Appendix C-1

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
UNITED STATES ATOMIC ENERGY COMMISSION
WASHINGTON 25, D. C.

September 26, 1960

Honorable John A. McCone
Chairman
U. S. Atomic Energy Commission
Washington 25, D. C.

Subject: CRITERIA FOR EVALUATION OF REACTOR SITES

Dear Mr. McCone:

This is with reference to Mr. Finan's letter to me under date of September 21, 1960, in which the Advisory Committee on Reactor Safeguards is requested to transmit comments to you regarding a draft of criteria for the evaluation of sites for power and testing reactors proposed by the Division of Licensing and Regulation.

While the Committee believes that the present document could be developed into a useful technical contribution to reactor safety studies, there are a number of reasons why we cannot recommend that it be given the status of a Commission regulation.

We are sending you in the near future a memorandum on site criteria which sets forth the Committee's views on this matter.

Sincerely yours,

ORIGINAL SIGNED BY
LESLIE SILVERMAN

Leslie Silverman
Chairman

cc: A. R. Luedecke, GM
W. F. Finan, AGRS
~~R. L.~~ Price, DLAR

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APPENDIX "D"

ATOMIC ENERGY COMMISSION

[10 CFR Part 51]

REACTOR SITE CRITERIA

Notice of Proposed Rule Making

Statement of Considerations. On May 23, 1959 the Atomic Energy Commission published in the Federal Register a Notice of Proposed Rule Making that set forth general criteria for the evaluation of proposed sites for power and testing reactors. Many comments were received from interested persons reflecting, generally, opposition to the publication of site criteria as an AEC regulation, both because such a regulation would, to some extent, incorporate arbitrary limitations and because it appeared that in view of the lack of available experimental and empirical data specific criteria could not be established.

Judgment of suitability of a reactor site for a nuclear plant is a complex task. In addition to normal factors considered for any industrial activity, the possibility of release of radioactive effluents requires that particular attention be paid to physical characteristics of the site, which may cause an incident or may be of significant importance in increasing or decreasing the hazard resulting from an incident. Moreover, inherent or engineered design features of the reactor are of paramount importance in determining the possibility and consequences of any release of radioactive effluents. All these factors must be considered in determining whether location of a proposed reactor at any specific site would create an undue hazard to surrounding population.

Recognizing that it is not possible at the present time to define site criteria with sufficient definiteness to eliminate the exercise of agency judgment, the proposed rule set forth below is designed primarily to identify a number of factors considered by the Commission and the general criteria which are utilized as guides in evaluating proposed sites. Through the use of certain assumptions and general calculational techniques set forth in Appendix "A", the proposed rule also attempts to establish a common starting point from which location factors can be assessed by the Commission, the applicant and other interested parties.

The proposed rule stems from the premise that a reactor should be so designed and located that ~~even~~ the accident having a credible ~~likelihood~~ of occurrence during the lifetime of the reactor, which would result in the most hazardous release of fission products (the maximum credible accident), would not result in undue hazard to the health and safety of the public. In assessing the potential hazard from the maximum credible accident, it is useful to consider its possible effect on three areas surrounding the reactor:

(1) The exclusion area upon which the reactor is located, an area access to which is under the direct control of the operator;

(2) The evacuation area surrounding the exclusion area, an area from which residents could be evacuated before any substantial radiological exposure could occur in the event of a reactor accident; and

(3) Nearby population centers, areas of high population density, evacuation from which probably would be neither desirable nor feasible.

The proposed rule describes a calculational procedure for establishing references, or bench marks, based on power level, for use as a beginning point in site evaluation for a particular reactor. For the purpose of establishing bench marks only the calculational procedure assumes that all reactors are alike except for power level and that all site conditions are alike. The bench marks are:

(1) A bench mark exclusion area of such size that an individual located at any point on its boundary for two hours immediately following onset of the maximum credible accident would receive a total radiation dose to the whole body of 25 rem or a total radiation dose of 300 rem to the thyroid from iodine exposure.

(2) A bench mark evacuation area of such size that an individual located at any point on its outer boundary who is exposed to the radioactive cloud resulting from the accident (during the entire period of its passage) would receive a total radiation dose to the whole body of 25 rem or a total radiation dose of 300 rem to the thyroid from iodine exposure.

(3) A bench mark population center distance of 133 1/3% of the distance from the reactor to the nearest population center of more than 25,000 residents. An individual at this distance who is exposed to the radioactive cloud (during the entire period of its passage) would receive a total

radiation dose in the range of 50 to 100 rems to the thyroid from iodine exposure.

The bench mark areas and distances are to be obtained through use of the table on the calculational techniques contained in Appendix "A", which are designed to incorporate conservative factors and assumptions.

The whole body dose of 25 rem referred to in the bench marks corresponds to the once in a lifetime accidental or emergency dose for radiation workers which the NCRP recommends may be disregarded in the determination of their radiation exposure status. (See Addendum dated April 15, 1958 to NBS Handbook 59). The NCRP has not published a similar statement with respect to portions of the body, including doses to the thyroid from iodine exposure. For the purpose of establishing bench mark areas and distances under the conditions assumed in the proposed rule, the whole body dose of 25 rem and the 300 rem dose to the thyroid from iodine are believed to be conservative values.

As previously indicated, these bench marks are only a starting point in the evaluation of a proposed reactor location. The proposed rule specifies that the Commission will also consider physical characteristics of the site, such as seismology, meteorology, hydrology, and geology; and characteristics of the reactor, such as maximum power level, proposed use, engineering safeguards, and unique design features. The overall judgment is based on these features as well as the population density factors represented by the bench marks. Obviously, as specifically indicated in the proposed rule, the Commission may approve a proposed

site which does not meet the bench marks or may disapprove a proposed site which does meet the bench marks.

Although approval or disapproval of a site will be evidenced by Commission action upon an application for a construction permit, the proposed rule provides that a preliminary report on site acceptability may be furnished by the Commission.

Notice is hereby given that adoption of the following rule is contemplated. All interested persons who desire to submit written comments and suggestions for consideration in connection with the proposed rule should send them to the Secretary, United States Atomic Energy Commission, Washington 25, D. C., Attention: Director, Division of Licensing and Regulation, within ninety days after publication of this notice in the Federal Register.

(List of Section Headings)

AUTHORITY:

GENERAL PROVISIONS

§ 51.1 Purpose. It is the purpose of the regulations in this part to describe the criteria which guide the Commission in its evaluation of the suitability of proposed sites for power and testing reactors subject to Part 50 of this chapter. Because it is not possible to define such criteria with definiteness to eliminate the exercise of agency judgment in the evaluation of these sites, the regulations set forth in this part are designed primarily to identify a number of factors considered by the Commission and the general criteria which are utilized as guides in approving or disapproving proposed sites.

§ 51.2 Scope. This part applies to applications filed under Part 50 of this chapter for construction permits and operating licenses for power and testing reactors.

§ 51.3 Definitions. As used in this part:

(a) "Exclusion area" means the area surrounding the reactor, access to which is under the full control of the reactor owner. This area may be traversed by a highway or railroad, provided such highway or railroad is not so close to the facility as to interfere with normal operations, and provided

appropriate and effective arrangements are made to control traffic on the highway or railroad to protect the public health and safety. Residence within the exclusion area shall be minimal and residents shall be subject to ready removal in case of necessity to minimize hazard. Activities unrelated to operation of the reactor may be permitted in an exclusion area provided that no significant hazards to the public health and safety will result from the location of the activity in the exclusion area.

b. "Evacuation area" means the area immediately surrounding the exclusion area which contains residents the total number of which is such that there is a reasonable probability that they could be evacuated from the area or other counter measures could be taken in the event of a maximum credible accident before receiving substantial radiation exposures. The Commission has not specified a permissible population density or total population within the evacuation area because it may vary from case to case. Whether a specific number of people can be evacuated from a specific area on a timely basis will depend on many factors such as location, number, and size of highways, scope and extent of advanced planning, and actual distribution of residents within the area.

(c) "Population center distance" means the distance from the reactor to the nearest boundary of a population center containing more than 25000 residents.

(d) "Maximum credible accident" means that accident having a credible possibility of occurrence during the lifetime of the reactor which would result in the most hazardous release of fission products.

(e) "Power reactor" means a nuclear reactor of a type described in §§ 50.21 (b) or 50.22 of Part 50 of this chapter designed to produce

electrical or heat energy.

(f) "Testing reactor" means a "testing facility" as defined in § 50.2 of Part 50 of this chapter.

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

SITE EVALUATION FACTORS

§ 51.10 Factors to be Considered When Evaluating Sites. In determining the acceptability of a site for a power or testing reactor, the Commission will take the following factors into consideration:

(a) Population density and use characteristics of the site and its environs, including, among other things, the exclusion area, evacuation area and population center distance.

(b) Physical characteristics of the site, including, among other things, seismology, meteorology, geology and hydrology.

(c) Characteristics of the proposed reactor and its use.

§ 51.11 Application of Site Evaluation Factors. The method by which the Commission will evaluate the factors described in § 51.10 is as follows:

1. Bench Mark Areas and Distances. A bench mark exclusion area, a bench mark evacuation area, and a bench mark population center distance will be established for each reactor by calculational procedures described in Appendix "A" of this part.

(i) The bench mark exclusion area is an exclusion area of such size that an individual located at any point on the exclusion area boundary for 2 hours immediately following the onset of the maximum credible accident would receive a total radiation dose to the whole body of 25 rem or a total radiation dose of 300 rem to the thyroid from radioactive iodine exposure.

(ii) The bench mark evacuation area is an evacuation area of such size that an individual who is located at any point on the outer boundary of the evacuation area and who is exposed to the radioactive cloud resulting from the maximum credible accident (during the entire period of the cloud's passage) would receive a total radiation dose to the whole body of 25 rem or a total radiation dose of 300 rem to the thyroid from radioactive iodine exposure.

(iii) The bench mark population center distance is 133 1/3 of the distance from the reactor to the outer boundary of the evacuation area.

2. Relation of Bench Mark Areas and Distances to Other Factors. The establishment of bench mark areas and distances is for preliminary guidance as a beginning point in site evaluation for a particular reactor. The calculational methods used in establishing the bench marks incorporate significant assumptions concerning matters which are not susceptible of proof by experimental or empirical data and do not take into account ~~particular~~ nuclear site characteristics or ~~particular~~ site reactor characteristics. Thus the bench mark areas and distances are not determinative for any reactor site but must be considered along with other relevant information. The Commission may approve a reactor site which does not meet the bench mark areas and distances, and it may disapprove a site which does meet the bench mark areas and distances. For example:

(i) Where the design of a particular facility incorporates extensive and well proven engineering safeguards or there are

favorable features of the site or surrounding area, a proposed site may be approved even though its areas and distances are less than the bench mark areas and distances.

(ii) A site which meets the bench mark areas and distances may be disapproved for a proposed facility if the site or surrounding area has unfavorable features or if the proposed facility has unproven features.

(iii) In considering the suitability of a site for a proposed power or testing reactor, the Commission will consider the earthquake history of the site and its environs. The design for the facility should conform to accepted building codes or standards for areas having equivalent earthquake histories. No facility should be located closer than 1/2 mile from the surface location of a known active earthquake fault.

(iv) In considering the suitability of a site for a proposed power or testing reactor, the Commission will consider special meteorological conditions at the site and in the surrounding area.

(v) In considering the suitability of a site for a proposed power or testing reactor, the Commission will consider geological and hydrological characteristics of the proposed site which might have a bearing on the consequences of an escape of radioactive material from the facility. Power and testing reactors should not be located at sites where radioactive liquid effluents from an accident might flow readily into nearby streams or rivers or might find ready access to underground water tables.

(vi) Where some particularly unfavorable feature of the site exists, such that one or more of the criteria specified in paragraphs (i) to (v) of this paragraph are not met, the proposed site may nevertheless be found to be acceptable if the design of the facility includes appropriate and adequate compensating engineering safeguards.

(vii) In considering the suitability of a site for a proposed power or testing reactor, the Commission will consider proposed maximum power level; proposed use of the facility; the extent to which the design of the proposed facility incorporates extensive and well proven engineering standards; and the extent to which the reactor incorporates unique or unusual features having a significant bearing on the probability or consequences of accidental releases of radioactive material.

§ 51.20 Preliminary Review. Approval or disapproval of a proposed site will be evidenced by Commission action upon an application for a construction permit in accordance with applicable procedures and requirements under the regulations in this chapter. The Commission may, however, furnish a preliminary report as to the acceptability of a site proposed for a power or testing reactor prior to the filing and action upon an application for a construction permit.

Annex 1 to Appendix "D"

Appendix A

Calculation of Bench Mark Areas and Distances

1. On the basis of specified calculation methods and assigned values of parameters involved, bench mark areas and distances for reactors of various power levels have been determined and are listed in the following table:

Power Level (Thermal Megawatt)	Exclusion Distance (Miles)	Evacuation Distance (Miles)	City Distance (Miles)
1500	.59	13.3	17.7
1200	.51	11.5	15.3
1000	.42	10	13.3
900	.41	9.2	12.3
800	.39	8.4	11.2
700	.35	8.0	10.7
600	.32	7.1	9.5
500	.28	6.2	8.3
400	.25	5.2	6.9
300	.23	4.3	5.7
200	.21	3.5	4.7
100	.18	2.2	2.9
50	.15	1.4	1.9
10	.08	.5	.7

2. This table has been based upon the following assumptions:

a. The maximum credible accident will release to the atmosphere of the reactor building 100% of the noble gases, 50% of the halogens and 1% of the solids in the fission product inventory. This release is equal to 15.8% of the total radioactivity of the fission product inventory. Of the 50% of the halogens released, one-half is assumed to condense out on the internal surfaces of the reactor building or adhere to internal components.

b. The release of radioactivity from the reactor building to the environment occurs at a leak rate of 0.1% per day of the atmosphere within the

building and the leakage rate persists throughout the effective course of the accident which, for practical purposes, is until the iodine activity has decayed away.

c. In calculating the doses which determine the size of the benchmark areas, radioactivity decay in the usual pattern has been assumed to occur during the time fission products are contained within the reactor building. No decay was assumed during the transit time after release from the reactor building.

d. No ground deposition of the radioactive materials that leak from the reactor building was assumed.

e. The atmospheric dispersion of material leaking from the reactor building was assumed to occur according to the following relationship:

$$X = \frac{20}{\pi u C_y C_z d^{2-n}}$$

where Q is rate of release of radioactivity from the containment vessel, the ("source term,"):

X is the atmospheric concentration of radioactivity at distance d from the reactor

u is the wind velocity

n is the atmospheric stability parameter

C_y and C_z are horizontal and vertical diffusion parameters resp.

π is a constant 3.1416.

f. Meteorological conditions of atmospheric dispersion were assumed to be those which are characteristic of the average "worst" (most unfavorable) weather conditions for average meteorological regimes over the country. For the

purposes of these calculations, the parameters used in the equation in section e. above had values as follows:

$$u = 1 \text{ m/sec}; \quad C_y = 0.40; \quad C_z = 0.07; \quad n = 0.5$$

g. The isotopes of iodine were assumed to be controlling for the evacuation and city distances. The evacuation distance results from integrating the effects of iodine 131 through 135. The city distance equals the evacuation distance increased by a factor of one-third.

h. The source strength for each iodine isotope was calculated to be as follows:

Isotope	Exclusion Q (curies/megawatt)	Evacuation Q (curies/megawatt)
I^{131}	.48	76.5
I^{132}	.55	1.44
I^{133}	.77	1.82
I^{134}	.62	.91
I^{135}	.87	5.4

These source terms combine the effects of fission yield under equilibrium conditions, radioactive decay during the holdup time in the reactor building, and the release rate from the reactor building.

i. For the exclusion distance, doses from both direct gamma radiation and from iodine in the cloud escaping from the reactor building must be calculated and the distance established on the basis of the effect requiring the greater isolation.

j. In calculating the thyroid doses which result from exposure of an individual to an atmosphere containing concentrations of radioactive iodine, the

following conversion factors were used to determine the dose received from breathing a concentration of one curie per cubic meter for one second:

Isotope	Dose (rem)
I^{131}	334
I^{132}	12.7
I^{133}	78.8
I^{134}	6.14
I^{135}	21.9

k. The whole body doses at the exclusion and evacuation distances due to direct gamma radiation from the fission products released into the reactor building in the maximum credible accident were derived from the following relationships:

$$D = \frac{483\ Be^{-ur}}{4\pi r^2} \int_0^t t^{-0.21}\, dt$$

where D is the exposure dose in roentgens per megawatt of reactor power

r is the distance in meters

B, the scattering factor, is equal to $(1 + ur + \frac{ur^2}{3})$

u is the air attenuation factor (0.01 for this calculation)

t is the exposure time in seconds.

In this formulation it was assumed that the shielding and building structures provided an attenuation factor of 10.

Annex 2 to Appendix "D"
Appendix A (alternate 1)

Calculation of Bench Mark Areas and Distances (concentration limits)

The calculational procedure to arrive at bench mark areas and distances defined in terms of concentration limits is basically the same as that shown in Annex 1. The table of bench mark distances would be identical but the explanation of the assumptions used in deriving the table would differ in the following ways:

a. The evacuation distances would be derived from the following relationship:

$$d^{2-n} = \frac{2\,Q}{\pi\, u\, Cy\, C_z\, X}$$

where:

d is the distance

Q is the rate of release of radioactivity from the reactor building

u is the wind velocity

n is the atmospheric stability parameter

Cy and C_z are horizontal and vertical diffusion parameters

π is the constant 3.1416

X is the concentration limit for iodine defining the bench mark distance

b. Iodine isotope 131 would be assumed to be controlling. The concentration limit X would be defined to reflect contributing effects of the other iodine isotopes.

c. Conversion of concentrations into doses as described in par. 2j of Annex 1 would not be required.

Annex 3 to Appendix "D"

Appendix A (Alternate 2)

Table of Bench Mark Areas and Distances

In establishing bench mark areas and distances the following table shall be used:

TABLE OF BENCH MARK LOCATION DISTANCES

Power Level (Thermal Megawatt)	Exclusion Distance (Miles)	Evacuation Distance (Miles)	City Distance (Miles)
1500	.59	13.3	17.7
1200	.51	11.5	15.3
1000	.42	10	13.3
900	.41	9.2	12.3
800	.39	8.4	11.2
700	.35	8.0	10.7
600	.32	7.1	9.5
500	.28	6.2	8.3
400	.25	5.2	6.9
300	.23	4.3	5.7
200	.21	3.5	4.7
100	.18	2.2	2.9
50	.15	1.4	1.9
10	.08	.5	.7

Note: This table represents a pre-calculation of the bench mark areas and distances precluding the need for reference in the regulation to either dose limits or concentration limits.

Appendix E

BENCH MARKS FOR SELECTED REACTORS

MWt	Reactor	Exclusion Area: Bench Mark Distance (miles)	Exclusion Area: Actual Distance (miles)	Evacuation Area: Bench Mark Distance (miles)	Evacuation Area: Actual Pop.Density in Bench Mark Area (people/sq.mi.)	Population Center Distance: Bench Mark Distance (miles)	Population Center Distance: Actual Distance (miles)
630	Dresden	.33	.5	7.4	38	9.9	14
585	Con. Ed.	.31	.3	7.0	403	9.4	17
485	Yankee	.28	.5	6.2	33	8.3	21
300	PRDC	.23	.75	4.5	24	6.1	7.5
270	PWR	.23	.4	4.2	298	5.7	7.5
240	Consumers	.22	.5	3.9	28	5.2	135
240	Hallam	.22	.25	3.9	10	5.2	17
203	Pathfinder	.21	.5	3.5	25	4.6	3.5
202	PG&E	.21	.25	3.5	172	4.6	3
200	ICBWR	.21	.2	3.5	86	4.6	10
115	Phila. Elec.	.19	.57	2.4	29	3.2	21
60	NASA	.16	.57	1.6	53	2.1	3
60	CVTR	.16	.5	1.6	12	2.1	25
60	Jamestown (Orig. site)	.16	.3	1.6	1200	2.1	0.5
60	Jamestown (New site)	.16	.3	1.6	66	2.1	2.4
58	Elk River	.16	.23	1.5	40	2.0	20
50	VBWR	.15	.4	1.4	23	1.9	15
48	Piqua	.15	.14	1.4	960	1.8	27
40	Pt. Loma	.14	.25	1.2	0	1.6	3