3\ \text{dB})^2$ residual variance is the sum of the measurement error variance $(1.5\ \text{dB})^2$ (from our previous analysis) and the variance between buildings, which must then be $((3\ \text{dB})^2-(1.5\ \text{dB})^2)^{1/2}=2.6$ dB. Thus, a ± 2 standard deviation allowance for building variability would be ± 5.2 dB leading to a design attenuation of 14.8 dB (hardly an impressive difference). The rough analysis above could be put in the form of a tolerance interval, but the size of our sample hardly justifies any further work.

The adjusted R^2 for this model is only 0.14, but this is because all of the isolated high attenuation cases have been omitted, thus reducing the total variability relative to the residual variance.

4.4. Discussion of Isolated High Attenuation Cases

Figures 4.2 thru 4.4 are plots of all the data versus city (with separation of individual houses) versus construction type with separation by frequency and versus insulation type with separation by frequency. Plots of data are difficult to interpret when more than one factor is influencing the data. However, by comparing several plots we can present an explanation of the statistical analysis as well as a discussion of the isolated cases that could not be included in the formal analysis.

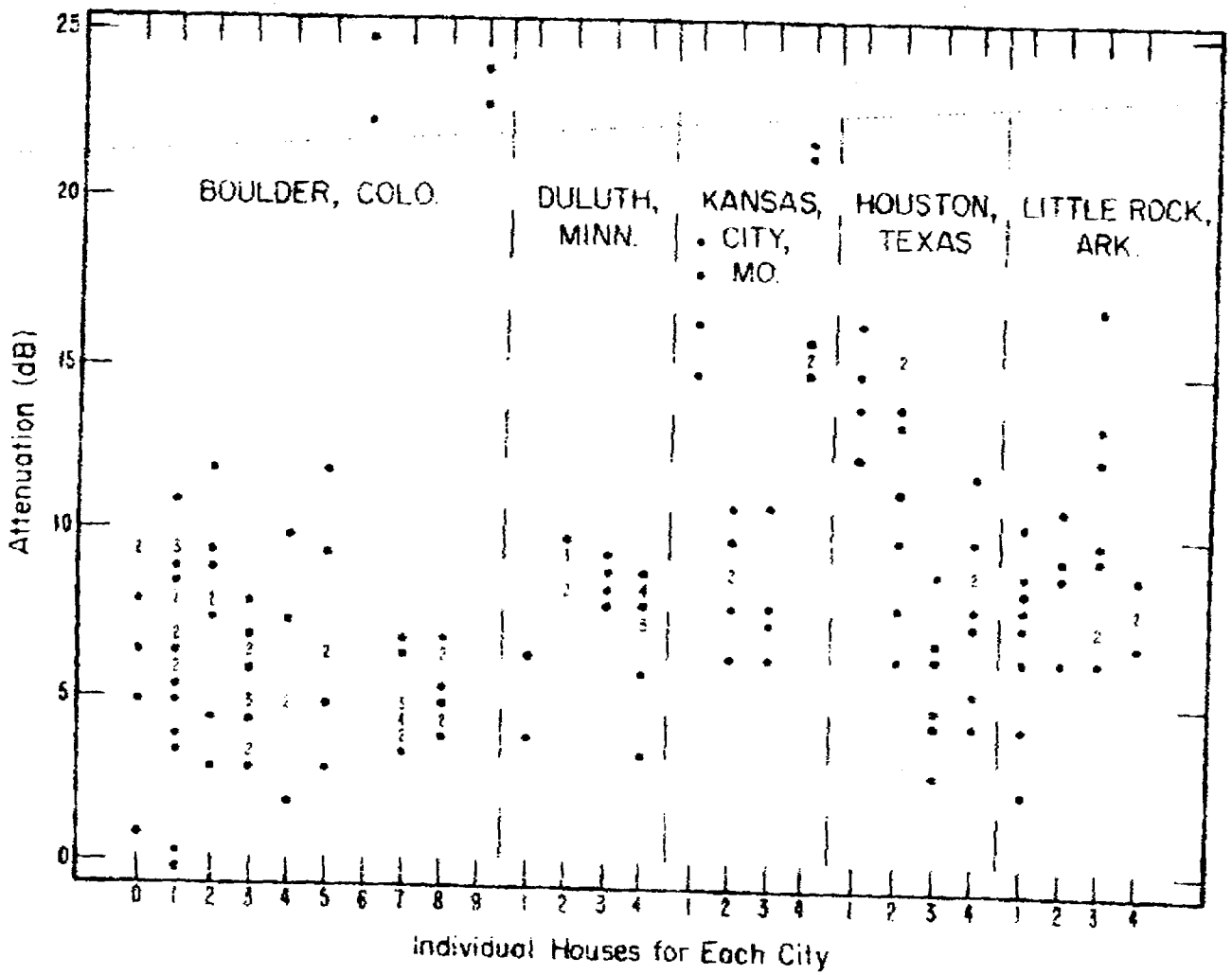


Figure 4.2. Plot of the average attenuation of rooms in individual houses, measurements at all frequencies are combined.

E #9c

NTIA Report 94-306

Building Penetration Loss Measurements at 900 MHz, 11.4 GHz, and 28.8 GHz

K.C. Allen
N. DeMinco
J.R. Hoffman
Y. Lo
P.B. Papazian

NTIA

report series

U.S. DEPARTMENT OF COMMERCE • National Telecommunications and Information Administration

NTIA Report 94-306

Building Penetration Loss Measurements at 900 MHz, 11.4 GHz, and 28.8 GHz

K.C. Allen
N. DeMinco
J.R. Hoffman
Y. Lo
P.B. Papazian

U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown, Secretary

Larry Irving, Assistant Secretary
for Communications and Information

May 1994

Nick
Demico
(303) 497-3660

July 6, 1995
conversation with N.D.

Attenuation

$$= -10 \log \left(\frac{\text{Power outside}}{\text{Power inside}} \right)$$

Ex:

$$-6\,dB = -10 \log (R)$$

$$.6 = \log R$$

$R = 4$ power outside is 4x as strong as inside

at high frequencies measure strength using $\frac{\text{power density}}{\text{not volts}}$.

CONTENTS

PAGE

FIGURES iv

TABLES ix

ABSTRACT 1

1. INTRODUCTION 1

2. DESCRIPTION OF THE EXPERIMENT 2

2.1 Instrumentation And Calibration 2

2.2 Measurement Sites 5

3. MEASUREMENT PROCEDURE 7

3.1 Radio Building 7

3.2 Private Residence 10

3.3 Storeroom With Metal Siding 10

4. DATA COLLECTION AND PROCESSING 13

4.1 Data Collection 13

4.2 Data Processing 13

5. DISCUSSION OF RESULTS 14

6. CONCLUSIONS 33

APPENDIX A: PENETRATION LOSS PLOTS FOR ALL MEASUREMENT PATHS

A.1 Radio Building Penetration Loss A-1

A.2 Private Residence Penetration Loss A-39

A.3 Storeroom Penetration Loss A-43

Exhibit 10

Worker Health and Safety rules of the Nuclear Regulatory Commission provide a precedent and model for what States and local jurisidictions may require and what record keeping the Commission may require.

§ 19.32 Discrimination prohibited.

No person shall on the ground of sex be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity licensed by the Nuclear Regulatory Commission. This provision will be enforced through agency provisions and rules similar to those already established, with respect to racial and other discrimination, under title VI of the Civil Rights Act of 1964. This remedy is not exclusive, however, and will not prejudice or cut off any other legal remedies available to a discriminatee.

[40 FR 6708, Mar. 3, 1975]

§ 19.40 Criminal penalties.

(a) Section 223 of the Atomic Energy Act of 1954, as amended, provides for criminal sanctions for willful violation of, attempted violation of, or conspiracy to violate, any regulation issued under sections 161b, 161i, or 161o of the Act. For purposes of section 223, all the regulations in part 19 are issued under one or more of sections 161b, 161i, or 161o, except for the sections listed in paragraph (b) of this section.

(b) The regulations in part 19 that are not issued under sections 161b, 161i, or 161o for the purposes of section 223 are as follows: §§ 19.1, 19.2, 19.3, 19.4, 19.5, 19.8, 19.16, 19.17, 19.18, 19.20, 19.32, and 19.40.

[57 FR 55071, Nov. 24, 1992]

PART 20—STANDARDS FOR PROTECTION AGAINST RADIATION

Subpart A—General Provisions

Sec.
20.1001 Purpose.
20.1002 Scope.
20.1003 Definitions.
20.1004 Units of radiation dose.
20.1005 Units of radioactivity.
20.1006 Interpretations.
20.1007 Communications.
20.1008 Implementation.
20.1009 Reporting, recording, and application requirements; OMB approval.

Subpart B—Radiation Protection Programs

20.1101 Radiation protection programs.

Subpart C—Occupational Dose Limits

20.1201 Occupational dose limits for adults.
20.1202 Compliance with requirements for summation of external and internal doses.
20.1203 Determination of external dose from airborne radioactive material.
20.1204 Determination of internal exposure.
20.1205 [Reserved]
20.1206 Planned special exposures.
20.1207 Occupational dose limits for minors.
20.1208 Dose to an embryo/fetus.

Subpart D—Radiation Dose Limits for Individual Members of the Public

20.1301 Dose limits for individual members of the public.
20.1302 Compliance with dose limits for individual members of the public.

Subpart E—[Reserved]

Subpart F—Surveys and Monitoring

20.1501 General.
20.1502 Conditions requiring individual monitoring of external and internal occupational dose.

Subpart G—Control of Exposure From External Sources in Restricted Areas

20.1601 Control of access to high radiation areas.
20.1602 Control of access to very high radiation areas.

Subpart H—Respiratory Protection and Controls to Restrict Internal Exposure in Restricted Areas

20.1701 Use of process or other engineering controls.
20.1702 Use of other controls.
20.1703 Use of individual respiratory protection equipment.
20.1704 Further restrictions on the use of respiratory protection equipment.

Subpart I—Storage and Control of Licensed Material

20.1801 Security of stored material.
20.1802 Control of material not in storage.

Subpart J—Precautionary Procedures

20.1901 Caution signs.
20.1902 Posting requirements.
20.1903 Exceptions to posting requirements.
20.1904 Labeling containers.
20.1905 Exemptions to labeling requirements.
20.1906 Procedures for receiving and opening packages.

Subpart K—Waste Disposal

20.2001 General requirements.
20.2002 Method for obtaining approval of proposed disposal procedures.
20.2003 Disposal by release into sanitary sewerage.
20.2004 Treatment or disposal by incineration.
20.2005 Disposal of specific wastes.
20.2006 Transfer for disposal and manifests.
20.2007 Compliance with environmental and health protection regulations.

Subpart L—Records

20.2101 General provisions.
20.2102 Records of radiation protection programs.
20.2103 Records of surveys.
20.2104 Determination of prior occupational dose.
20.2105 Records of planned special exposures.
20.2106 Records of individual monitoring results.
20.2107 Records of dose to individual members of the public.
20.2108 Records of waste disposal.
20.2109 [Reserved]
20.2110 Form of records.

Subpart M—Reports

20.2201 Reports of theft or loss of licensed material.
20.2202 Notification of incidents.
20.2203 Reports of exposures, radiation levels, and concentrations of radioactive material exceeding the limits.
20.2204 Reports of planned special exposures.
20.2205 Reports to individuals of exceeding dose limits.
20.2206 Reports of individual monitoring.

Subpart N—Exemptions and Additional Requirements

20.2301 Applications for exemptions.
20.2302 Additional requirements.

Subpart O—Enforcement

20.2401 Violations.
20.2402 Criminal penalties.
APPENDIX A TO PART 20—PROTECTION FACTORS FOR RESPIRATORS
APPENDIX B TO PART 20—ANNUAL LIMITS ON INTAKE (ALIS) AND DERIVED AIR CONCENTRATIONS (DACS) OF RADIONUCLIDES FOR OCCUPATIONAL EXPOSURE; EFFLUENT CONCENTRATIONS; CONCENTRATIONS FOR RELEASE TO SEWERAGE
APPENDIX C TO PART 20—QUANTITIES OF LICENSED MATERIAL REQUIRING LABELING
APPENDIX D TO PART 20—UNITED STATES NUCLEAR REGULATORY COMMISSION REGIONAL OFFICES
APPENDIX E TO PART 20—[RESERVED]
APPENDIX F TO PART 20—REQUIREMENTS FOR LOW-LEVEL WASTE TRANSFER FOR DISPOSAL AT LAND DISPOSAL FACILITIES AND MANIFESTS
APPENDIX G TO PART 20—REQUIREMENTS FOR TRANSFERS OF LOW-LEVEL RADIOACTIVE WASTE INTENDED FOR DISPOSAL AT LICENSED LAND DISPOSAL FACILITIES AND MANIFESTS

AUTHORITY: Secs. 53, 63, 65, 81, 103, 104, 161, 182, 186, 68 Stat. 930, 933, 935, 948, 953, 954, 955, as amended, sec. 1701, 106 Stat. 2951, 2952, 2953 (42 U.S.C. 2073, 2093, 2095, 2111, 2133, 2134, 2201, 2232, 2236, 2297f); secs. 201, as amended, 202, 206, 88 Stat. 1242, as amended, 1244, 1246 (42 U.S.C. 5841, 5842, 5846).

Subpart A—General Provisions

SOURCE: 56 FR 23360, May 21, 1991, unless otherwise noted.

§ 20.1001 Purpose.

(a) The regulations in this part establish standards for protection against ionizing radiation resulting from activities conducted under licenses issued by the Nuclear Regulatory Commission. These regulations are issued under the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974, as amended.

(b) It is the purpose of the regulations in this part to control the receipt, possession, use, transfer, and disposal of licensed material by any licensee in such a manner that the total dose to an individual (including doses resulting from licensed and unlicensed radioactive material and from radiation sources other than background radiation) does not exceed the standards for protection against radiation prescribed in the regulations in this part. However, nothing in this part shall be construed as limiting actions that may be necessary to protect health and safety.

§ 20.1002 Scope.

The regulations in this part apply to persons licensed by the Commission to receive, possess, use, transfer, or dispose of byproduct, source, or special nuclear material or to operate a production or utilization facility under parts 30 through 36, 39, 40, 50, 60, 61, 70,

or 72 of this chapter, and in accordance with 10 CFR 76.60 to persons required to obtain a certificate of compliance or an approved compliance plan under part 76 of this chapter. The limits in this part do not apply to doses due to background radiation, due to any medical administration the individual has received, or due to voluntary participation in medical research programs.

(60 FR 49686, Sept. 26, 1995)

§ 20.1003 Definitions.

As used in this part:

Absorbed dose means the energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the gray (Gy).

Act means the Atomic Energy Act of 1954 (42 U.S.C. 2011 *et seq.*), as amended.

Activity is the rate of disintegration (transformation) or decay of radioactive material. The units of activity are the curie (Ci) and the becquerel (Bq).

Adult means an individual 18 or more years of age.

Airborne radioactive material means radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases.

Airborne radioactivity area means a room, enclosure, or area in which airborne radioactive materials, composed wholly or partly of licensed material, exist in concentrations—

(1) In excess of the derived air concentrations (DACs) specified in appendix B, to §§ 20.1001–20.2401, or

(2) To such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 percent of the annual limit on intake (ALI) or 12 DAC-hours.

ALARA (acronym for "as low as is reasonably achievable") means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Annual limit on intake (ALI) means the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man that would result in a committed effective dose equivalent of 5 rems (0.05 Sv) or a committed dose equivalent of 50 rems (0.5 Sv) to any individual organ or tissue. (ALI values for intake by ingestion and by inhalation of selected radionuclides are given in Table 1, Columns 1 and 2, of appendix B to §§ 20.1001–20.2401).

Background radiation means radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material) and global fallout as it exists in the environment from the testing of nuclear explosive devices. "Background radiation" does not include radiation from source, byproduct, or special nuclear materials regulated by the Commission.

Bioassay (radiobioassay) means the determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

Byproduct material means—

(1) Any radioactive material (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or utilizing special nuclear material; and

(2) The tailings or wastes produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by these solution extraction operations do not constitute

"byproduct material" within this definition.

Class (*or lung class* or *inhalation class*) means a classification scheme for inhaled material according to its rate of clearance from the pulmonary region of the lung. Materials are classified as D, W, or Y, which applies to a range of clearance half-times: for Class D (Days) of less than 10 days, for Class W (Weeks) from 10 to 100 days, and for Class Y (Years) of greater than 100 days.

Collective dose is the sum of the individual doses received in a given period of time by a specified population from exposure to a specified source of radiation.

Commission means the Nuclear Regulatory Commission or its duly authorized representatives.

Committed dose equivalent ($H_{T,50}$) means the dose equivalent to organs or tissues of reference (T) that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Committed effective dose equivalent ($H_{E,50}$) is the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues ($H_{E,50} = \Sigma w_T H_{T,50}$).

Controlled area means an area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason.

Declared pregnant woman means a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

Deep-dose equivalent (H_d), which applies to external whole-body exposure, is the dose equivalent at a tissue depth of 1 cm (1000 mg/cm^2).

Department means the Department of Energy established by the Department of Energy Organization Act (Pub. L. 95–91, 91 Stat. 565, 42 U.S.C. 7101 *et seq.*) to the extent that the Department, or its duly authorized representatives, exercises functions formerly vested in the U.S. Atomic Energy Commission, its Chairman, members, officers, and components and transferred to the U.S. Energy Research and Development Administration and to the Administrator thereof pursuant to sections 104 (b), (c), and (d) of the Energy Reorganization Act of 1974 (Pub. L. 93–438, 88 Stat. 1233 at 1237, 42 U.S.C. 5814) and retransferred to the Secretary of Energy pursuant to section 301(a) of the Department of Energy Organization Act (Pub. L. 95–91, 91 Stat. 565 at 577–578, 42 U.S.C. 7151).

Derived air concentration (DAC) means the concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in an intake of one ALI. DAC values are given in Table 1, Column 3, of appendix B to §§ 20.1001–20.2401.

Derived air concentration-hour (DAC-hour) is the product of the concentration of radioactive material in air (expressed as a fraction or multiple of the derived air concentration for each radionuclide) and the time of exposure to that radionuclide, in hours. A licensee may take 2,000 DAC-hours to represent one ALI, equivalent to a committed effective dose equivalent of 5 rems (0.05 Sv).

Dose or *radiation dose* is a generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in other paragraphs of this section.

Dose equivalent (H_T) means the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and sievert (Sv).

Dosimetry processor means an individual or organization that processes and evaluates individual monitoring equipment in order to determine the radiation dose delivered to the equipment.

Effective dose equivalent (H_E) is the sum of the products of the dose equivalent to the organ or tissue (H_T) and the weighting factors (w_T) applicable to each of the body organs or tissues that are irradiated ($H_E = \Sigma w_T H_T$).

Embryo/fetus means the developing human organism from conception until the time of birth.

Entrance or access point means any location through which an individual could gain access to radiation areas or

radioactive materials. This includes entry or exit portals of sufficient size to permit human entry, irrespective of their intended use.

Exposure means being exposed to ionizing radiation or to radioactive material.

External dose means that portion of the dose equivalent received from radiation sources outside the body.

Extremity means hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

Eye dose equivalent applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm²).

Generally applicable environmental radiation standards means standards issued by the Environmental Protection Agency (EPA) under the authority of the Atomic Energy Act of 1954, as amended, that impose limits on radiation exposures or levels, or concentrations or quantities of radioactive material, in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material.

Government agency means any executive department, commission, independent establishment, corporation wholly or partly owned by the United States of America, which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government.

Gray [See § 20.1004].

High radiation area means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Individual means any human being.

Individual monitoring means—

(1) The assessment of dose equivalent by the use of devices designed to be worn by an individual;

(2) The assessment of committed effective dose equivalent by bioassay (see *Bioassay*) or by determination of the time-weighted air concentrations to which an individual has been exposed, i.e., DAC-hours; or

(3) The assessment of dose equivalent by the use of survey data.

Individual Monitoring Devices (Individual monitoring equipment) means devices designed to be worn by a single individual for the assessment of dose equivalent such as film badges, thermoluminescent dosimeters (TLDs), pocket ionization chambers, and personal ("lapel") air sampling devices.

Internal dose means that portion of the dose equivalent received from radioactive material taken into the body.

License means a license issued under the regulations in parts 30 through 36, 39, 40, 50, 60, 61, 70, or 72 of this chapter.

Licensed material means source material, special nuclear material, or byproduct material received, possessed, used, transferred or disposed of under a general or specific license issued by the Commission.

Licensee means the holder of a license.

Limits (dose limits) means the permissible upper bounds of radiation doses.

Lost or missing licensed material means licensed material whose location is unknown. It includes material that has been shipped but has not reached its destination and whose location cannot be readily traced in the transportation system.

Member of the public means any individual except when that individual is receiving an occupational dose.[1]

Minor means an individual less than 18 years of age.

Monitoring (radiation monitoring, radiation protection monitoring) means the measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.

Nonstochastic effect means health effects, the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a nonstochastic effect (also called a deterministic effect).

[1] Except as delineated in other parts of 10 CFR chapter I.

NRC means the Nuclear Regulatory Commission or its duly authorized representatives.

Occupational dose means the dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation and/or radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include doses received from background radiation, from any medical administration the individual has received, from voluntary participation in medical research programs, or as a member of the public.

Person means—

(1) Any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission or the Department of Energy (except that the Department shall be considered a person within the meaning of the regulations in 10 CFR chapter I to the extent that its facilities and activities are subject to the licensing and related regulatory authority of the Commission under section 202 of the Energy Reorganization Act of 1974 (88 Stat. 1244), the Uranium Mill Tailings Radiation Control Act of 1978 (92 Stat. 3021), the Nuclear Waste Policy Act of 1982 (96 Stat. 2201), and section 3(b)(2) of the Low-Level Radioactive Waste Policy Amendments Act of 1985 (99 Stat. 1842)), any State or any political subdivision of or any political entity within a State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and

(2) Any legal successor, representative, agent, or agency of the foregoing.

Planned special exposure means an infrequent exposure to radiation, separate from and in addition to the annual dose limits.

Public dose means the dose received by a member of the public from exposure to radiation and/or radioactive material released by a licensee, or to any other source of radiation under the control of the licensee. Public dose does not include occupational dose or doses received from background radiation, from any medical administration the individual has received, or from voluntary participation in medical research programs.

Quality Factor (Q) means the modifying factor (listed in table 1004(b).1 and 1004(b).2 of § 20.1004) that is used to derive dose equivalent from absorbed dose.

Quarter means a period of time equal to one-fourth of the year observed by the licensee (approximately 13 consecutive weeks), providing that the beginning of the first quarter in a year coincides with the starting date of the year and that no day is omitted or duplicated in consecutive quarters.

Rad (See § 20.1004).

Radiation (ionizing radiation) means alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation, as used in this part, does not include non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or ultraviolet light.

Radiation area means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Reference man means a hypothetical aggregation of human physical and physiological characteristics arrived at by international consensus. These characteristics may be used by researchers and public health workers to standardize results of experiments and to relate biological insult to a common base.

Rem (See § 20.1004).

Respiratory protective device means an apparatus, such as a respirator, used to reduce the individual's intake of airborne radioactive materials.

Restricted area means an area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. Restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be set apart as a restricted area.

Sanitary sewerage means a system of public sewers for carrying off waste water and refuse, but excluding sewage

treatment facilities, septic tanks, and leach fields owned or operated by the licensee.

Shallow-dose equivalent (H_s), which applies to the external exposure of the skin or an extremity, is taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm²) averaged over an area of 1 square centimeter.

Sievert (See § 20.1004).

Site boundary means that line beyond which the land or property is not owned, leased, or otherwise controlled by the licensee.

Source material means—

(1) Uranium or thorium or any combination of uranium and thorium in any physical or chemical form; or

(2) Ores that contain, by weight, one-twentieth of 1 percent (0.05 percent), or more, of uranium, thorium, or any combination of uranium and thorium. Source material does not include special nuclear material.

Special nuclear material means—

(1) Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material that the Commission, pursuant to the provisions of section 51 of the Act, determines to be special nuclear material, but does not include source material; or

(2) Any material artificially enriched by any of the foregoing but does not include source material.

Stochastic effects means health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

Survey means an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

Total Effective Dose Equivalent (TEDE) means the sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Unrestricted area means an area, access to which is neither limited nor controlled by the licensee.

Uranium fuel cycle means the operations of milling of uranium ore, chemical conversion of uranium, isotopic enrichment of uranium, fabrication of uranium fuel, generation of electricity by a light-water-cooled nuclear power plant using uranium fuel, and reprocessing of spent uranium fuel to the extent that these activities directly support the production of electrical power for public use. Uranium fuel cycle does not include mining operations, operations at waste disposal sites, transportation of radioactive material in support of these operations, and the reuse of recovered non-uranium special nuclear and byproduct materials from the cycle.

Very high radiation area means an area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in 1 hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

(NOTE: At very high doses received at high dose rates, units of absorbed dose (e.g., rads and grays) are appropriate, rather than units of dose equivalent (e.g., rems and sieverts)).

Week means 7 consecutive days starting on Sunday.

Weighting factor w_T, for an organ or tissue (T) is the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly. For calculating the effective dose equivalent, the values of w_T are:

ORGAN DOSE WEIGHTING FACTORS

Organ or tissue	w_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	[1] 0.30
Whole Body	[2] 1.00

[1] 0.30 results from 0.06 for each of 5 "remainder" organs (excluding the skin and the lens of the eye) that receive the highest doses.

[2] For the purpose of weighting the external whole body dose (for adding it to the internal dose), a single weighting factor, w_T=1.0, has been specified. The use of other weighting factors for external exposure will be approved on a case-by-case basis until such time as specific guidance is issued.

Whole body means, for purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee.

Working level (WL) is any combination of short-lived radon daughters (for radon-222: polonium-218, lead-214, bismuth-214, and polonium-214; and for radon-220: polonium-216, lead-212, bismuth-212, and polonium-212) in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha particle energy.

Working level month (WLM) means an exposure to 1 working level for 170 hours (2,000 working hours per year/12 months per year=approximately 170 hours per month).

Year means the period of time beginning in January used to determine compliance with the provisions of this part. The licensee may change the starting date of the year used to determine compliance by the licensee provided that the change is made at the beginning of the year and that no day is omitted or duplicated in consecutive years.

[56 FR 23391, May 21, 1991, as amended at 57 FR 55738, Dec. 9, 1992; 58 FR 7736, Feb. 9, 1993; 60 FR 20643, July 13, 1995; 60 FR 48625, Sept. 20, 1995]

§ 20.1004 Units of radiation dose.

(a) Definitions. As used in this part, the units of radiation dose are:

Gray (Gy) is the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule/kilogram (100 rads).

Rad is the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram (0.01 gray).

Rem is the special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem=0.01 sievert).

Sievert is the SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv=100 rems).

(b) As used in this part, the quality factors for converting absorbed dose to dose equivalent are shown in table 1004(b).1.

TABLE 1004(b).1—QUALITY FACTORS AND ABSORBED DOSE EQUIVALENCIES

Type of radiation	Quality factor (Q)	Absorbed dose equal to a unit dose equivalent[1]
X-, gamma, or beta radiation	1	1
Alpha particles, multiple-charged particles, fission fragments and heavy particles of unknown charge	20	0.05
Neutrons of unknown energy	10	0.1
High-energy protons	10	0.1

[1] Absorbed dose in rad equal to 1 rem or the absorbed dose in gray equal to 1 sievert.

(c) If it is more convenient to measure the neutron fluence rate than to determine the neutron dose equivalent rate in rems per hour or sieverts per hour, as provided in paragraph (b) of this section, 1 rem (0.01 Sv) of neutron radiation of unknown energies may, for purposes of the regulations in this part, be assumed to result from a total fluence of 25 million neutrons per square centimeter incident upon the body. If sufficient information exists to estimate the approximate energy distribution of the neutrons, the licensee may use the fluence rate per unit dose equivalent or the appropriate Q value from table 1004(b).2 to convert a measured tissue dose in rads to dose equivalent in rems.

TABLE 1004(b).2—MEAN QUALITY FACTORS, Q, AND FLUENCE PER UNIT DOSE EQUIVALENT FOR MONOENERGETIC NEUTRONS

	Neutron energy (MeV)	Quality factor[1] (Q)	Fluence per unit dose equivalent[2] (neutrons cm⁻² rem⁻¹)
(Thermal)	2.5×10^{-8}	2	980×10^6
	1×10^{-7}	2	980×10^6
	1×10^{-6}	2	810×10^6
	1×10^{-5}	2	810×10^6
	1×10^{-4}	2	840×10^6
	1×10^{-3}	2	980×10^6
	1×10^{-2}	2.5	1010×10^6
	1×10^{-1}	7.5	170×10^6
	5×10^{-1}	11	39×10^6
	1	11	27×10^6
	2.5	9	29×10^6
	5	8	23×10^6
	7	7	24×10^6
	10	6.5	24×10^6
	14	7.5	17×10^6
	20	8	16×10^6

TABLE 1004(b).2—MEAN QUALITY FACTORS, Q, AND FLUENCE PER UNIT DOSE EQUIVALENT FOR MONOENERGETIC NEUTRONS—Continued

Neutron energy (MeV)	Quality factor[a] (Q)	Fluence per unit dose equivalent[b] (neutrons cm⁻² rem⁻¹)
2[illegible]	7	[illegible]
5[illegible]	8.0	[illegible]
6×10⁻[illegible]	8	[illegible]
2×10⁻[illegible]	7.5	[illegible]
3×10⁻[illegible]	7.5	[illegible]
4×10⁻[illegible]	7.5	[illegible]

[a]Value of quality factor (Q) at the point where the dose equivalent is maximum in a 30-cm diameter cylinder tissue-equivalent phantom.

[b]Monoenergetic neutrons incident normally on a 30-cm diameter cylinder tissue-equivalent phantom.

§ 20.1005 Units of radioactivity.

For the purposes of this part, activity is expressed in the special unit of curies (Ci) or in the SI unit of becquerels (Bq), or their multiples, or disintegrations (transformations) per unit of time.

(a) One becquerel=1 disintegration per second (s^{-1}).

(b) One curie=3.7×10^{10} disintegrations per second=3.7×10^{10} becquerels=2.22×10^{12} disintegrations per minute.

[56 FR 23360, May 21, 1991; 56 FR 61352, Dec. 3, 1991]

§ 20.1006 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 20.1007 Communications.

Unless otherwise specified, communications or reports concerning the regulations in this part should be addressed to the Executive Director for Operations, U.S. Nuclear Regulatory Commission, Washington, DC 20555. A communication, report, or application may be delivered in person to the Office of the Executive Director for Operations, 11555 Rockville Pike, Rockville, MD 20852.

§ 20.1008 Implementation.

(a) [Reserved]

(b) The applicable section of §§ 20.1001–20.2402 must be used in lieu of requirements in the standards for protection against radiation in effect prior to January 1, 1994[1] that are cited in license conditions or technical specifications, except as specified in paragraphs (c), (d), and (e) of this section. If the requirements of this part are more restrictive than the existing license condition, then the licensee shall comply with this part unless exempted by paragraph (d) of this section.

(c) Any existing license condition or technical specification that is more restrictive than a requirement in §§ 20.1001–20.2402 remains in force until there is a technical specification change, license amendment, or license renewal.

(d) If a license condition or technical specification exempted a licensee from a requirement in the standards for protection against radiation in effect prior to January 1, 1994,[1] it continues to exempt a licensee from the corresponding provision of §§ 20.1001–20.2402.

(e) If a license condition cites provisions in requirements in the standards for protection against radiation in effect prior to January 1, 1994[1] and there are no corresponding provisions in §§ 20.1001–20.2402, then the license condition remains in force until there is a technical specification change, license amendment, or license renewal that modifies or removes this condition.

[59 FR 43362, Aug. 18, 1994]

§ 20.1009 Reporting, recording, and application requirements: OMB approval.

(a) The Nuclear Regulatory Commission has submitted the information collection requirements contained in this part to the Office of Management and Budget (OMB) for approval as required by the Paperwork Reduction Act of 1980 (44 U.S.C. 3501 *et seq.*). OMB has approved the information collection requirements contained in this part under control number 3150-0014.

(b) The approved information collection requirements contained in this

[1]See §§ 20.1–20.602 codified as of January 1, 1993.

[1]See §§ 20.1–20.602 codified as of January 1, 1993.

[1]See §§ 20.1–20.602 codified as of January 1, 1993.

part appear in §§ 20.1101, 20.1202, 20.1204, 20.1206, 20.1301, 20.1501, 20.1601, 20.1701, 20.1702, 20.1801, 20.1802, 20.1804, 20.1805, 20.2002, 20.2004, 20.2006, 20.2102, 20.2103, 20.2104, 20.2105, 20.2106, 20.2107, 20.2109, 20.2110, 20.2201, 20.2202, 20.2203, 20.2204, 20.2206, and appendix F to 20.1001–20.2401.

(c) This part contains information collection requirements in addition to those approved under the control number specified in paragraph (a) of this section. These information collection requirements and the control numbers under which they are approved are as follows:

(1) In § 20.2104, NRC Form 4 is approved under control number 3150-0005.

(2) In §§ 20.2106 and 20.2206, NRC Form 5 is approved under control number 3150-0008.

[57 FR 57878, Dec. 8, 1992]

EFFECTIVE DATE NOTE: At 60 FR 15603, Mar. 27, 1995, § 20.1009 was revised, effective March 1, 1995. For the convenience of the reader, the revised text is set forth below.

§ 20.1009 Information collection requirements: OMB approval.

(a) The Nuclear Regulatory Commission has submitted the information collection requirements contained in this part to the Office of Management and Budget (OMB) for approval as required by the Paperwork Reduction Act of 1980 (44 U.S.C. 3501 *et seq.*). The OMB has approved the information collection requirements contained in this part under control number 3150-0014.

(b) The approved information collection requirements contained in this part appear in §§ 20.1101, 20.1201, 20.1204, 20.1206, 20.1301, 20.1302, 20.1501, 20.1601, 20.1701, 20.1702, 20.1801, 20.1802, 20.1804, 20.1805, 20.1806, 20.2002, 20.2004, 20.2006, 20.2102, 20.2103, 20.2104, 20.2105, 20.2106, 20.2107, 20.2108, 20.2109, 20.2110, 20.2201, 20.2202, 20.2203, 20.2204, 20.2206, and appendices F and G to 10 CFR part 20.

(c) This part contains information collection requirements in addition to those approved under the control number specified in paragraph (a) of this section. These information collection requirements and the control numbers under which they are approved are as follows:

(1) In § 20.2104, NRC Form 4 is approved under control number 3150-0005.

(2) In §§ 20.2106 and 20.2206, NRC Form 5 is approved under control number 3150-0008.

(3) In § 20.2006 and appendix G to 10 CFR part 20, NRC Form 540 and 540A is approved under control number 3150-0164.

(4) In § 20.2006 and appendix G to 10 CFR part 20, NRC Form 541 and 541A is approved under control number 3150-0165.

(5) In § 20.2006 and appendix G to 10 CFR part 20, NRC Form 542 and 542A is approved under control number 3150-0166.

[60 FR 15603, Mar. 27, 1995]

Subpart B—Radiation Protection Programs

SOURCE: 56 FR 23360, May 21, 1991, unless otherwise noted.

§ 20.1101 Radiation protection programs.

(a) Each licensee shall develop, document, and implement a radiation protection program commensurate with the scope and extent of licensed activities and sufficient to ensure compliance with the provisions of this part. (See § 20.2102 for recordkeeping requirements relating to these programs.)

(b) The licensee shall use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA).

(c) The licensee shall periodically (at least annually) review the radiation protection program content and implementation.

Subpart C—Occupational Dose Limits

SOURCE: 56 FR 23360, May 21, 1991, unless otherwise noted.

§ 20.1201 Occupational dose limits for adults.

(a) The licensee shall control the occupational dose to individual adults, except for planned special exposures under § 20.1206, to the following dose limits.

(1) An annual limit, which is the more limiting of—

(i) The total effective dose equivalent being equal to 5 rems (0.05 Sv); or

(ii) The sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye being equal to 50 rems (0.5 Sv).

(2) The annual limits to the lens of the eye, to the skin, and to the extremities, which are:

(ii) An eye dose equivalent of 15 rems (0.15 Sv), and

(iii) A shallow-dose equivalent of 50 rems (0.50 Sv) to the skin or to any extremity.

(b) Doses received in excess of the annual limits, including doses received during accidents, emergencies, and planned special exposures, must be subtracted from the limits for planned special exposures that the individual may receive during the current year (see §20.1206(a)(1)) and during the individual's lifetime (see §20.1206(a)(2)).

(c) The assigned deep-dose equivalent and shallow-dose equivalent must be for the part of the body receiving the highest exposure. The deep-dose equivalent, eye dose equivalent and shallow-dose equivalent may be assessed from surveys or other radiation measurements for the purpose of demonstrating compliance with the occupational dose limits, if the individual monitoring device was not in the region of highest potential exposure, or the results of individual monitoring are unavailable.

(d) Derived air concentration (DAC) and annual limit on intake (ALI) values are presented in table 1 of appendix B to part 20 and may be used to determine the individual's dose (see §20.1202) and to demonstrate compliance with the occupational dose limits.

(e) In addition to the annual dose limits, the licensee shall limit the soluble uranium intake by an individual to 10 milligrams in a week in consideration of chemical toxicity (see footnote 3 of appendix B to part 20).

(f) The licensee shall reduce the dose that an individual may be allowed to receive in the current year by the amount of occupational dose received while employed by any other person (see §20.1202(e)).

[56 FR 23360, May 21, 1991, as amended at 62 FR 39095, Apr. 22, 1997]

§ 20.1202 Compliance with requirements for summation of external and internal doses.

(a) If the licensee is required to monitor under both §20.1502(a) and (b), the licensee shall demonstrate compliance with the dose limits by summing external and internal doses. If the licensee is required to monitor only under §20.1502(a) or only under §20.1502(b), then summation is not required to demonstrate compliance with the dose limits. The licensee may demonstrate compliance with the requirements for summation of external and internal doses by meeting one of the conditions specified in paragraph (b) of this section and the conditions in paragraphs (c) and (d) of this section.

(Note: The dose equivalents for the lens of the eye, the skin, and the extremities are not included in the summation, but are subject to separate limits.)

(b) *Intake by inhalation.* If the only intake of radionuclides is by inhalation, the total effective dose equivalent limit is not exceeded if the sum of the deep-dose equivalent divided by the total effective dose equivalent limit, and one of the following, does not exceed unity:

(1) The sum of the fractions of the inhalation ALI for each radionuclide, or

(2) The total number of derived air concentration-hours (DAC-hours) for all radionuclides divided by 2,000, or

(3) The sum of the calculated committed effective dose equivalents to all significantly irradiated[1] organs or tissues (T) calculated from bioassay data using appropriate biological models and expressed as a fraction of the annual limit.

(c) *Intake by oral ingestion.* If the occupationally exposed individual also receives an intake of radionuclides by oral ingestion greater than 10 percent of the applicable oral ALI, the licensee shall account for this intake and include it in demonstrating compliance with the limits.

(d) *Intake through wounds or absorption through skin.* The licensee shall evaluate and, to the extent practical, account for intakes through wounds or skin absorption.

NOTE: The intake through intact skin has been included in the calculation of DAC for hydrogen-3 and does not need to be further evaluated.

[56 FR 23360, May 21, 1991, as amended at 57 FR 54160, Nov. 6, 1992]

§ 20.1203 Determination of external dose from airborne radioactive material.

Licensees shall, when determining the dose from airborne radioactive material, include the contribution to the deep-dose equivalent, eye dose equivalent, and shallow-dose equivalent from external exposure to the radioactive cloud (see appendix B to part 20, footnotes 1 and 2).

NOTE: Airborne radioactivity measurements and DAC values should not be used as the primary means to assess the deep-dose equivalent when the airborne radioactive material includes radionuclides other than noble gases or if the cloud of airborne radioactive material is not relatively uniform. The determination of the deep-dose equivalent to an individual should be based upon measurements using instruments or individual monitoring devices.

[56 FR 23360, May 21, 1991, as amended at 62 FR 39095, Apr. 22, 1997]

§ 20.1204 Determination of internal exposure.

(a) For purposes of assessing doses used to determine compliance with occupational dose equivalent limits, the licensee shall, when required under §20.1502, take suitable and timely measurements of—

(1) Concentrations of radioactive materials in air in work areas; or

(2) Quantities of radionuclides in the body; or

(3) Quantities of radionuclides excreted from the body; or

(4) Combinations of these measurements.

(b) Unless respiratory protective equipment is used, as provided in §20.1703, or the assessment of intake is based on bioassays, the licensee shall assume that an individual inhales radioactive material at the airborne concentration in which the individual is present.

(c) When specific information on the physical and biochemical properties of the radionuclides taken into the body or the behavior or the material in an individual is known, the licensee may—

(1) Use that information to calculate the committed effective dose equivalent, and, if used, the licensee shall document that information in the individual's record; and

(2) Upon prior approval of the Commission, adjust the DAC or ALI values to reflect the actual physical and chemical characteristics of airborne radioactive material (e.g., aerosol size distribution or density); and

(3) Separately assess the contribution of fractional intakes of Class D, W, or Y compounds of a given radionuclide (see appendix B to part 20) to the committed effective dose equivalent.

(d) If the licensee chooses to assess intakes of Class Y material using the measurements given in §20.1204(a)(2) or (3), the licensee may delay the recording and reporting of the assessments for periods up to 7 months, unless otherwise required by §§20.2202 or 20.2203, in order to permit the licensee to make additional measurements basic to the assessments.

(e) If the identity and concentration of each radionuclide in a mixture are known, the fraction of the DAC applicable to the mixture for use in calculating DAC-hours must be either—

(1) The sum of the ratios of the concentration to the appropriate DAC value (e.g., D, W, Y) from appendix B to part 20 for each radionuclide in the mixture; or

(2) The ratio of the total concentration for all radionuclides in the mixture to the most restrictive DAC value for any radionuclide in the mixture.

(f) If the identity of each radionuclide in a mixture is known, but the concentration of one or more of the radionuclides in the mixture is not known, the DAC for the mixture must be the most restrictive DAC of any radionuclide in the mixture.

(g) When a mixture of radionuclides in air exists, licensees may disregard certain radionuclides in the mixture if—

(1) The licensee uses the total activity of the mixture in demonstrating compliance with the dose limits in §20.1201 and in complying with the monitoring requirements in §20.1502(b), and

[1] An organ or tissue is deemed to be significantly irradiated if, for that organ or tissue, the product of the weighting factor, w_T, and the committed dose equivalent, $H_{T,50}$, per unit intake is greater than 10 percent of the maximum weighted value of $H_{T,50}$ (i.e., $w_T H_{T,50}$) per unit intake for any organ or tissue.