August 28, 1960

To : The Honorable John A. McCone

From : ACRS

Subject: REACTOR SITE CRITERIA

You have asked that we supply you with a set of criteria which could be used for judging the adequacy of proposed sites for reactors. The ACRS has devoted considerable time to this problem and has appointed a subcommittee which also has devoted considerable time. A large part of our delay in submitting site criteria stems from the fact that we believe it is premature to establish quantitative limits on the variables involved in site evaluations - especially if such limits will appear in federal regulations. We recognize that the correctness of the numbers which could be selected now cannot be proved by experimental backup; and, therefore, these numbers give a false sense of positiveness which cannot be supported upon detailed scrutiny. Numbers chosen now will be expected to change as more information develops. For example, a quantitative calculation of dosage must include some estimate of the fraction of the total fission product inventory which may be air-borne. This fraction is currently under experimental examination and will be subject to rapid change. The committee believes that the inmutability of quantitative numbers will stifle progress toward a better selection of numbers. It is very true that the ideas and interpretations from applicants themselves have played a major part in the formulation of the current bases for site evaluation. It would be a significant loss to stop the flow of new ideas from the applicants. The committee also expects that the appearance of quantitative numbers in a federal regulation will reduce the continual awareness of the applicant that he has assumed a responsibility to be alert to and to act on unforeseen disadvantages of a site even after the site has been approved. The committee therefore advises that a quantitative statement of site criteria not be included in federal regulations. These comments do not mean that the ACRS has no bases for judging the adequacy of sites. They merely emphasize that site selection is still largely a matter of judgment.

Inasmuch as the ACRS has been making judgments on sites, it may be helpful to review the framework on which these judgments are being made.

It is a prerequisite, of course, that the reactor be carefully designed, constructed, and inspected in a manner equivalent to that given boilers, bridges, and other structures which may present public hazards. Also, these site criteria are applicable only to those reactors on which definitive experience has been developed. Reactors which are novel in design or unproved as prototypes belong at isolated sites. Thus, current site criteria are pertinent primarily to pressurized water reactors, boiling water reactors, sodium cooled thermal reactors, and organic moderated reactors-using standard containment vessels.

Our site evaluations stem from several concepts. These are overlapping, but not ~~a conflict~~:

(1) Almost everyone off-site should have a reasonably good chance of not being seriously hurt if a credible* reactor accident should occur.

(2) The exposure to society in terms of integrated man-rems should not be such as to cause a large shortening of integrated lifetime or a significant genetic damage or a significant increase in leukemia - should a credible* reactor accident occur.

(3) There should be an explicitly defined value to society resulting from locating a plant at a proposed site, rather than in a more isolated area.

(4) Should the most serious accident possible (not credible*) occur, the numbers of people killed should not be catastrophic.

Incidentally, we reject, as premature, the concept that damage to people from reactor accidents be no greater than that accepted in other industries, although in the future this might become a guiding principle. The reasons for this rejection are twofold: We do not have sufficient information on the probability of accidents to make use of this concept in site evaluations. We do use, of course, the fact that the probability of a serious accident is very low. Secondly, we recognize that the atomic power business has not yet reached the status of supplying an economic need in a manner similar to that of more mature industries; and, therefore, arguments of taking customary risks for the greater good of the public are somewhat weak. At the same time, we do not want to imply that the restrictions placed on site locations during the development life of atomic power will necessarily be carried over to the period of maturity of the atomic power industry.

The reduction of these concepts to a judgment as to the adequacy of a proposed site requires further logic and the introduction of some numerical estimates. We believe that the soul-searching analysis which is necessary at this stage should be done independently by the owner of the reactor, using the characteristics which are peculiar to his site and to his specific reactor. This step, we believe, is essential to developing his continuing alertness of his responsibility to the community surrounding the site. However, in committee deliberation, we balance his analysis against a generalized accident situation which serves the purpose of a reference point from which we can better understand the analysis submitted by the applicant.

Our generalized accident analysis assumes that a serious accident has occurred and predicts in rough terms the consequences of such an analysis. It is obvious that the generalized accident is an arbitrary artifact subject to change and has value only so far as it aids judgment. In the generalized accident, we must make numerical assumptions as to the amount and rate of radioactivity released (the source term), the dispersal of the radioactivity in the air and in the hydrosphere, and the effect of this radioactivity on people.

Source Term

An arbitrary accident is assumed to occur which results in the release of fission products into the containment shell. Roughly 100% of the total radioactive inventory gases, 50% of the halogens, and 5% of the bone seekers are assumed to be so released. It is then assumed that this mixture leaks out of containment sphere at a rate defined by the designed leak rate of the container. The reasoning back of this source term is admittedly loose. It stems primarily from a present inability to be convinced that coolant cannot be lost somehow from the reactor core, either by spontaneous fracture of some element in the primary system or by a fracture caused by mal-operation (instrumental or human) of the control rods. It is also tacitly assumed that in this accident the containment vessel will not rupture. The logic behind this assumption is that we require all of the components restraining the pressure of the primary system to be operating at temperatures above their nil-ductility temperature. We are therefore more confident, but not certain, that failure will occur by tearing rather than by brittle-fracture and that the probability of ejection of missiles which penetrate the containment shell is low. The necessary supporting structures and shielding also protect against missile damage.

Dispersal of the Radioactivity

Meteorology

In the generalized accident, we assume a Sutton-type dilution of airborne activity using constants which reflect unfavorable wind conditions, rather than average wind conditions. The constants are a function of the local topography. Those proposed by HEB, with the advice of the U.S. Weather Bureau, are adequate for the generalized accident out to 10-20 miles. At about this distance, the constancy of wind direction is lessened so that the air-borne radioactivity is considered to be more or less uniformly distributed over a large arc such as 45 to 60°.

Hydrology

The model for dispersal by hydrology is largely influenced by the idea that the reactor complex should be designed so that water movement can be stopped if the movement is fast; and, if it is slow, such as percolation through the ground, there is no need to expose people to this radioactivity since plenty of time remains to take action. Thus, for any site it is a requisite that ground water flows be amenable to damming, and it must be established that underground flows are slow and do not connect readily with water supply systems.

Effect of Radioactivity on People

The upper limit to the exposure to the public in the generalized accident should be no higher than the maximum one-in-a-lifetime emergency dose. This level has not been officially set by AEC. We are arbitrarily choosing a figure of about 25 r whole body or equivalent integrated dose for this level. This figure is mentioned in Handbook 59 of the National Bureau of Standards, Pages 69-70. It is also about what an adult individual will have received at death from background radiation. The dosage so far mentioned refers to limits to people when the people are considered as independent individuals. When large numbers of individuals are exposed to radiation, another limit also exists because of genetic effects and because of the statistical nature of induced leukemia and the shortening of the life span. The limits of exposure to large groups of people are better expressed in terms of integrated man-rems. We are tentatively using a figure of 10^7 man-rems for this limit for the people who might be exposed to radiation doses falling between 1 and 25 rems.

The implication of these numbers is this. About a reactor site, there should be an exclusion radius in which no one resides. Surrounding this, there should be a region of low population density, so low that individuals can be evacuated if the need arises in a time which will prevent their receiving more than a dose of 25 r. Beyond this evacuation area, there should be no large cities (about 10,000) sufficiently close so that the individuals in these cities might receive more than the lower of the following: (1) 10^7 man-rems in the generalized accident, (2) 400 rems under the extremely improbable accident in which the containment sphere fails completely to restrain all radioactivity.

It is apparent that the committee is accepting for its generalized accident that presented by HEB, plus the addition of a restriction on total man-rems when large numbers of people are exposed to low levels of radiation. The major and important difference between the viewpoint of the ACRS and that of HEB concerns the formalization of the generalized accident into regulations. The committee wishes to emphasize that it recommends against entering quantitative numbers into the regulations on site locations at the present time because the numbers have much less experimental backup than most other numbers given regulation status.

We think it much more desirable to include in the regulations general statements of site criteria. These general statements, of course, can take any one of a number of different forms. As a suggestion, the committee is presenting an attachment to this letter - General Site Criteria - which we believe to be adequate for the current need. In addition, we think that it is highly desirable that individuals in HEB (and other informed AEC employes) present as technical papers, but not as regulations, their working approach to making judgments on the adequacy of proposed reactor sites.

WPC:jmb
Attach.

GENERAL SITE CRITERIA

In judging whether or not a given site is suitable, the following factors must be taken into consideration.

1. The amount of radioactive materials which will be contained in the reactor under planned conditions of operation - primarily determined by the power level of the reactor and the length of operating cycle.

2. The characteristics of the reactor, including the reactor design, materials of construction, and method of operation.

3. The probability and nature of release of radioactive material. These quantities can be bracketed from an intensive analysis of what might fail in the reactor for any reason whatsoever. Consideration should be focused upon reactor design, materials of construction, adequacy of inspection, method of operation, and also on the experience which has been gained from the operation of this type and similar types of reactors.

4. The features of the surrounding environment which may be damaged by the release of radioactive material, including damage to people, contamination of water supplies, and the contamination of ground and crops.

It is emphasized that all power reactor plants should be built in accordance with the best conservative engineering principles and using materials which are of high quality. These plants should be designed so that assurance can be given that there will be no failure of their equipment, in the same sense that assurance can be given that there will be no failure of bridges, boilers, locomotives, automobiles, etc. Reactor plants of types with which there is limited experience will be required to be located in areas of low population density and remote from important water supplies or cities or crops, unless it can be shown that reliable barriers or devices will be used to cope with the results of failures within the plant due to unforeseen causes in compensation for the poor location.

In selecting the balance between designed safeguards and isolation which these plants must have to provide an adequate margin of safety against accidents which will endanger people, consideration should be given to the damage which might result from the maximum credible release of radioactivity.

First, persons living in the immediate vicinity of the exclusion area of the reactor plant may be subject to relative high rates of radiation dosage. The estimated dose delivered to these people should not exceed 25 rem to the whole body or equivalent for meteorological conditions somewhat more pessimistic than average conditions for the site. Accordingly, it should be supportable that these people can take appropriate action, such as evacuation or entering suitable shelters so that almost everyone would have a reasonable chance of escaping serious injury. This infers that a relatively few people would be involved.

Second, the release of radioactive material should not expose people to radiation doses which will result in a statistically significant increase in leukemia or shortening of life to large numbers of people.

Third, large numbers of people should not be exposed to radiation doses which will significantly affect the genetic pool.