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February 19, 1960

MEMORANDUM

To: All Members of the ACRS

From: C. Rogers McCullough, Chairman, Environmental Subcommittee

Subject: STUDIES ON SITE CRITERIA

The attached material from Frank Gifford is pertinent to the site criteria problem. You will recall that Mr. McCone mentioned to the Committee his desire to get something more definite on site criteria at as early a time as possible.

The site criteria problem has also been raised at the recent 202 Hearings. This is an extremely complex and difficult problem but I believe we ought to give a little time to study it because of the issues which have been raised. I personally feel that we can get very little further without a considerable amount of work by some persons spending full time on the project.

Nevertheless, I would appreciate any comments you can give on this problem.

ACRS ENVIRONMENTAL SUBCOMMITTEE

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Attachments
a) Draft notes prepared for site criteria subcommittee meeting, F.A. Gifford, 2/16/59
b) A meteorological population index for reactor site location, W. M. Culkowski, August 1959.

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Draft notes prepared for site criteria
Sub-committee meeting - F. Gifford
16 February 1959.

BACKGROUND ON SITE CRITERIA

A. References:

(1) Downes and Singer, 1958: "A numerical method for reactor site evaluation.....", mimeo.

(2) Tait, G.W.C., 1956: "Reactor siting, the exclusion area concept and an alternative approach," CRHP-677 (AECL No. 388).

(3) Menegus and Ring, 1958: "Accidental dispersion of reactor poisons and the controlled distance required," DP-105 (Rev. 2).

(4) Farmer, Fletcher, and Fry, 1958: "Safety considerations for gas cooled thermal reactors of the Calder Hall Type," A/Conf. 15/P/2331.

(5) Gomberg, H. J., 1958: "A quantitative approach to evaluation of risk in locating a reactor on a given site", A/Conf. 15/P/436.

(6) "Theoretical possibilities and consequences of....," WASH 740.

(7) Holland, J. Z., 1954: "Review of reactor exclusion radius formulas," WASH 169 (Decl.)

(8) McCullough, C. R., 1958: "Acceptable total public damage," draft notes.

(9) Fitzgerald, J. J., 1958: "Reactor Hazards" (in Sax, "Dangerous Materials").

(10) Marley and Fry, 1956: "radiological hazards from....", Proceedings of the 1st Geneva Conf., Vol. 13.

(11) Parker and Healy, 1956: "Environmental effects....", ibid.

(12) Meteorology and Atomic Energy, USWB, 1955. (AECU 3066).

B. Current Approaches to Reactor Hazard Analysis:

(1) Reactor hazard summary reports: Over the years a reasonably systematic approach to the hazard of particular reactors has developed, as can be found in a large number of hazard summary reports. Various accidents are postulated, based on design studies, and possible releases to the environment from one (the Maximum Credible Accident) or more of these are studied. Meteorology of dispersion has been largely standardized, and methods evolved, i.e. refs. (9) or (12), to compute resulting internal and external dosages, deposition dosage, etc.

Important areas of uncertainty are involved in these computations: Some examples are, percentage release of fission products, dispersion in stable meteorological conditions (which occur 40-60% of the time almost everywhere), biological hazard thresholds, etc. But if one accepts reasonable values of these, the method leads directly and quantitatively to ground dosage pattern predictions. By combining these with population densities, i.e., ref. (5), the number of persons affected by specified radiation dosages is obtained, as well as the degree of land and crop contamination. It would seem evident that, suitably extended and varied, this general methodology could be used relatively, to rank reactors, and absolutely, to determine injury, deaths and property damage for any particular reactor.

(2) <u>Generalized hazard studies:</u> In an attempt to simplify and sort out the many factors involved, and having in mind, no doubt, the desirability of arriving at reactor site criteria, several authors have attempted generalized hazard studies, refs. (6), (3), and (5). [The latter, although inspired by a specific reactor problem, is essentially a generalized approach. Ref. (1) is essentially an extract from procedures developed in ref. (6).] All these studies assume that the probability of an accident is unity; i.e., they study the hazard per reactor accident. Probabilistic nomenclature, not specifically introduced into the computations of approach number (1), may arise in these generalized studies in dealing with the effects of wind direction, rainfall, population distribution, and so on. The consequences of reactor accidents can then be expressed in terms of the probabilities (per accident) of deaths, injuries or property damage per unit power level.

(3) <u>Are the specific hazard studies and the generalized studies different?</u> The answer seems to be that, apart from different weighting of the effects of various factors, the basic approach is the same in all these studies: namely, one assumes a bad reactor accident, tries to determine the fission product release, sees how the meteorology will spread the material around, and estimates the effect on people and/or land use.

However, the generalized studies attempt to place all reactors on a comparable basis. In doing so, each has incorporated some simplifying assumptions which have more or less serious effects on the results. These assumptions could be classed as:

(a) those common to all hazard studies, and shared by the approach in paragraph B (1); an example is the assumption of certain Sutton C and n values for stable meteorological conditions.

(b) those incorporated as matters of expediency; an example is the assumption of a power law population distribution, in ref. (1). This simplifies the math, but is sometimes not reasonable.

(c) those made in error; an example is the assumption, in WASH 740 (page 42) that inhalation dose inside a building during cloud passage is "negligible" compared with that outside.

There seems to be no good reason for accepting assumptions in categories(b) or(c). In this respect, Gomberg's study seems superior to the others of paragrah B (2).

C. <u>Some Alternative Suggestions:</u>

(1) <u>Tait's criticism:</u> In an exceptionally lucid and readable critique, ref. (2), Tait made the main point that all published estimates grossly underestimate the hazard arising from a release in stable meteorological conditions. Whereas observational evidence, e.g., Hilst, <u>J. Meteor.</u>, <u>15</u>, p 125, (as well as other sources), indicates that there is little or no vertical diffusion under stable meteor-

ological conditions(which occur roughly half the time, c.f. Gifford, TID 757?) hazard studies have assumed a vertical Sutton diffusion coefficient of $C_z = .05$. A more realistic value would be .01. But he points out that the consequence of assuming this value in terms of siting for "perfect safety" under stable meteorology would require exclusion areas of the order of 1000 square miles for a 1 MW fission product release. In general, this is unattainable (as is perfect safety in any industry).

As an alternative, he suggests acceptance of a limited degree of hazard, balancing cost and likely frequency of occurrence against service to the community by the reactor. He defines the concept of a "maximum permissible escape", and suggests (as a basis for high level policy discussion) these:

	Built up Areas	Unsettled country
Power reactor (1000 MW)	1 MW	10 MW
Minor reactors of proven design	.1 MW	1 MW
Experimental and untested reactors	-	0.1 MW

(2) Acceptable total public damage: McCullough, ref. (8), suggests assuming a long term (10 year) acceptable total damage level nation-wide, and prorating this by existing and expected reactors, weighting each for its share of the total power product that it contributes.

(3) Newson's suggestion: This is an attempt to allow credit for favorable reactor desing figures by combining proba~~bilities~~ of

simultaneous failure of the original system, inner-containment, outer-containment, etc.

(4) Silverman's checklist: This is a comprehensive listing of major pertinent factors in reactor safety, with an arbitrary value rating for each, that can be applied to a reactor proposal. The result is a figure of merit by means of which reactors could be inter-compared from the safety standpoint.

D. Summary of the Present Position:

(1) As a result of pioneering and continuing work by many groups and individuals in the reactor safety field (para. A), highly developed methodology now exists (para. B) by means of which, for a specific reactor proposal and assuming the occurrence of an accidental release, the dosage to surrounding populations can be estimated, supposedly with fair precision.

Research and experience in the application of these methods have delineated certain areas where, lacking necessary basic information, we are forced to make educated guesses.

(2) Recognizing, rightfully, that the methodology of para. B does not adequately distinguish among basic reactor types by giving credit for safety mechanisms other than containment and exclusion, and that absolute safety may be an unrealizable as well as an unrealistic objective, tentative alternative suggestions have been made (para. C).

(3) The proposals of para. C are at present in quite preliminary form. To become a method of hazard analysis, embodying the background of accumulated knowledge of reactor hazards reflected in methods B, any or all these proposals will need first to go through a period considerable development.

E. The Problem of Choice of Hazard Criteria; Some Opinions and Recommendations:

(1) We do not today possess all the basic physical information needed to reduce the problem of reactor hazard evaluation to a straightforward, engineering handbook type of calculation. Some of the most important things we do not know or badly need to know better are, for example:

(a) the probability of failure of significant reactor systems;

(b) the effect of atmospheric transport under stable conditions;

(c) the amounts of fission products released under accident conditions;

(d) the concentrations of various fission products and radioactivity levels that will result in various degrees of biological damage.

(2) The reactor hazard evaluation problem is very complicated. It seems too much to hope that attempts to simplify it grossly, such as those described in paras C and B (2), will at the same time provide enough flexibility and realism to result in hazard estimates as precise as those available through the detailed methods of para. B (1). The generalized approaches seem nevertheless to be excellent

means of discriminating relatively among reactors, as to hazard.

(3) Hazard criteria, i.e. permissible emergency dosages, containment requirements, and so on, should be (it seems to me) rooted insofar as possible in definite, physically derived numbers; i.e., number of deaths or injury expected, and so on. A relative hazard rating is very useful for discussion and orientation purposes but should probably not be given independent, legal status, or imposed as a design criterion.

(4) In attempting to formulate site criteria the attempt should be to arrive at hazard criteria and hazard study requirements which tend to impose on an applicant the necessity for a hazrd analysis roughly along the lines of the "best", i.e., the most acceptable to the ACRS, of past hazard reports. I think it would,in the long run, be unwise to propose, at this time, a set of site evaluation standards less generalized than the recent draft proposed by the HEB and might, on further review, favor even fewer specific requirements.

There are two reasons for this feeling. One is, of course, that when information now lacking on points mentioned above becomes available, specific numbers may need to be changed. The second reason is, perhaps, not so obvious. In the past, much of the basic information on reactor hazards has been developed by the contractors and operators as each faced for himself the unknown or uncertain aspects of ractor hazards. To fix criteria absolutely at this point would in effect cut off this line of progress.

(5) I believe it is urgent that comprehensive studies of reactor hazards be made by a competent group, with the object of improving knowledge on the subject. I believe that these studies should be sponsored by the AEC and endorsed by the committee.

A Meteorological Population Index for Reactor Site Location

W. M. Culkowski
August 1959

ABSTRACT

The need for a simple, yet flexible method of comparing one reactor site, meteorologically, with another is becoming increasingly apparent. The method outlined below, though only an index, can be executed in less than four hours for most reactor sites.

There are many factors in estimating the risk involved in locating a reactor at a particular site. Each factor, in turn may be evaluated in a number of ways. Meteorologically, the approach has generally been to assume the worst possible meteorological conditions, the maximum credible accident, and from them determine the resulting damage. This approach is a sound one, and may be considered to be a mandatory inclusion in any complete examination of site conditions. Obviously, however, every possible condition, not just the worst, should be used to secure a fair evaluation. This can be done easily via climalotogical records and a fairly accurate map of the population distribution. A Rand-McNally, or similar road atlas, a wind-rose, a pair of dividers and the set of figures included below are sufficient to give a qualitative reactor hazard index.

Holland (1) derived a formula for average concentration from Sutton's continuous point source equation. For an 8-point wind direction, the equation is:

$$X_0 = \sum_{i=1}^{R} F_i \frac{8Q_0}{\pi^{3/2} c_i X^{\frac{4-n}{2}} \bar{u}_i} \exp\left[-\left(\frac{h^2}{c_i^{2} X^{2-n}}\right)\right]$$

Where X_o = average concentration in each direction (parts/meter^3)

Q_o = emission rate of effluent (parts/second)

C = diffusion coefficient (meters$^{\frac{n}{2}}$)

n = stability parameter; non-dimensional

x = distance downwind from source (meters)

h = height of source, (meters)

u_i = average speed for wind speed group "i" (meters/second)

F_i = fraction of time wind is from direction D, wind speed group i

R = index denoting the number of wind speed groups in the annual distribution

In practice, little is usually gained by breaking the wind speeds into groups. Therefore, in equation (1) the average wind speed for each direction may be used to shorten computation.

By allowing Q_o = 1 part/second the average experienced concentration of effluent at any distance from the source may be estimated. If we are dealing with radioactive matter, Q_o becomes 1 curie/second, multiplying the population density by the concentration distribution and adding, we obtain the total "curie experience" of the population. Dealing in convenient units, the term "man-microcuries" becomes convenient to use.

This total of man-microcuries can be thought of as the mean of a "parent distribution" or "total population" of all possible accidents. If we now suppose that the curies are released at random, the best estimate of the resulting man-microcurie experience would be the mean of the original parent distribution. (Note that since we are dealing with averages, knowledge of the total time of release or total amount is unnecessary as long as we assume a release rate of 1 curie/second). Similarly, the best estimate of the man-microcurie experience of a single release is the mean of the parent distribution.

Figure 1 is a set of curves used in computing average downwind concentration. The assumption is made of 14 hours of "daytime" conditions, 10 hours of nighttime. The ordinate is plotted as concentration, the abcissa as distance. For each average wind speed, the concentration in each direction can be determined. Calling this concentration $\overline{X}_R$, and multiplying by the percent of time the wind is from that direction, F, results in the average yearly or (average release) concentration data, X_o i.e. $\overline{X}_o = X_R \cdot F$.

For example, suppose the Elk River Reactor malfunctioned. It becomes necessary to release 1200 curies of long-lived fission products. For convenience, we will say that the total time of release is 1200 seconds. We may use figure one to find the average urban exposure for this release up to 25 miles.

Elk River is near to the Minneapolis-St. Paul area, so we may use Minneapolis-St. Paul wind data. From this data we find:

Wind direction (from)	Affects communities in the direction	Frequency	Average speed
N	S	8%	11 mph
NE	SW	8%	11 mph
E	W	10%	10 mph
SE	NW	23%	11 mph
S	N	8%	10 mph
SW	NE	9%	9 mph
W	E	8%	12 mph
NW	SE	26%	13 mph

Consider the town of Big Lake, Wisconsin, 8 miles west of the reactor. From the graph we see the average downwind concentration for 8 miles, 10 mph winds is about 7.5×10^{-8} curies/cu meter. The frequency of winds, toward Big Lake, however, is only 10%, and the population is about 480 people. Therefore,

$$480 \times 7.5 \times 10^{-8} \times .10 = 3600 \times 10^{-9} = 3.6 \text{ man-microcuries/cu meter.}$$

Continuing this process for the entire urban population within 25 miles of the Elk River Reactor, the total urban exposure (on the average) would be 312.9 man-microcuries/cubic meter during the period of release.

Similar studies of the Dresden Reactor show that the urban population within 25 miles will average 548.5 man-microcuries/cu meter during the time of a 1 curie/sec release.

In the above examples, included only a 25 mile radius. In actual practice 50-100 miles would be better since the larger cities would then be included.

It should be stressed, however, that this method is only as index, or estimate, not a prediction. As an index, it serves as a convenient method of comparing various sites, and of course, it is an <u>average</u>. Some releases of "k" curies will greatly exceed the index, while others will fall far below. This index based on the <u>urban</u> population because of the ease of obtaining data (i.e. a Rand-McNally Road Atlas). A rural index, based on a homogenous population distribution could also be made but difficulties are encountered because of the odd shapes of some counties.

Though only an index, this method has the virtue of being rapidly clculated for any location in the U.S. by anyone familiar with simple computational techniques.