Title
METHODOLOGIES FOR REVIEW OF THE HEALTH AND SAFETY ASPECTS OF PROPOSED NUCLEAR, GEOTHERMAL, AND FOSSIL-FUEL SITES AND FACILITIES. VOLUME 9 OF THE FINAL REPORT ON HEALTH AND SAFETY IMPACTS OF NUCLEAR, GEOTHERMAL, AND FOSSIL-FUEL ELECTRIC GENERATION IN...

Author
Nero, A.V.

Publication Date
1977

Volume 9 of the final report on

HEALTH AND SAFETY IMPACTS OF
NUCLEAR, GEOTHERMAL, AND FOSSIL-FUEL
ELECTRIC GENERATION IN CALIFORNIA

A project performed for the
California Energy Resources
Conservation and Development Commission,
Contract no. 4-0123

Energy and Environment Division

Methodologies for Review of the Health and Safety Aspects of Proposed Nuclear, Geothermal, and Fossil-Fuel Sites and Facilities

A.V. Nero and M.S. Quinby-Hunt

January, 1977

Lawrence Berkeley Laboratory University of California/Berkeley

Prepared for the U.S. Energy Research and Development Administration under Contract No. W-7405-ENG-48

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
Price: Printed Copy $7.75; Microfiche $2.25

LBL-5923

METHODOLOGIES FOR REVIEW OF THE HEALTH AND SAFETY ASPECTS OF PROPOSED NUCLEAR, GEOTHERMAL, AND FOSSIL-FUEL SITES AND FACILITIES

A. V. Nero and M. S. Quinby-Hunt

Volume 9

of

HEALTH AND SAFETY IMPACTS OF

NUCLEAR, GEOTHERMAL, AND FOSSIL-FUEL

ELECTRIC GENERATION IN CALIFORNIA

Energy and Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

January 1977

This is a report of work performed for the State of California Energy Resources Conservation and Development Commission, which provided funding under contract No. 4-0123. This work was done with support from the U. S. Energy Research and Development Administration.

This is one of a series of reports prepared as part of the Lawrence Berkeley Laboratory project, "Health and Safety Impacts of Nuclear, Geothermal, and Fossil-Fuel Electric Generation in California." This project was performed for the State of California Energy Resources Conservation and Development Commission as its "Health and Safety Methodology" project, funded under contract number 4-0123. The reports resulting from this work are listed below. Their relationship to one another is described fully in volume 1, the Overview Report.

Vol. 1: "Health and Safety Impacts of Nuclear, Geothermal, and Fossil-Fuel Electric Generation in California: Overview Report," by the entire staff, Lawrence Berkeley Laboratory Report LBL-5924. Includes "Executive Summary" for the project.

Vol. 2: "Radiological Health and Related Standards for Nuclear Power Plants," by A.V. Nero and Y.C. Wong, Lawrence Berkeley Laboratory Report LBL-5285.

Vol. 3: "A Review of Light-Water Reactor Safety Studies," by A.V. Nero and M.R.K. Farnaam, Lawrence Berkeley Laboratory Report LBL-5286.

Vol. 4: "Radiological Emergency Response Planning for Nuclear Power Plants in California," by W.W.S. Yen, Lawrence Berkeley Laboratory Report LBL-5920.

Vol. 5: "Control of Population Densities Surrounding Nuclear Power Plants," by A.V. Nero, C.H. Schroeder, and W.W.S. Yen, Lawrence Berkeley Laboratory Report LBL-5921.

Vol. 6: "Health Effects and Related Standards for Fossil-Fuel and Geothermal Power Plants," by G.D. Case, T.A. Bertolli, J.C. Bodington, T.A. Choy, and A.V. Nero, Lawrence Berkeley Report LBL-5287.

Vol. 7: "Power Plant Reliability-Availability and State Regulation," by A.V. Nero and I.N.M.N. Bouromand, Lawrence Berkeley Laboratory Report LBL-5922.

Vol. 8: "A Review of Air Quality Modeling Techniques," by L.C. Rosen, Lawrence Berkeley Laboratory Report LBL-5998.

Vol. 9: "Methodologies for Review of the Health and Safety Aspects of Proposed Nuclear, Geothermal, and Fossil-Fuel Sites and Facilities," by A.V. Nero, M.S. Quinby-Hunt, *et al.*, Lawrence Berkeley Laboratory Report LBL-5923.

METHODOLOGIES FOR REVIEW OF THE HEALTH AND SAFETY ASPECTS OF PROPOSED NUCLEAR, GEOTHERMAL, AND FOSSIL-FUEL SITES AND FACILITIES

ABSTRACT

This report sets forth methodologies for review of the health and safety aspects of proposed nuclear, geothermal, and fossil-fuel sites and facilities for electric power generation. The review is divided into a Notice of Intention process and an Application for Certification process, in accordance with the structure to be used by the California Energy Resources Conservation and Development Commission, the first emphasizing site-specific considerations, the second examining the detailed facility design as well. The Notice of Intention review is divided into three possible stages: an examination of emissions and site characteristics, a basic impact analysis, and an assessment of public impacts. The Application for Certification review is divided into five possible stages: a review of the Notice of Intention treatment, review of the emission control equipment, review of the safety design, review of the general facility design, and an overall assessment of site and facility acceptability.

Acknowledgment

Thanks are given to M. J. Angwin and T. A. Choy for assistance in assembling the material for these methodologies.

PREFACE

This report presents a possible structure for the health and safety review of proposed sites and facilities. It is divided into the two sections specified for the California Energy Resources Conservation and Development Commission review process: a Notice of Intention (NOI) process and an Application for Certification (AFC) process. For each portion of the review structure, review methodologies are presented, specifying possible areas of review, standards for review, and review techniques.

The basic considerations for formulation of a health and safety review are presented in a separate report, the Overview Report for this project. The Overview Report discusses the basic rationale for health and safety review and emphasizes those matters which need action, often in the form of a decision, by the ERCDC. Those matters will also be apparent on careful examination of the methodologies presented in this report.

The first stage of review, the Notice of Intention, is initiated by submission of several alternative sites, the merits of which are considered in conjunction with a proposed generic facility type. The outcome of the review process is a judgment of the suitability of the proposed sites for the facility type intended. This stage of review therefore consists of a site-specific review. The primary consideration in choosing a site from the health and safety point of view is the potential impact on surrounding populations. The NOI health and safety review therefore devotes considerable effort to examination of the emissions, either routine or accidental, from a proposed plant and to determination of the impact these would have on the public. The NOI review would also examine carefully the interaction between the site itself and the proposed facilities in order to determine whether the site is physically suitable for the intended power plant.

The bulk of this report is devoted to methodologies for the NOI review, since the role to be played by regulatory control of emissions and site selection is most easily defined. The corresponding regulatory role at the second stage of review, the Application for Certification, is not as certain. As a result, the development of the AFC methodologies is not as complete as for the NOI. However, there is correspondingly longer discussion, particularly in the Overview Report, of possible emphases for the AFC health and safety review.

The AFC stage consists of a review process to determine whether the design of a proposed facility, intended for a site approved at the NOI stage, meets applicable requirements. For the health and safety review these requirements can be performance specifications implicit in the emission rates which were assumed at the NOI stage, or they may take the form of actual design specifications for various aspects of the proposed facilities. The extent of review in these areas will depend very strongly on choices which must be made by the ERCDC. In the past, substantial effort has been expended by federal agencies in review of the explicitly safety-related aspects of nuclear power plants. Such an effort has not ordinarily been made, by either federal, state, or local agencies, in the case of fossil-fuel and geothermal power plants. Choosing what design areas will be examined during the AFC review, and — in the case of nuclear — determining the manner of coordination with the Nuclear Regulatory Commission, will have a decided impact on the health and safety review, particularly at the AFC stage.

In this report, the NOI and AFC methodologies are presented separately, each preceded by an introduction specifying the proposed structure. The types of power plants considered are nuclear (either pressurized-water or boiling-water reactor) geothermal (either vapor or liquid dominated) and fossil-fuel fired (either coal, oil, or gas). The treatment is organized with a common methodological approach wherever appropriate.

TABLE OF CONTENTS

Abbreviations

AFC	–	Application for Certification
ANSI	–	American National Standards Institute
APCD	–	Air Pollution Control District
ASME	–	American Society of Mechanical Engineers
ASTM	–	American Society for Testing and Materials
BPVC	–	Boiler and Pressure Vessel Code
BWR	–	Boiling water reactor
CAC	–	California Administrative Code
CFR	–	United States Code of Federal Regulations
dBA	–	decibels, A Scale
ECCS	–	Emergency Core Cooling System
EPA	–	United States Environmental Protection Agency
ERCDC	–	State of California, Energy Resources Conservation and Development Commission
ERDA	–	United States Energy Research and Development Administration
FDA	–	United States Food and Drug Administration
FR	–	The Federal Register
GRID	–	National Geothermal Information Resource
Hz	–	Hertz
IEEE	–	Institute of Electrical and Electronics Engineers
mrem	–	a unit of radiation dose equivalent
NOI	–	Notice of Intention
NRC	–	Nuclear Regulatory Commission
OSHA	–	Occupational Safety and Health Administration
PAH	–	polyaromatic hydrocarbons
P.L.	–	Public Law
ppb	–	parts per billion
ppbv	–	parts per billion by volume
ppbw	–	parts per billion by weight
PWR	–	pressurized water reactor
QA	–	quality assurance
SRP	–	Standard Review Plan
T.D.	–	totally dissolved
VRP	–	visibility reducing particles
WASH-1400	–	report of the NRC Reactor Safety Study

NOI
INTRODUCTION

The basic purpose of the NOI review is to examine site-related aspects of proposed sites and facilities. The basic focus of this "health and safety" methodology is on emissions from the plant, which may have impacts on surroundings of the plant, and on the interaction of the proposed facility with the site itself.

The methodology is divided into three stages which are characterized roughly by their depth of review. These stages are:

Stage 1. Emissions and site characteristics

Stage 1 deals with fundamental parameters of the facility and of the site. These parameters are those which may be compared directly with applicable standards and guidelines, without any detailed analysis. The emissions are characterized on the basis of a generic facility type. This stage of review represents a preliminary assessment of the general character of the facility and the site and of their trivial compliance with regulatory requirements.

Stage 2. Basic impact analysis

Stage 2 deals with the impacts of the facility on the site and surroundings, calculated from the emissions and site characteristics determined in the first stage. The results of this analysis would, for example, include concentrations at various distances from the site. These concentrations could then be compared with applicable air quality standards and used to calculate the effect of air pollutants on other media ("interactive effects"). The basic distinction between this stage and the first is that the first is restricted to an examination of, effectively, specifications of the facility and site, whereas the second uses this information for detailed analysis.

Stage 3. Assessment of human impacts

Stage 3 examines, to the extent possible, the health and safety impact of the proposed facility on the populations surrounding the site. It uses as part of its input data, the results of the first two stages. This stage would include any judgments and comparisons which are to be made, such as between alternative sites and facilities, or between costs and benefits.

The general categories or subjects of NOI review are:

Categories of Review:
- air emissions
- water emissions
- noise emissions
- waste disposal
- site geographical characteristics
- site developmental characteristics

Stages 1 and 2 of the review follow this outline explicitly. This is not possible at the third stage, where various types of assessment and comparison must be made. The first three subjects listed above are explicit emissions which may have human impacts. The last three subjects include aspects of the site and facility which may affect these emissions or their human impacts.

For each category of review, it may be necessary to consider several different operational modes. These include:

Operational Modes:
- normal operation (including startup and shutdown of the facility)
- abnormal operation (such as use of the facility with a fuel for which it was not specifically designed)
- emergencies (which may include either plant emergencies, such as explosion or other abnormal occurrences, or external regional emergencies, such as air pollution episodes)

For every category of review, if appropriate, explicit consideration is given to the construction of the facility, in addition to its operation.

For any operational modes, it is possible to consider several different portions of the facility:

Portions of the Facility	
	basic generation facility (including, for example, the boiler and turbogenerator)
	fuel storage facilities
	waste disposal facilities
	transmission lines
	transportation facilities (i.e., supply and disposal)

Ordinarily, these different facilities will only be considered explicitly in the examination of normal operation.

Finally, for each category in the review methodology, an attempt is made to divide the section into three parts:

I. Methodological approach

II. Generally applicable considerations

III. Technology-specific considerations (i.e., fossil fuel, geothermal, nuclear)

To recapitulate, the NOI review is divided into three stages. Each of these include several categories of review. For each category, the specified methodologies are divided into parts on overall approach, generally applicable, and technology-specific considerations. The second and third parts often consider explicitly the differing modes of operation and portions of the facility.

A preliminary step to the review methodology itself is the collection of the data necessary to perform the review. These data may be required of the applicant or may be acquired by the ERCDC staff or its agents. To some extent, a large portion of the information, in the form of the actual standards which are applicable to proposed facilities, will be maintained by ERCDC staff, or other regulatory agencies, on a continuous basis. However, for practical reasons, for any particular review the local regulations will have to be verified and updated at the time of the review.

We briefly summarize other data requirements by stage and broad subject of review. For details, see the individual sections of the methodology.

DATA REQUIREMENTS

STAGE 1 — EMISSION AND SITE CHARACTERISTICS

Facility-Related Information

Emissions: air, water, noise; uncontrolled, based on generic plant type. All modes of operation.

Pollution Control Equipment: and its operating efficiency based on manufacturers specifications or on previous experience with similar equipment and plant type.

Site-Related Information

Geophysical Characteristics:
- ground stability
- seismic activity
- hydrology

Developmental Characteristics:
- population distribution
- land availability/use
- utilities availability

STAGE 2 — BASIC IMPACT ANALYSIS

Facility-Related Information

Emissions: air, water, noise, from Stage 1 (assuming controls as specified)

Site Related Information

Geophysical Characteristics:
- topography
- air and water quality data
- biota in the area
- meteorological data

Developmental Characteristics:
- source inventory (other than proposed facility);
- "background" pollutant concentrations

Modeling-Related Information

Depletion Parameters

Chemical and Physical Processes and Their Kinetics

STAGE 3 - ASSESSMENT OF PUBLIC IMPACTS

Facility-Related Information

Dispersion of Pollutants, from Stage 2

Relative Import and Probability of Emergency Situations

Emergency Plans

Site-Related Information

Demography-Density and Character of Surrounding Populations

Public Health and Safety Information

Health Impacts of Emissions

Adequacy of Monitoring and Standards

Health Impacts of Emergency Situations

STAGE 1. EMISSIONS AND SITE CHARACTERISTICS

SECTION 1.1 AIR EMISSIONS

For purposes of this review, the air emissions from electric generating facilities are categorized as gases, particulate matter, radioactive matter, thermal discharges, and electromagnetic emanations. There are federal, state regional, and local standards governing the emission of many of these "materials." In Stage 1, the reviewer must determine the amounts of these emissions from the generic facilities being proposed and must consider the legal limitations and guidelines applicable to these emissions. Information developed at this stage also serves, in part, as the basis for the analysis of Stage 2.

1.1.1 Methodological Approach

In general, a reviewer has three options:

- Explicit Review — determination of emissions and comparison with standards
- Expert Opinion — hiring of an outside consultant to make recommendations
- Previous Experience — reliance on knowledge of previous plant experience with similar equipment and design

Were Expert Opinion or Previous Experience experience to serve as sole basis of the review, a decision would not require the treatment presented in the remainder of Section 1.1.

Explicit Review

1. Determination of emissions:

Data required

Net plant emissions — estimated by applicant

or

Uncontrolled emissions — supplied by applicant or estimated by the manufacturer, an outside consulting firm, or by previous experience with the generic plant type.

Control equipment data — supplied by manufacturer, or more ideally by previous experience with the equipment of the generic plant type.

2. Comparison with appropriate standards:

Air emission standards for conventional pollutants (either gases or particulate matter) may be found in the "Compilation of Air Pollution Control Regulations and Standards," ERCDC Staff Draft, Updated Version.[1]

For generally applicable radioactive emission (actually concentration) standards, see 10 CFR 20, Appendix B. The 10 CFR 20 standards apply to nuclear plants, as well as to other facilities. It is important to note that these standards do not place limitations on actual emissions (by mass), but rather on concentrations in air. Strictly speaking, these standards are applicable to an uncontrolled area, but for convenience they are often applied at the stack of the facility, although often with some modification. The reason for this ambiguity is that the primary standards for radioactive material are given in terms of doses to humans, and not in terms of emission or ambient concentrations. The latter are typically derived from the limitations on dose. (Calculation of these doses constitutes part of the Stage 2 review.) For radioactive emissions from nuclear plants stricter standards than 10 CFR 20 are applied; refer to the NRC procedures for determining compliance with 10 CFR 50, Appendix I.[2]

Thermal pollution is not currently considered an air pollutant; there are no standards.

1.1.2 Generally Applicable Considerations

To avoid duplication, certain common considerations — largely related to peripheral operations or aspects of the facilities — are considered in this section. Detailed information on those emissions which are particularly important for each technology are contained in the Technology-Specific Considerations (1.1.3).

1.1.2.1 Construction

Construction emissions are largely associated with the use of various sorts of vehicles (for transport of equipment, materials, or workers) and with physical operations involved directly in the construction process

Emissions of importance are:

Particulate matter

Visible emissions

Vehicular emissions
(not treated in this work; the reviewer is referred to applicable vehicular codes for the State of California; however, Ref. 1 does contain standards for storage of petroleum products)

1.1.2.2 Normal Operation

Under normal operation, the emissions associated with the basic generation facility (which produces and/or utilizes steam for electricity production) are relatively technology-specific, although the standards referred to above apply in each case. However, the plants may have similar peripheral facilities:

1. Fuel storage, transfer, and transport (petroleum) — regulations regarding petroleum storage and loading are included in Ref. 1. (Regulations regarding fuel transfer into vehicles have been considered beyond the scope of this report, but may easily be obtained from local air pollution control districts (APDC).)

For transport facilities such as roads and rails, or pipelines, the reviewer should consider particulate matter and other emissions arising from these links to the facility. If any explicit analysis is to be performed on this subject, that may be deferred to the corresponding section of Stage 2 of the NOI Review.

2. Sewage treatment — emissions to air from treatment facilities should be considered in accordance with APCD regulations.

3. Transmission lines — there are two major types of transmission systems: surface lines (conventionally used for long distance transmissions) and underground lines. The air emissions associated with these are similar though varying in degree.

Emissions of importance are:[3]

Ozone (O_3)

Electric fields — see Ref. 3 for grounding criteria

Magnetic fields — recommended standard is 200 gauss

Electromagnetic radiation — currently no standard for exposure at 60 Hz, but the matter is under study.[3]

Particulate matter or visible emissions — associated with routine maintenance

1.1.3 Technology-Specific Considerations

1.1.3.1 Fossil Fuel

The three fuels, coal, oil, and gas will be discussed separately because of their substantially different character.

1.1.3.1.1 Coal

1. Normal Operation

Several facets of a coal-fired power plant will contribute air emissions which should be considered:

a. Basic Generation Facility:

Particulate matter:

combustion contaminants

dust and fumes

visible emissions

hazardous trace metals — lead, mercury, selenium, etc.

Gases:

sulfur compounds

sulfur oxides (SO_x)

nitrogen oxides (NO_x)

carbon monoxide (CO)

hydrocarbons

Radioactive material

Thermal discharge — not currently considered an air pollutant

Standards for the first three categories are given in Refs. 1 and 2 (see Section 1.1.1). The applicant may be asked to provide data showing its projected controlled and uncontrolled emissions, an analysis of its particulate waste, fuel, and its proposed control equipment. See Ref. 4, for sample emission data, sample ash data and analyses of various western coals.

b. Fuel Storage and Transport:

Three types of fuel storage are potentially found at a coal facility: indoor coal storage, outdoor coal piles, and petroleum (gasoline) storage. Only the last two have substantial potential for air emissions, the principle ones being:

Particulate matter

Visible emissions

Carbon monoxide, from spontaneous combustion

Gas fumes

(See Ref. 1 for applicable standards.) Two types of transport should be considered:

Roads and rails — primary emissions:

Particulates and visible emissions

Vehicular emissions — regulations governing these would be found in state vehicular codes, and are beyond the scope of this review. The effect of these emissions must be considered later in Stage 2.

Slurry lines — after construction, no particular emissions.

c. Solid Waste Disposal

The sludge produced by most SO_2 scrubbers and particulate collectors may, in principle, be disposed of in the area of the power plant. (Even if it is elsewhere, the disposal area may be considered under the jurisdiction of the NOI review.) Primary emissions:

Particulate matter

Visible emissions

II. Abnormal Operation

The two main conditions to be considered are maintenance operations (possibly including the operations of starting up or shutting down the facility, although this should actually be considered under the category of normal operations) and fuel substitution. During operations which alter the operating condition of the plant, such as maintenance, short periods during which applicable standards are exceeded may occur. Issuance of a variance would technically cover such occurrences.

The use of an alternative fuel, particularly if long-term or chronic, could conceivably pose a health hazard and cause standards to be exceeded. Initial review of the facility should therefore carefully consider the reliability of the source of the proposed initial fuel and the composition of alternative fuels available in case the initial fuel becomes unavailable. (See Ref. 4, for sample analyses of western coals.)

III. Emergency Operation

The air emissions associated with an internal emergency, such as fire or explosion, are not of sufficient probability and external consequence to be analyzed in detail during the NOI review. Nor are those associated with natural disasters. Their generic consequences might be considered.

However, during an air pollution episode, limitations on the operation of coal-fired power plants might appropriately be required (see Ref. 4, Section 2, for emergency standards and for sample emergency procedures).

1.1.3.1.2 Oil

I. Normal Operation

a. Basic Generation Facility

Basically the same group of emissions as are listed under Coal, Normal Operation, should be considered, although in many cases the emissions from an oil-fired plant are substantially less than those from a coal-fired plant. They are:

Particulate matter:
- combustion contaminants
- visible emissions
- hazardous trace metals

Gases:
- sulfur compounds
- sulfur oxides (SO_x)
- nitrogen oxides (NO_x)
- carbon monoxide (CO)
- hydrocarbons

Thermal discharge (not at present considered a pollutant)

Regulations are found in Ref. 1. The utility can be expected to provide fuel analyses projected emissions (controlled and uncontrolled; for a sample, see Ref. 4), and method of control.

b. Fuel Storage and Transport

Fuel storage standards appear in Ref. 1. See Ref. 4, for sample tank evaporation data.

Fuel transport problems are not distinctly different from those of coal.

Road and rail emissions:
- particulates
- visible emissions
- vehicular emissions

Pipeline emissions:
- none of importance after construction

c. Waste Disposal

With low sulfur fuel this is a minor problem. High sulfur fuels provide a sludge which must be considered if disposed of on-site (or if its disposal is deemed under the jurisdiction of the NOI review); this could produce:

Particulate matter
Visible emissions

II. Abnormal Operation

The primary consideration for oil-fired plants is not maintenance, but rather the possibility of alternative fuel usage. Since using a lower grade fuel either intermittently or chronically could result in a hazard to health and exceeding a standard, the reviewer should consider the reliability of the proposed fuel and, possibly, the use of the plant as a multi-fuel facility, with controls appropriate to the most troublesome fuel (if coal, see section on Coal).

III. Emergency Operation

For operation during air-pollution episodes, similar considerations as stated for coal apply.

The major emergencies associated with any oil-fired operation (which could effect the public) are associated with oil spills and the fires associated with them. These can result from pipeline breaks and spills during transport or transfer. There are no simple standards which can be applied at this stage of review, but the matter will be considered in Stages 2 and 3 and in the AFC portion of review.

1.1.3.1.3 Gas

For this technology, an unusually important consideration is the possible need for alternative fuels (see Abnormal Operation).

I. Normal Operation

a. Basic Generation Facility:

Major emissions are principally those in Oil (1.1.3.1.2), but the amounts are typically much less. Of primary importance are:

Nitrogen oxides (NO_x)

Standards are found in Ref. 1. The utility can provide gas analyses and controlled and uncontrolled emissions (Ref. 4 contains sample data) and methods to be used for control.

b. Fuel Storage, Transfer and Transport

Storage and transfer problems relate mostly to alternative fuels and gasoline for plant vehicles. See above under the alternative fuel (oil or coal). Gasoline storage standards are found in Ref. 1. Transport (via pipeline) should cause no substantial emissions.

II. Abnormal Operation

This is one of the most important considerations for the siting of a gas-fired plant. Because gas is a relatively clean fuel, compared with coal and oil, a plant might be sited in a potentially sensitive area. The use of alternative fuels, with their substantially greater emissions, in such an area could have important consequences. The reviewer may consider treating the plant as a multi-fuel facility, as was also noted under Oil, Abnormal Operation. In such a case, he should review the plant as if it were using the alternative fuel and see sections in the methodology referring to that fuel.

III. Emergency Operation

As in other fossil-fuel plants, internal fire and explosion does not pose substantial danger to the public, although it may be somewhat more significant for gas-fired plants because of the volatility of the fuel. However, this would more easily be treated as an occupational hazard, and can be considered under the detailed design of the facility (at the AFC review).

On the other hand, because of its relatively low emissions, a gas-fired plant would be less likely to contribute to an air pollution episode than other types of fossil-fueled plants.

The most important emergency situation is that of a gas leak in a pipeline which would emit potentially explosive fumes, possibly in populated areas. Even at this stage of review, the routing of pipelines should be considered. (See also below under 1.6, Land Use.)

1.1.3.2 Geothermal

Facilities based on vapor- and liquid-dominated fluids are considered separately. However, it should be noted that, generally, the substances which are in principle available for emission into the air are similar: gases (such as H_2S, NH_3, and radon), particulate matter, heavy metals, and borates. The amounts which actually escape into the air depend markedly on the particular plant type and control technology. Generally applicable air quality standards were given in Ref. 1.

1.1.3.2.1 Vapor Dominated Fields

I. Normal Operation

a. Basic Generation Facility

Important emissions are:

Particulate matter:

particulate matter
visible emissions
hazardous trace metals: lead, mercury, selenium, etc.
borates and other salts

Gases:

sulfur compounds
hydrogen sulfide (H_2S)
ammonia (NH_3)

Radioactive matter:

radon-222

Thermal discharge

Applicable standards are in Ref. 1. An applicant may be asked to provide data showing controlled and uncontrolled emissions, an analysis of particulate waste and proposed control equipment.

b. Geothermal Field Emissions

Drilling new wells and venting are all potential sources of emissions. While not currently considered on-site (the steam is sold to a utility at the Geysers), they are still sources of pollution associated with a new facility. If they are not considered at Stage 1 as emissions from the facility, they certainly have to be considered as additional sources at Stage 2. In no case, should the effect of these emissions be ignored.

II. Abnormal Operation

Shutdown of the plant itself often leads to direct venting of the vapor to the atmosphere (without controls); this may be regarded as an extraordinary emission due to abnormal operation of the plant.

Blowouts are often associated with the field, but should perhaps be considered as one aspect of the plant's operation. If these abnormalities occur frequently (reviewer's discretion), they must be considered as emissions potentially important associated with the plant. If the standards are exceeded too often the site or facility may be unacceptable.

1.1.3.2.2 Liquid-Dominated Fields

I. Normal Operation

Primary considerations are:

Particulate matter:
- particulate matter
- visible emissions
- hazardous trace metals: lead, mercury, etc.
- borates and other salts

Gases:
- sulfur compounds
- hydrogen sulfide
- ammonia

Radioactivity:
- radon-222

Thermal discharge

Standards are in Ref. 1. The applicant would be asked to supply liquid and gas composition and emission, controlled and uncontrolled, and projected control equipment.

II. Abnormal Operation

The most important considerations are ruptures in transport lines: either to the facility with hot liquid (see emissions, uncontrolled, under Normal Operation) and from the plant for reinjection. In this case the major hazard is: hydrogen sulfide (H_2S).

1.1.3.3 Nuclear

No distinction has been made between pressurized-water and boiling-water reactor power plants. The variety of emissions is similar for the two types, although the amounts differ somewhat; these amounts, however, depend strongly on the specific control equipment. In the case of nuclear, moreover, we have not distinguished between the basic facility and the fuel storage facilities, for fresh or irradiated fuel, since they are typically housed in the same building complex, and the emissions given above are presumed to include those originating from these ancillary facilities.

I. Normal Operation

Radioactive matter emitted into the air stands as the primary health and safety consideration for nuclear power plants. Important emissions, including conventional emissions, are:

Radioactive emissions:

- halogens - principally iodine-129, 131, and 133.
- noble gases - principally krypton-85 and xenon-131 and -133
- tritium - i.e., hydrogen-3, typically emitted in water vapor
- particulate emissions — although as measured in curies or ultimate dose, these are not as important as the emissions just mentioned.

Particulate matter:
- particulate matter
- visible emissions
- hazardous trace metals
- hydrocarbons

Gases:
- sulfur compounds
- sulfur oxides
- nitrogen oxides
- carbon monoxide
- hydrocarbons

Thermal discharge

The ordinary gases and particulate matter are emitted from nuclear power plants in significant amounts, largely due to auxiliary boilers that are used during start-up periods or when the reactor is shut down. The standards of Ref. 1 apply to these emissions, and detailed consideration of these categories is given in the Section 1.1.3.1 on fossil fuels, where the emissions discussed under oil-fired plants are particularly applicable.

The standards for the radioactive emissions and procedures for applying them are in Ref. 2.

II. Emergency Operation

Under accident conditions, a much larger class of emissions are possible from a nuclear power plant than listed above. Moreover, the amounts of release may be much greater. However, these emissions are not licensable, i.e., there are no emission or exposure standards directly applicable to the emissions. Accidental releases are controlled through the detailed engineering design of the facility, a subject of review at the AFC stage.

SECTION 1.2 WATER EMISSIONS

Power generation can produce three types of water pollutants:

Chemical - including chemical, physical (such as particulate matter or visibility-reducing particles), biological, bacteriological, or toxic

Radioactive

Thermal

The standards applicable to these emissions may be found in several references compiled by the Water Resources Board and the ERCDC:

"Water Quality Control Plan: Ocean Waters of California," State of California Water Resources Control Board, adopted and effective, July 6, 1972.[5]

"Water Quality Control Policy of the Use of Inland Waters" Used for Powerplant Cooling, California State Water Resources Control Board, June 1975.[6]

"Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California," State of California Water Resources Control Board, June 5, 1972.[7]

"Compilation of Water Quality Standards Applicable in California," Facility Siting Division, Energy Resources Conservation and Development Commission, Ed Piekarz, Steve Leung and Frank Hahn (Staff Draft).[8]

40 CFR part 423, "Steam Electric Power Generating Point Source Category"

A distinction is made between discharges or effluents ("the maximum concentration of constituents acceptable in waste streams into receiving waters") and receiving water standards or objectives ("maximum concentrations of various constituents permissible in receiving waters").[8] These categories correspond respectively, to air emission standards and ambient air quality standards.

1.2.1 Methodological Approach

The reviewer may determine emissions and the degree of compliance with applicable standards by following essentially the same procedure as outlined in Section 1.1.1. He always has the option of relying on expert opinion or previous experience. Or he may make these determinations himself (Explicit Review).

If the last is chosen wholly or in part, he must:

Explicit Review

1. Determine effluence:

Data required

Effluence, net -- supplied by the applicant, or based on previous experience with the projected control equipment and plant type,

or

Effluence, uncontrolled -- supplied by applicant, outside consultant or previous experience with the plant type,

and

Control Equipment, Data - supplied by the manufacturer, or by previous experience with the equipment on the generic plant type.

2. Compare with the appropriate standard:

Standards are contained in Refs. 5 through 8 and 40 CFR 423. In general, reference will have to be made to the California Water Resources Board and local regional boards. It will be necessary to work with the State Board to determine the requirements for obtaining an NPDES (National Pollutant Discharge Elimination System) permit. The permit may require limitations more stringent than any other applicable federal, state or local standards. It must be at least as stringent. The EPA is also considering more stringent underground inspection regulations: 40 CFR 146, proposal in 41 FR 36730 (8-31-76).

1.2.2 Generally Applicable Considerations

Table 1.2-1 is an outline showing the sources of chemical waste in any power generation facility. Many of these sources would emit similar substances for any means of generation, but some (such as coal-pile runoff) are technology-specific (see Section 1.2.3).

Thermal emissions occur in every type of electricity generation because of the need to dispose of waste heat, and in many instances the heat is discharged to water bodies. Possible cooling systems,[9] aside from simple once-through cooling, are given in Table 1.2-2.

TABLE 1.2-1 Sources of Chemical Wastes — adapted from Ref. 9.

NORMAL OPERATION

Generation:
- Condenser Cooling System
  - a. Once through
  - b. Recirculating
- Water Treatment (see waste disposal)
- Miscellaneous Waste Streams
  - a. Plant laboratory and sampling streams
  - b. Intake stream backwash
  - c. Closed cooling water systems

Fuel Storage:
- Rainfall runoff — coal pile
- Geothermal wells

Waste Disposal:
- Water Treatment
  - a. Clarification
  - b. Softening
  - c. Ion exchange
  - d. Evaporator
  - e. Filtration
  - f. Other treatment
- Ash Handling
  - a. Oil-fired plants fly ash
  - b. Coal-fired plants
    - 1. fly ash
    - 2. bottom ash
- Air Pollution Control Devices
- Miscellaneous Waste Streams
  - a. Sanitary wastes
  - b. Low level rad wastes
  - c. Floor drains

CONSTRUCTION
- Rainfall Runoff
  - a. Facility construction
  - b. Transmission system construction
  - c. Construction equipment

ABNORMAL OPERATION
- Maintenance
- Cleaning
  - a. Boiler
  - b. Boiler fireside
  - c. Air preheater
  - d. Miscellaneous small equipment
  - e. Stack
  - f. Cooling tower basin
- Boiler or PWR Steam Generator Blowdown
- Transmission Line Maintenance Runoff

EMERGENCY
- Internal
  - a. Rupture of Control Equipment
  - b. Water Treatment Equipment Breakdown
  - c. Transmission Line Break
  - d. Geothermal Well Blow
  - e. Other
- External

Table 1.2-2 Technologies for Waste Heat Removal - from Ref. 9.

- Cooling ponds or lakes
- Spray augmented ponds
- Canals with powered spray modules
- Rotating spray system
- Wet tower, natural draft — crossflow
- Wet tower, natural draft — counterflow
- Wet tower, mechanical forced draft
- Wet tower, mechanical induced draft, crossflow
- Wet tower, mechanical induced draft, counterflow
- Dry tower, direct
- Dry tower, indirect
- Combined wet/dry mechanical draft tower

Table 1.2-3 Chemicals Used in Steam Electric Power Plants — reproduced from Ref. 9.

Use	Chemical
Coagulant in clarification water treatment	Aluminum sulfate
	Sodium aluminate
	Ferrous sulfate
	Ferric chloride
	Calcium carbonate
Regeneration of ion exchange water treatment	Sulfuric acid
	Caustic soda
	Hydrochloric acid
	Common salt
	Soda ash
	Ammonium hydroxide
Lime soda softening water treatment	Soda ash
	Lime
	Activated magnesia
	Ferric coagulate
	Dolomitic lime
Corrosion inhibition or scale prevention in boilers	Disodium phosphate
	Trisodium phosphate
	Sodium nitrate
pH control in boilers	Ammonia
	Cyclohexylamine
Sludge conditioning	Tannins
	Lignins
	Chelates such as EDTA,NTA
Oxygen scavengers in boilers	Hydrazine
	Morphaline
Boiler cleaning	Hydrochloric acid
	Citric acid
	Formic acid
	Hydroxyacetic acid
	Potassium bromate
	Phosphates
	Thiourea
	Hydrazine
	Ammonium hydroxide
	Sodium hydroxide
	Sodium carbonate
	Nitrates
Regenerants of ion exchange for condensate treatment	Caustic soda
	Sulfuric acid
	Ammonex
Corrosion inhibition or scale prevention in cooling towers	Organic phosphates
	Sodium phosphate
	Chromates
	Zinc salts
	Synthetic organics
Biocides in cooling towers	Chlorine
	Hydrochlorous acid
	Sodium hypochlorite
	Calcium hypochlorite
	Organic chromates
	Organic zinc compounds
	Chlorophenates
	Thiocyanates
	Organic sulfurs
pH control in cooling towers	Sulfuric acid
	Hydrochloric acid
Dispersing agents in cooling towers	Lignins
	Tannins
	Polyacrylonitrile
	Polyacrylamide
	Polyacrylic acids
	Polyacrylic acid salts
Biocides in condenser cooling water systems	Chlorine
	Hypochlorites
Additives to house service water systems	Chlorine
	Chromates
	Caustic soda
	Borates
	Nitrates
Additives to primary coolant in nuclear units	Boric acid
	Lithium hydroxide
	Hydrazine
Numerous uses	Numerous proprietary chemicals

Radioactive effluences are primarily associated with nuclear power plants but, nevertheless, occur in other types of generation.

Most of the attention below is given to chemical or radioactive effluents. However, the regulations on thermal pollution can be quite strict and therefore it is necessary, in each instance, to check with the local water resources board. See Ref. 7 for a discussion.

Table 1.2-3 indicates the chemicals which are used within power plant systems. A listing of the chemical wastes generally associated with power plant effluence, and their sources, is given in Table 1.2-4. Important to all three technologies are:

- Chemicals, associated with cooling, cleaning and water treatment:
    - iron
    - chlorine
    - vanadium
    - copper
    - phosphates
- Particulate matter, associated with construction, general equipment, and transmission lines:
    - suspended solids
    - visibility-reducing particles
    - oil and grease
- Biological and Bacteriological Wastes, associated with sewage, etc.
- Thermal Discharge
- Radioactivity

Regulations regarding conventional pollutants are given in Refs. 5 - 8. The generally applicable standards governing radioactive water pollutants are given in 10 CFR 20, Appendix B; regulation applying specifically to nuclear plants arise from 10 CFR 50, Appendix I and its implementation.

TABLE 1.2-4 Waste Streams — Chemical Discharges and Their Source reproduced from Ref. 9.

APPLICABILITY OF PARAMETERS TO CHEMICAL WASTE STREAMS

PARAMETER	Condenser Cooling System		Water Treatment				Chemical Cleaning								
	Once Through	Recircu-lating	Clarifi-cation Wastes	Ion Ex-change Wastes	Evaporator	Boiler Blowdown	Boiler Tubes	Air Pre-heater	Boiler Fireside	Ash Pond Overflow	Coal Pile Drainage	Floor Drains	Air Pollution Devices SO2 Removal	Sanitary Wastes	Low Rad Wastes
ALKALINITY	X	X	X	X	X	X	X	X	X	X			X		
BOD		X	X	X	X	X	X	X		X		X	X	X	
COD		X	X	X	X	X	X	X	X	X		X		X	
TS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
TDS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
TSS		X	X	X	X	X	X	X	X	X	X	X	X	X	
AMMONIA		X	X	X	X	X	X	X	X	X	X			X	
NITRATE		X	X	X	X	X	X			X	X			X	
PHOSPHOROUS		X	X	X	X	X	X			X	X		X	X	
TURBIDITY		X	X		X	X	X	X	X	X	X	X	X	X	
FECAL COLIFORM														X	
ACIDITY							X	X	X	X	X	X	X		
HARDNESS, TOTAL		X	X	X	X	X	X			X		X	X		
SULFATE		X	X	X	X	X	X	X	X	X	X	X	X		
SULFITE								X	X	X		X	X		
BROMIDE							X								
CHLORIDE		X	X		X	X	X	X	X	X	X			X	
FLUORIDE		X	X	X			X			X					
ALUMINUM		X	X		X	X	X		X	X	X		X		
BORON															X
CHROMIUM		X	X	X	X	X	X	X	X	X	X				
COPPER	X	X	X	X	X	X	X	X	X	X	X				
IRON		X	X	X	X	X	X	X	X	X	X		X		
LEAD										X	X	X			
MAGNESIUM		X	X	X	X	X	X	X	X	X	X	X	X		
MERCURY				X	X		X			X	X				
NICKEL		X	X	X	X	X	X	X	X	X	X				
SELENIUM							X			X	X				
VANADIUM									X	X			X		
ZINC		X	X	X	X	X	X			X	X				
OIL & GREASE				X			X			X		X	X		
PHENOLS		X	X		X					X	X				
SURFACTANTS					X		X			X		X		X	
ALGICIDES	X	X												X	
CHLORINE	X	X													
MANGANESE		X		X	X	X	X		X	X	X		X		

NOTE: Miscellaneous streams such as laboratory sampling, stack chemical cleanings, etc. are not included since the species are accounted for in other streams.

1.2.3 Technology-Specific Considerations

1.2.3.1 Fossil Fuel

1.2.3.1.1 Coal

I. Normal Operation

a. Basic Generation Facilities. See Section 1.2.2

b. Fuel Storage

Coal pile runoff is the most important consideration. Emissions for which there are or may be regulations

Particulate matter

Trace metals — mercury, iron, etc.

Dust-proofing agents (organic sprays, $CaCl_2$)

c. Waste Disposal

There are two sources of water pollutants: scrubber sludge and ash (bottom and trapped). Under normal operations they are introduced into the water system either from the control system directly or from settling ponds or rainful runoff through disposal sites. Effluence for which there is or may be regulations are:

sulfate-sulfite pH range totally suspended solid chlorine copper iron polychlorinated biphenyls oil and grease nitrate-nitrite etc.	} New Source Performance Standards, Ref. 8

Regulations also apply to disposal by burial (see Cal. State Health and Safety Code, Title 17-5.4.3, Section 30288).

1.2.3.1.2 Oil

The most important consideration specific to oil-fired plants is the possibility of an oil spill, to which regulations on oil and grease discharges would apply.

Abnormal operation (fuel substitution, especially coal) would warrant broader scrutiny (see Section 1.2.2).

1.2.3.1.3 Gas

Generally applicable standards must be met, but gas-fired plants under normal operation do not have large liquid-waste discharges. Under abnormal operation (especially fuel substitution), discharges may increase substantially. (see Section 1.2.2).

1.2.3.2 Geothermal

I. Normal Operation

a. Basic Generation Facility — see Section 1.2.2

b. Fuel Transport

If the transport lines are operating properly then there will be no particular problems. However, should leaks develop in the transfer pipes, surrounding ground and surface water could be effected. Important effluents are:

- Particulate matter
  - hazardous trace materials: arsenic boron, mercury
  - visibility-reducing particles
- Dissolved gases
  - ammonia
  - hydrogen sulfide
  - chlorine
  - fluorine

Dissolved salts
- borates
- alkalinity
- chlorides

Thermal pollution

c. Waste Disposal

Fluid Disposal

Actual effluence depends upon the technology chosen and the fluid composition. Of particular significance is the fact that fluids typically will be reinjected. The primary dangers arise from

- Spills
- Reinjection at the wrong level
- Reinjection at too high pressure, causing cracks in the surrounding rock
- Reinjection in areas of sloping aquifers, or with lens-shaped cap
- Natural development of cracks in the disposal area

The probability and consequences of such events must be assessed, to the extent the ERCDC concerns itself with matters apart from the generation facility. Such assessment would require the attention of expert professionals. The effluents associated with spills are the same as those mentioned under fuel transport. It is important that the injection system be in compliance with 40 CFR 146, and it would be appropriate to be in compliance with the proposed regulations which would apply to extant disposal sites.

Solid Waste Disposal

There are several sources of pollution associated with leaching from the solid wastes of a geothermal facility. They are:

From Drilling Muds:
- Particulate matter
  - visibility-reducing particles
  - suspended solids
  - rock flour
  - hazardous trace metals

Dissolved pollutants
- borates
- silicates
- chlorides
- alkalinity
- sodium compounds
- detergents

From Control Equipment (depending upon method):
- iron hydroxide or nickel hydroxide
- sulfur
- lead-210
- mercury
- vanadium oxides and organic oxidants

d. Drilling

Drilling mud disposal effluents are considered under waste disposal

1.2.3.3 Nuclear

I. Normal Operation

In addition to the effluents mentioned in Section 1.2.2, the following contaminants are important:

Radioactive matter:
- tritium — hydrogen-3, incorporated in water molecules

Chemical waste:
- hydrazine
- lithium hydroxide
- boric acid

(The chemical effluents are used in the treatment of the primary coolant for the nuclear reactor.)

II. Emergencies

As in air, the types and amounts of radioactive species which may be discharged as a result of reactor accident can be much larger than the routine emissions associated with nuclear plants. If the water supplies which could be contaminated affect the drinking supplies of the surrounding population, then the site may not be appropriate.

(Note: For nuclear, no distinction is made in the above treatment between PWR and BWR. Moreover, the fuel storage pools are not distinguished as facilities separate from the basic generating facilities, since they are housed in common buildings.)

SECTION 1.3 NOISE EMISSIONS

1.3.1 Methodological Approach

Precisely the same set of possibilities as were available in Sections 1.1 and 1.2 may be used to analyze the noise of a proposed facility. They are expert opinion, previous experience, explicit review by the ERCDC staff, or a mix of all three.

Explicit Review

1. Determination of emissions:

 Data Required

 Net Noise Generated — by all parts of the plant and their construction, supplied by the applicant, or estimated by an outside consulting firm, or by previous experience

 or

 Uncontrolled Noise Levels — supplied by the same sources as Net Noise

 Abatement Procedures — procedures to be supplied by the applicant, their efficiency may be provided by the applicant, the manufacturer of any equipment used, the total effect to be estimated by the ERCDC staff, an outside consultant or by previous experience with similar problems and solutions

2. Compare with the appropriate standard:

Noise standards other than OSHA standards (ref. 4; these are, strictly speaking, the subject of AFC review) are highly local. It has been the practice in the past for the utility to provide the noise regulations applicable to the particular sites. The Office of Noise Pollution has a collation available. In general, it will be necessary to determine the applicable standards at the time of the review.

1.3.2 Generally Applicable Considerations

Although many aspects of a power generation facility, such as the turbine, produce noise, the primary source occurs at the construction phase. A major consideration during this phase is the OSHA standards designed to protect workers at the site, although local ordinances are also applicable. Other sources of noise are:

Basic generating facility:
- turbine
- moving equipment

Transmission lines

There is little prospect in abatement of the noise produced by transmission lines, although use of landscaping has been of some help. The actual generating facility does produce noise apparent to workers at the site, however, it is unlikely that this would produce off-site noise levels higher than those normally associated with industrial processes. It is worth keeping in mind however, that applicable regulations may not be explicit. The reviewer should also keep in mind the power of a nuisance clause in an area where the population is opposed to the establishment of a facility. This admonition applies to any considerations of any pollutant for which applicable regulations are not specific. Applicable regulations may not fully reflect the effect which moderate ambient levels may have on the physiological and psychological well-being of the local population. This problem is considered further in Stage 3.

1.3.3 Technology-Specific Considerations

1.3.3.1 Fossil Fuel

1.3.3.1.1 Coal

The major source, other than conventional industrial noise, is coal handling or pulverizing equipment.

1.3.3.1.2 Oil

No considerations beyond standard industrial noise levels.

1.3.3.1.3 Gas

Ordinarily no considerations beyond those of standard industrial levels.

1.3.3.2 Geothermal

Principle sources of noise that are peculiar to geothermal facilities are well-drilling and steam venting. It is important to realize that some of the noise associated with geothermal development and power production may be reduced by muffling. However, in spite of this, noise levels will be high.

1.3.3.3 Nuclear

No considerations beyond standard industrial noise levels.

SECTION 1.4 SOLID WASTES

The solid wastes considered in this section are only those directly produced in the process of power generation. Wastes such as sewage have standard methods for disposal which are not considered in this review.

For the solid wastes from power generation, the review of this section pertains to the basic methods of disposal. The review does not regard the solid wastes *per se* as an "emission" or effluent from the plant. However, the respects in which the solid wastes can contaminate the air and water are considered above in Sections 1.1 and 1.2, respectively, of this review.

Because the solid wastes associated with specific electric generation technologies are quite distinct, methodologies for their review are presented in separate sections which follow.

1.4.1 Fossil Fuel

1.4.1.1 General Considerations

The amount of solid waste varies with fuel type: Coal-fired plants generate a large volume of waste as ash and as scrubber sludge. Oil-fired plants produce only a moderate amount which depends on the grade of oil. Gas-fired plants generate almost no solid waste, and for this reason are not considered in this section.

The basic purpose of the present review is to determine the stability of any on-site disposal of solid wastes. Alternatives to simple on-site disposal are transport off-site or reprocessing (such as of scrubber sludge).

On-Site Disposal — two basic considerations:

a) Whether the disposal site is stable physically, so that ground motion is not induced.

b) Whether the site is stable enough to prevent leakage into air and water.

Off-Site Disposal — the reviewer must determine the adequacy of transportation from the site.

Reprocessing — whether on-site or off-site, the standards applicable to chemical processing must be applied. It is not clear whether such a plant, if on-site, falls under the jurisdiction of this review.

1.4.1.2 Methodological Approach

In general, the review may be conducted on the basis of previous experience, expert opinion, or staff review.

Explicit Review

1. Determine the amount (by mass and/or volume) and type of wastes.

The data would be supplied by utility directly or be determined by staff on the basis of some combination of information from the utility and/or manufacturer on plant type and control measures (those which produce solid wastes).

2. Determine adequacy of means by disposal (from the point of view of the site being considered).

a. On-site disposal:

- Determine capacity of site and compare with need
- Determine stability of site and any constraints on waste (in this matter, the opinion of an engineer experienced in waste disposal would be appropriate). The question of site stability *per se* is to be considered in Section 1.5. Standards for any emissions into air and water are to be considered in Sections 1.1 and 1.2, respectively.

b. Off-site disposal:

- Determine adequacy of transportation off-site (Section 1.6) (associated emissions into air and water are to be considered in Sections 1.1 and 1.2, respectively).

c. On-site reprocessing: may be regarded as a separate facility with independent regulatory procedures.

1.4.2 Geothermal

The general methodology for solid waste in geothermal power plants is the same as for fossil fuel power plants (see Section 1.4.1.2).

1.4.2.1 Vapor-Dominated

For vapor-dominated fields, the most significant solid waste will be sulfur generated by H_2S pollution-abatement processes. This sulfur may be in the form of an impure slurry in the cooling tower basin or pure sulfur from another process. Disposal of the sulfur will probably be off-site.

1.4.2.2 Liquid-Dominated

The solid wastes associated with a liquid-dominated field will depend on the energy cycle chosen. If ponding is used, large quantities of material may remain after evaporation. Sulfur may also be generated by H_2S pollution abatement processes.

1.4.3 Nuclear

Nuclear may produce some of the same type of solid waste as from fossil fuel or geothermal plants. Were these not to contain amounts of radioactivity above "background" levels, they could be treated in the same manner as in the other technologies. However, in general, sufficient radioactivity will be present in wastes to require that they be handled as radioactive materials and disposed of off-site.

Three general classes of radioactive material leave the site:

a. irradiated fuel — this contains material which is certainly "wastes", but some of the contained materials may also be recycled. In either case, the material is shipped off-site, so that the reviewer must only assure the adequacy of transportation facilities (see Section 1.6).

b. solid and liquid residues — from emission control and water treatment systems; shipped off-site (see Section 1.6).

c. tools, clothing, etc. with radioactive contaminations — shipped off-site (see Section 1.6).

For each of these classes, the material is securely contained for shipment. In the course of shipment, some persons in proximity to the material may receive doses of radiation. (No radioactive material need escape from the shipping containers, but some penetrating radiation can pass through the container walls, exposing nearby persons.) This dose should be reviewed (in Section 2.4). There is, moreover, some potential for radioactive releases through accidents during transportation; and review of this potential danger should take place in Section 2.4 or in Stage 3.

SECTION 1.5 SITE GEOPHYSICAL CHARACTERISTICS

This section makes a basic determination of the suitability of the geophysical characteristics of the site, including:

mechanical characteristics:

- general stability and soil characteristics (suitability as a base for large structures, or for disposal areas)
- seismicity (potential for earthquakes)

hydrological characteristics:

- potential for water contamination
- potential for floods

(Note: Meteorological characteristics could be construed to be included in geophysical characteristics. However, this rarely has health and safety implications *per se*—except for the high winds due to tornadoes, hurricanes etc—so that the effects of meteorology are incorporated in the review of Stage 2, Section 2.1 on dispersion of air emissions.)

1.5.1 Methodological Approach

For each consideration, a determination must be made of whether judgment is most appropriately made on the basis of previous experience, expert opinion, or staff/applicant analysis. Unless a staff member has geological engineering qualifications, the first two bases should be utilized. (In any instance where staff analysis is appropriate, i.e., where an applicable standard or guideline exists, the staff may make a direct comparison based on the data supplied by the applicant or collected by the staff or its agents.)

1.5.2 Generally Applicable Considerations

Ground characteristics — mechanical stability and soil comparison must be adequate for the proposed facilities (in lieu of applicable standards, expert opinion — presumably the contractor designing the facility or the utility — is needed).

<u>Seismic characteristics</u> — generally will require dependence on expert opinion, except where the basic seismic information is generally available (i.e. fault positions and lengths, with associated maximum earthquake information) <u>and</u> an applicable standard exists. The nuclear approach may be used as a model.

<u>Hydrology</u> — characteristics that could lead to contamination of ground water (actual analysis would be performed in Section 1.2) or to the occurrence of floods (for which expert opinion is required).

The consideration of ground characteristics as they pertain to the ability of the ground to sustain the loading of the proposed facilities is directly applicable to the <u>construction</u> phase, as well as to other operational conditions (whether normal or emergency), and applies — not only to the basic generation facility — but to ancillary facilities, particularly including fuel storage, any on-site waste disposal facilities, and transmission lines. (Hydrology would also apply directly to any underground facilities such as transmission lines.)

1.5.3. <u>Technology-Specific Considerations</u>

The comments above apply generally to any plant type, and adequately cover the considerations for a fossil-fuel plant. For a geothermal plant, the data developed here would lead to a consideration of the possibility of subsidence (in Section 2.5). Nuclear plants require more detailed treatment of seismicity (Section 2.5).

SECTION 1.6 SITE DEVELOPMENTAL CHARACTERISTICS

This section performs a basic examination of the developmental characteristics of proposed sites:

Population distribution in the region — basically to determine the population at risk from plant emissions

Land availability and/or use — any basic criteria on land use should be applied here

Availability of transportation and other utilities — must ascertain whether required facilities will be available

1.6.1 Methodological Approach

For most developmental characteristics, review can be based on staff/applicant analysis or comparison. The basic approach is to

1. collect data on the particular consideration or need.
2. compare with applicable standards or required facilities.

1.6.2 Generally Applicable Considerations

Population distribution — density-limiting criteria may be set for different plant types. This is especially true of nuclear, where it is possible that controls may be imposed to limit population growth in the vicinity of the plant (see analysis of Section 2.6). If a simple criterion is applicable, the comparison may be made at this stage.

For nuclear, staff should also check on the establishment of contacts between the utility and public agencies for the purpose of emergency planning.

Land use/availability —

- Ownership of the site itself should be determined;

any applicable criteria which could restrict the region under consideration from power plant siting should be checked.

- for any type of plant, establish criteria for minimum site size — especially possible for nuclear; see also determination of exclusion zone and low population zone in Section 2.6. Establish criteria for controls beyond the site itself, especially for nuclear (see Section 2.6).

Availability of utilities —

- transportation needs (by road, rail, or pipeline) for workers, fuels, wastes, and human requirements; fuel and waste requirements are facility-dependent; all require a simple comparison of anticipated needs with transportation facilities which will be available.
- other utilities — water, cooling water, gas, medical, etc. — simple comparison of needs and availability.

These all apply to various modes of facility operation.

For the construction phase, the availability of utilities must be considered specifically.

In general, land use criteria must be applied to all of the basic plant and ancillary facilities; among the latter, transmission lines and pipelines are to be considered particularly.

STAGE 2. BASIC IMPACT ANALYSIS

SECTION 2.1 AIR EMISSIONS

The purpose of this section is to determine the effect which the emissions into air determined in Section 1.1 have on air quality. This may lead to comparison with applicable standards or objectives (federal, state, or regional), to assessment of interactive effects, i.e., of air pollution on water, biota, etc., or to an assessment (in Stage 3) of the impact of these alterations on human health, to the extent that such an assessment is possible.

2.1.1 Methodological Approach

A choice of approaches between:

a. expert opinion
b. previous experience — in this case the past situation must bear great similarities to the proposed facility and site
c. explicit review

Unless a past situation exists which bears the necessary similarities to the current situation, it will be necessary for some sort of analysis. The staff may choose to perform the analysis itself, (if so see Explicit Review below) or consult an outside expert or consulting firm, which may have computer program flexibility and experience as well as access to the necessary computer.

Such an analysis almost invariably depends on computer modeling of the manner in which emissions from the proposed facility would disperse from the emission point and add to or interact with other substances in the air in the region in which the facility is to be located. The choice of model will depend largely on the information required and on the conditions prevailing in the region of the proposed site. In turn, the model will determine input data requirements. For this reason, the air impact methodology can take on varying forms and levels of sophistication.

Explicit Review

1. Preliminary determination of analysis to be made.

Initially, the reviewer will need to decide upon:

Model — needs to be available on a computer whose size, speed, and sophistication will depend on the model chosen. A choice of models of varying complexity is given below in Section 2.1.2, Generally Applicable Treatment.

Results Desired — must be carefully defined, will depend largely on the character of the standards with which the results are to be compared and on the detail with which the actual assessment of health impacts (in Stage 3) may be attempted.

Input Data — including:

emissions — net, from the proposed facility (from Stage 1).

competing sources — either ambient levels of various pollutants and reactive species in the surrounding region OR emissions from specific nearby sources of pollution and reactive species plus ambient background levels.

meteorological and topographical characteristics — their detail and the extent of the region to be covered would depend upon the model chosen

chemical and physical processes — should include those which the model is able to handle and/or those which are known to be of importance. In the latter case, a model should be chosen which is able to calculate their effect.

2. Perform the analysis.

This may be done by the ERCDC staff or by an outside consultant (or other agency) who would provide the results of a calculation based upon decisions made in Step 1 above.

3. Compare with appropriate standard.

One general difficulty will be that ambient air quality depends upon multiple sources, and that permits are often issued based on consideration of all sources in the area. It may be possible that adjustments could be made with the competing sources if the facility to be established is a particularly important one. Further, if after the establishment of a new facility, the standards would still be exceeded, but the quality of the air would have been improved due to trade-off with other facilities, it may be possible to agree to its siting.

Standards can be found in Refs. 1 and 2.

4. Assessment of "Interactive Effects".

Additional data necessary:

water in the region
biota in the region
Food and Drug Administration standards
interactive effects

An example of the type of analysis to be performed: A coal-fired plant will release finite amounts of mercury in the air. If there is a lake in the area, the mercury will settle in it to some extent. Through various physical processes, the mercury may accumulate in the fish, which in turn convert it to organic forms. The FDA standard for mercury in fish is 500 ppbw. If the fish in the lake already have high background levels of mercury, then the standard may be exceeded.

A general discussion of "interactive effects" is included in Section 2.1.2.2, Generally Applicable Treatment, Interactive Effects. Other possible specific "interactive effects" will be included in the sections on specific technologies.

2.1.2 Generally Applicable Considerations

2.1.2.1 Direct Considerations: Models Available for Dispersion Analysis

Presuming analysis beyond simple dependence on either past experience or expert opinion will be performed, a number of different types of analysis are possible and appropriate, of which we set out three, with differing levels of sophistication:

2.1.2.1.1 "Primitive" or Statistical Analysis

Data Required:

Experimental tracer measurements
Ambient levels in the absence of the proposed facility
Emissions, from Stage 1

Method of Analysis:

a. Off-site measurement of tracers released at the site, yielding a direct but very simplistic indication of the extent to which emissions alter off-site ambient levels. The resultant predictions may be added to existing concentrations from other sources to yield net levels.

b. Comparison of proposed emissions with statistical analysis of other similar examples or with experience in the region of proposed site. For example, could use linear relationship (established on the basis of past experience) between emissions and alteration of concentrations. The data requirements are emissions from Stage 1 and correlations based on past experience.

Advantages

The major advantages are low cost, high speed, and simplicity.

Limitations

- Can only be applied in simple situations, as far as meteorology and topography are concerned, or where well tested correlations exist.
- Does not take chemical reactions into account; the person doing the measurements must know what reactions occur.

- Relies on accurate measurements by advantageously placed monitors.

2.1.2.1.2 "Intermediate" Analysis

A Gaussian plume model or variants on it may be used. As opposed to the above possibility, this is a deterministic approach applicable to relatively simple meteorological and topographical situations which yields limited results.

Data Required

- Emissions — net, from the proposed facility (from Stage 1). (No chemical reactions necessary since Gaussian models do not permit such interactions.)
- Ambient levels — as applicable, from other sources (simply to be added to the results from the Gaussian model).
- Wind conditions — appropriate to the site (only simple averaging of results over variability of the wind is possible; variability is not incorporated in the model itself).
- Turbulent diffusivity
- Depletion parameters

The results of this approach are calculated concentrations in the plume

Advantages

- Greater flexibility than in the simplistic approach, but not requiring the large data base, personnel, or computer required by the sophisticated approach below.

Disadvantages

- Inability to handle complex situations with respect to meteorology, topography, or chemistry.

2.1.2.1.3 "Sophisticated" Analysis

The reviewer may attempt determinations of concentrations from more physically accurate models, and ones which are more difficult to use, which permit:

- Partial confinement of the emissions from the proposed facility and other sources in a region (air basin)
- Variability in meteorological conditions, such as wind direction
- Chemical reactions

Data Required

As for the Gaussian model above:

Net emissions
Ambient levels
Wind conditions
Turbulent diffusivity
Depletion parameters

PLUS

Competing sources, a detailed inventory
Meteorological data — including wind field or equivalent, with temporal and spatial variations
Chemical reactions between pollutants, thermodynamics and kinetics — as an example, a possible mechanism for a typical Los Angeles smog can be found in Ref. 10 (reaction rates have been postulated where possible). A typical SO_2-type smog mechanism is in Ref. 11, again with reaction rates where possible.

The results of such analyses are time-varying concentrations in a regional air basin.

Advantages

This is the only approach which, on a deterministic basis, gives the detailed information required for either a comprehensive comparison with air quality standards or for a realistic determination of human exposure.

Disadvantages

- An extensive data base is necessary
- The model requires substantial personnel and computer time

For a more extensive discussion of possible types of models, see the separate report, "A Review of Air Quality Modeling Techniques,"[12] See also applicable Nuclear Regulatory Commission Regulatory Guides (including 1.3, 1.4, 1.109, 1.111); a brief discussion is contained in Ref. 13.

These analytical approaches can apply to any emissions into air: conventional pollutants (gaseous and particulate) — in addition to the difficulty of any detailed calculation, such as associated with possibility 3, large uncertainties exist in describing the chemical and physical transformations which may take place in the atmosphere, so that a completely reliable calculation is not presently possible. However, for certain classes of pollutants, useful results, at least for comparative purposes, may be obtained. It may still be that routine application of such methods will have to await improved information.

Radioactive pollutants (gaseous and particulate) — to some extent these suffer the same complications as for conventional pollutants, but at least any transformations do not noticeably increase the amount of radioactivity. As a result simpler data bases on chemical reactions may be employed, and in fact, chemical reactions in the atmosphere are often ignored. Moreover, the information exists to obtain doses to individuals subjected to the calculated concentrations. Primary standards for radioactivity are stated in terms of these doses, rather than in terms of concentrations. These doses, on the basis of simplifying assumptions, may then be used for health assessment purposes (see Stage 3) providing population distribution information is developed (from Section 1.6).

In principle, the emissions associated with construction of the facilities, i.e., dust, hydrocarbon fumes, and vehicular emissions, may serve as the basis for a similar analysis, although their impact on regional air quality will often be substantially less than the actual operation of the facility.

In general, it is presumed that all of the possible emissions determined under the review of Section 1.1 may serve as source terms for the analysis of this section. This includes emissions, not only from the basic generating facilities, but from ancillary facilities as well, and for normal as well as other operational modes. The one clear exception is the review of any electromagnetic levels or emissions (listed for convenience in Section 1.1) from transmission lines. In this case, the analysis is somewhat simpler, and, moreover, not the primary consideration. The review of the details of transmission line construction are principally a subject to be deferred to the AFC review.

2.1.2.2 Interactive Mechanisms

Interactive effects from one medium to another require another level of treatment, considering ambient concentrations for one medium and using algorithms or models to assess the impact on other media.

The most important effects of conventional air pollutants are on surrounding water and biota. Radioactive pollutants can also contaminate the land itself (as can some conventional pollutants).

Major mechanisms for removal of pollutants from the air:

fallout or sedimentation
rainout
absorption (into liquids)
adsorption (onto solids)
impaction

Various of these mechanisms may deposit the pollutant directly onto water, land or biota, and subsequent to this deposition — substances may be transferred among these media.

Below is a list of various interactive effects which can apply to the pollutants of all three means of power generation. They are classed by medium and by ultimate effect:

air pollutant plus biota air pollutant plus regional water air pollutant plus land	food chain effects (2.1.2.2.1)
air pollutant plus materials	safety effects (2.1.2.2.2)

There are, of course, often severe environmental impacts, but only those which affect humans more or less directly through the food chain or through the stability of his structures, are considered here. Psychological impacts only are not considered here.

Water quality standards are applicable to possible effects on water (whether direct or through run-off); food chain standards apply to pollutants taken up by biota (whether directly or through water or from land); for radioactive materials, limits on dose equivalent to men applies to land contamination as well as to concentrations in other media. Air pollutants may also affect materials (such as buildings); however, there are no applicable standards.

2.1.2.2.1 Food Chain Effects

a. Heavy Metal Deposition: mercury, lead, arsenic, etc.

- on regional water: they can enter the food chain directly through consumption by the fish (FDA standard), or by first being incorporated into the vegetation and then consumed by the fish. Sea vegetation can be consumed by humans and could present a health hazard. Both routes convert inorganic forms of mercury (for example) to much more dangerous organic forms (methyl mercury).
- onto regional foliage: can either be consumed directly by humans or first by animals and thereby enter the food chain.
- onto land: can enter the food chain through uptake of the vegetation.

- food chain depletion — the heavy metals can damage biota. In addition to depleting the human food supply this can have further consequences for humans:
    - a. destruction of foliage can reduce the food supply for the surrounding animal population.
    - b. destruction of vegetative ground cover leads to erosion, causing:
        1. increased sediment into lakes and streams with ecological results
        2. decreased water infiltration into the soil causing greater water runoff, thereby decreasing the water supply, etc.

b. Acid Rain: addition of acid salts to the rain (nitrates, borates, sulfates) This can have many of the same effects as heavy metal deposition (above) including those listed for deposition onto water and foliage.

c. Salt drift from cooling towers will reduce vegetation (see above).

d. Pollutant effects: an air pollutant entering regional waters clearly effects the ambient levels of that pollutant in the water. While this was not considered a water effluent (Stage 1), it may properly be considered a water pollutant at Stage 2 and should be considered as such in any modeling done in Section 2.2.

2.1.2.2.2 Safety Effects

a. Corrosive effects, either directly such as:

$$H_2S + \text{metals} \twoheadrightarrow \text{darkening, corrosion}$$

or through acid rain which has the same effect on metals. (However, rain may also wash pollutants from structures.)

b. Deposition of abrasive particulates and corrosive salts and acids into regional waters: can be caused by rain-out, acid rain (and erosion of land) and may lead to corrosion and erosion of building substructures.

2.1.3 Technology-Specific Considerations

2.1.3.1 Fossil Fuel

The pollutants which fossil-fuel plants can contribute and for which there are ambient air standards are virtually the same for the different fuels. These pollutants may be contributed directly as emissions or indirectly through reactions in the atmosphere. The standards, as stated in concentrations, vary considerably among the pollutants.

Most of the important substances to be considered may be found by referring to Section 1.1.3.1. In addition, there are important classes whose amounts can be significantly increased through reactions in the atmosphere, including

particulates (including sulfates)
oxidants

See Refs. 1 and 2 for applicable standards. A class of pollutants which differs from those mentioned are odorous compounds, for which there may be applicable standards.

Interactive Effects: primarily those discussed in Section 2.1.2.2

2.1.3.2 Geothermal

Geothermal plants may contribute to pollutants in the atmosphere either by direct emission or by reactions involving these emissions. Direct emissions were mentioned in Section 1.1.3.2. Of particular significance among atmospheric transformations is the conversion of H_2S to:

SO_2
particulates (including sulfates)

A possible complication for geothermal is the fact that the total emissions associated with the field and generating facility arise from a distributed source. However, models can accommodate this fact. Moreover, the difficulty posed depends on the extent to which this review considers the geothermal field.

Interactive Effects: primarily those discussed in Section 2.1.2.2.

2.1.3.3 Nuclear

See Section 1.1.3.3 for discussion of the principle emissions from nuclear plants. As for the other technologies, these may undergo chemical transformations; however, these do not alter the radioactive character of the species emitted, so that the chemical transformations do not have the direct significance associated with conventional pollutants.

However, a special consideration for nuclear is the fact that the applicable standards are actually exposure (i.e., dose equivalent) standards; the concentrations given in 10 CFR 20, Appendix B, are derived from these more basic standards. The doses to test persons at various points near the nuclear plant site may be calculated by simple tabular conversions of the concentrations calculated in this Section.

The fundamental numerical limit for routine dose equivalent is 500 mrem/year; however, the Nuclear Regulatory Commission, in applying the more general standards of "as low as is reasonably achievable," has adopted a limit of 5 mrem/year whole body, for the operation of nuclear power plants. This applies to normal operations.

For emergencies, i.e., accidents at nuclear facilities, there is no strict standard (i.e., one does not license accidents)(see Stage 3). However, there are being developed standards for emergency actions with respect to the populations subject to unusually high exposures as a result of nuclear accidents; these are the Protective Action Guides being developed by the Environmental Protection Agency. (It should be noted that because the 500 mrem/year standard is intended to be a dose rate at which persons can be subjected without significant harm throughout their lifetime, choosing 500 mrem as an action level has no basis. Not surprisingly, the guides being developed by the EPA differ from this number.) As for the dispersion analysis of this section, the array of nuclides to be considered during an accident, and their mode of release (e.g., height), will differ from routine emissions.

Interactive Effects: most significant is the iodine → ground → cow → milk → human chain. (The applicable limit is still dose equivalent to humans.) In addition, see Section 2.1.2.2.

SECTION 2.2 WATER EMISSIONS

The purpose of this Section is to determine the effect which the emissions into water determined in Section 1.2 have on water quality of the receiving water. This may lead to a comparison with applicable standards (federal, state, or regional), to an analysis of interactive effects (such as of water pollutants on biota), or to an assessment (in Stage 3) of the impact of these alterations on human health, to the extent that such an assessment is now possible.

Federal, state, regional, and local agencies have developed standards (or objectives) applicable to virtually all receiving waters, whether inland or ocean, surface or ground. Water quality standards may refer to chemical, physical, radiological, toxicological, bacteriological, and biological characteristics. "Ambient" standards for water quality are as varied as are those for water emissions; the reviewer is referred to the same references named in Section 1.2 (Refs. 5 - 8) and 40 CFR parts 146 and 423 and to the federal, state, and regional water resources boards. In addition, restrictions which will be imposed in the NPDES permit should be determined.

2.2.1 Methodological Approach

The reviewer may rely on expert opinion or previous experience with similar plants and control equipment to determine compliance with water quality standards. If, on the other hand, actual analysis is chosen, the following is necessary:

Explicit Review

1. Determine effluence:

Input data

Effluences from the proposed facility (from section 1.2).

Water data, i.e., on water quality in the absence of the proposed facility.

Dispersion-related data — meteorology (i.e., rainfall), flow rates, surface and bottom topography.

2. Once results are obtained, appropriate comparisons may be made with standards, which should be checked with the standard-setting agencies at the time of review.

3. Assessment of Interactive Effects

Additional data necessary

biota in the water supply

FDA standards

interactive effects

2.2.2 Generally Applicable Considerations

2.2.2.1 Direct Considerations

Ambient standards apply to most emissions discussed in Section 1.2.2 and, in addition, set other criteria. Some of these criteria and regulations apply equally to the three technologies and are listed in this Section: (for more complete information, see Refs. 5 to 8 and 40 CFR 423). Some of the pollutants which are important to all three technologies are:

chlorine	conductance (salts)
sulfates	dissolved oxygen
boron	pH
sodium	hardness (Ca^{++}, Mg^{++})
nitrogen	T.D. solids
metals	particulates
chemicals, organic	bacteria
chemicals, inorganic	oil and grease
radioactivity	toxicity
	turbidity
thermal pollution	color

and many more (see Refs. above)

In addition, the discharge may not affect the taste, color, or odor of marine life or its habitat. (This is a specific case of interactive effects, water on biota; see Section 2.2.2.2.)

---

*For example, possible models for simulating thermal effects are found in Refs. 14, 15 and 16. Further models for predicting dispersion of normal effluence or spills appear frequently in the literature. When the Commission is ready to start computer analysis, it should examine, at <u>that</u> time, the models which are available.

Normal operation of a facility can affect many of the factors listed above. Any disruption of the emission control equipment could result in unusually large amounts of material being discharged via liquid effluence into receiving waters and the ground water system. The reviewer should determine whether the risks posed by such emergencies are adequately small considering, for example, proximity of communities using water supplies affected, etc. Table 1.2-3 lists chemicals routinely used within a power generating facility and which could, in principle, be discharged during abnormalities.

2.2.2.2 Interactive Effects

Interactive effects may be determined, largely by very approximate methods, once alterations of waters are known. The most important media on which concentrations of pollutants (or other factors) in water may have significant effects are biota and land. Biota are clearly affected by the quality of the water and, more importantly for man, may concentrate certain pollutants carried in water (heavy metals such as mercury and radioactivity being prime examples). The most important mechanisms for this concentration process are simple ingestion or uptake with water. Standards which are less specifically designed for the protection of humans are, for example, the prohibition against the change of the temperature of a cold water stream because of its affect on marine life (trout).

Water-carried pollutants may directly contaminate land by physical and chemical processes; however, the most important effects of such contamination are usually through possible harm to, or contamination of, biota. In the case of severe pollution, the abrasion and corrosion of substructures can become significant.

2.2.2.2.1 Food Chain Effects

Primarily those which can be inferred from the interactive effects in Section 2.1.2.2.1. In addition:

- Thermal effects and turbidity can affect the reproduction and life-span of marine life, affecting the food supply and drastically affecting the ecology of the area
- Water consumption effects: withdrawal of water from certain fresh water supplies causes salt water intrusion which can:
    - a. pollute human water supplies for drinking
    - b. pollute irrigation water supplies which can deplete food supplies and destroy ground cover (see above)

2.2.2.2.2 Safety Effects

Largely those which can be inferred from Section 2.1.2.2.2.

2.2.3 Technology-Specific Considerations

2.2.3.1 Fossil Fuel

A broad spectrum of discharges into water may take place, as indicated in Section 1.2.2 and 1.2.3. These may have significant affects on the various water quality parameters, including those listed in Section 2.2.2. To some extent, certain aspects of the problem may be fuel-specific.

Coal plants are especially apt to affect:

particulate matter
turbidity
trace metals
Ca^{++}

via coal pile runoff, and these as well as:

chlorine
nitrates and nitrites
sulfates and sulfites

via on-site waste disposal.

Oil-fired plants present the possibility of oil spills from pipeline or tanker transport.

Interactive Effects: see Sections 2.2.2.2 and 2.1.2.2, especially heavy metal contamination of marine life.

2.2.3.2 Geothermal

The emissions indicated in Section 1.2.2 and 1.2.3 may affect various water quality parameters listed above. A major effect could occur, were geothermal fluids accidentally released directly into receiving waters or fresh water aquifers.

Interactive Effects: see Sections 2.2.2.2 and 2.1.2.2.

2.2.3.3 Nuclear

Exposures due to the major effluents into water should be assessed. This will depend on the situation:

- for ocean once-through cooling, little direct effect, since oceans do not contribute to drinking waters
- for fresh water usage, even for simply receiving cooling tower blowdown and other effluents, exposures may be possible

For emergencies involving large releases, possible exposures are substantial; analysis will depend on the release mode and detailed consideration of the possible pathways (see Ref. 16).

Interactive Effects: see Sections 2.2.2.2, 2.1.2.2, and 2.1.3.3.

SECTION 2.3 NOISE

The considerations set forth in Section 1.2 on noise are actually based on ambient levels, not on "emissions" (which would be stated in terms of sonic energy or some equivalent). For this reason, no treatment beyond that of Section 1.3 need be performed at this stage. The importance of psychological stress could be assessed in Stage 3.

Interactive Effects: noise can cause material stress.

SECTION 2.4 SOLID WASTE DISPOSAL

The treatment in Stage 1 of solid waste disposal is sufficient for the purposes of the present review, with the exception of considering in detail the exposure of individuals (workers and members of the general public) as a result of transport of radioactive wastes from the site. This exposure arises from penetration of the shipping containers by gamma radiation, and can be estimated on the basis of available parameters for the shipped material (primarily the spent fuel) and the containers. Although the total dose (in man-rem) will be small compared with doses obtained by the exposed individuals from background, the dose will be found to be significant as compared with the doses from routine emissions of radioactive material from the plant itself.

The Nuclear Regulatory Commission controls the latter doses to 5 mrem/yr to any members of the general public (although the generally applicable standard in 10 CFR 20, Appendix B is 500 mrem/yr), and it is to be expected that routine doses due to transportation should not exceed this level.

Transportation accidents could cause large short-term doses, much as accidents at the power plant itself could cause unusually high doses.

SECTION 2.5 SITE GEOPHYSICAL CHARACTERISTICS

This section performs any analysis required for the specific technologies, to determine the adequacy of the site as far as mechanical characteristics (ground stability and seismicity) and hydrology (particularly the potential for floods). For the most part, these characteristics will have been sufficiently examined in Stage 1, except for special circumstances, such as:

Ground stability — for geothermal facilities, the possibility that the facility itself could have a substantial effect on ground stability must be considered. It is possible that this effect, i.e., subsidence, can be treated analytically; whether or not this is possible, substantial dependence on expert opinion is likely. (The same would be true of a coal plant at the mine site.)

Seismic activity —

- The possibility that the facility may induce seismicity should be considered, but only for the geothermal case (note that this could then cause unusually large emissions into air and water).
- Consideration must be given to the effect that seismic activity could have on the facility. This is particularly true of nuclear, where extraordinary releases of radioactivity could, in principle, be caused. The plant must be designed for some maximum reasonable earthquake appropriate to the site being considered. This can be determined (although expert opinion must be used to do so) on the basis of information on fault position and size from Stage 1.

Interactive Effects: Erosion, especially that induced by construction, may affect water and air (see Sections 2.1 and 2.2).

SECTION 2.6 SITE DEVELOPMENTAL CHARACTERISTICS

This section performs any analysis required to determine the form or adequacy of measures for protecting populations from potential adverse effects from power plants. Examination of conformity with directly applicable population density and land-use standards will have taken place in Stage 1. (Moreover, the adequacy of transportation and other utilities will have been examined at that Stage.) At Stage 2, in the particular case of nuclear:

- The adequacy of measures for protecting populations (such as evacuation planning) should be analyzed.
- Controlled zones (i.e., the exclusion zone and the low population zone) should be determined. Moreover, as appropriate, measures for insuring adequately low population densities should be selected from the land-use control techniques available.

STAGE 3. ASSESSMENT OF PUBLIC IMPACTS

SECTION 3.1 INTRODUCTION AND GENERAL CONSIDERATIONS

The basic purpose of Stage 3 is to assess, to the extent possible, the health and safety impact of the proposed facility on the general public. Because the basis of this assessment is highly dependent on the specific technologies, they are treated separately (rather than by the review categories of Stages 1 and 2):

3.2 Fossil Fuel

3.3 Geothermal

3.4 Nuclear

For each technology, it will be necessary to consider two modes:

Routine Operation

and

Emergency Situations

The relative importance of each of these modes to each technology will be discussed within the technology-related section. For fossil-fuel and geothermal facilities, the problems associated with the normal plant operation appear to outweigh the danger to the public associated with an internal emergency. On the other hand, the potential danger associated with a nuclear accident is of greater importance than the routine emissions of the plant. In both cases, since there are no specific regulations or numerical standards for impact assessment, the reviewing agency must reach a judgment as to the importance of these impacts. It must also consider the beneficial aspects of establishing the facility, as compared with the assessed health and safety impacts.

The outline below sets forth the basic considerations to be treated in the technology specific sections.

3.1.1 Routine Operation

3.1.1.1 Emissions

The emissions section will discuss the most important emissions of the plant (air, water, and noise), their health impact, and the regulatory and monitoring problems associated with their control. Several facets of the operation of any plant contribute to the impact of the operation of the plant during normal operation. These are:

- Basic generation facility
- Fuel storage transfer and transport facilities
- Waste disposal and transport facilities

In this section, there will be three categories:

(1) Specific Pollutants of Major Importance
(2) Regulatory and Monitoring Problems
(3) Health and Safety Assessment

3.1.1.1.1 Specific Pollutants of Major Importance

This section will merely enumerate the significant pollutants of a particular technology.

3.1.1.1.2 Regulatory and Monitoring Problems

Regulations and standards are set in order to protect the public. Ideally if they have been established using adequate guidelines, the public will be protected from the emissions (governed by those standards) from the routine operation of a power plant. The ideal does not always exist for several reasons:

(a) There are no regulations concerning some of the emissions of a plant; for some of the interactive effects, they may be impossible to set.

(b) Where regulations do exist, they have sometimes been based on data which is inaccurate, outdated, or insufficient. The reviewer should be aware of current medical information, and consider the effect of the facility in light of this new data.

(c) Even if the standard exists and is adequate, the method of monitoring is often either controversial or notably inaccurate.

The technology-specific sections will therefore discuss the problems associated with the different means of power generation.

3.1.1.1.3 Health and Safety Assessment

Assessment of impacts on the public may be distinguished from calculation of effects on air and water quality. The public health and safety impact of individual technologies is treated in Sections 3.2 (fossil-fuel), 3.3 (geothermal), and 3.4 (nuclear). A general methodological approach to assuring these impacts may be utilized and is outlined here.

General Methodological Approach: Health and Safety Assessment

1. Data Necessary:

Dispersion Information — calculated in Section 2.1.2.

Demographic Information — obtained from census information or the local political unit

Health Effect Information —

2. Exposure Categories should be established.

Exposure categories would allow the reviewer to assess the health effect of a certain pollutant. They will consider:

a. dosage.

(1) length of exposure
(2) level of exposure
(3) is the exposure chronic or episodal?

b. effect, by degree and type:

(1) physical
(2) psychological

Because information regarding the health effects of low-level, long-term exposure to the major pollutants from fossil-fuel and geothermal power plants is unavailable or inadequate, it would be difficult to attempt to establish exposure categories for these pollutants at this time. Standards are usually based on observed effects with a risk factor built in. This is not always adequate for predicting long-term, low-level effects. The difficulty involved in evaluating such effects may be seen in the recent criticisms of the CHESS study. Increasingly, researchers will be able to provide sufficient information to establish these categories. If the commission wishes to make some quantitative assessment at this time, a study in conjunction with the Department of Health might be appropriate. Possible surrogate measures are discussed in Sections 3.2.1.1.3 and 3.3.1.1.3.

For radioactive pollutants, it is possible to estimate health effects on the presumption of a linear dose-response relationship, for routine exposures. This is discussed in Section 3.4.1.1.3.

3. Populations at risk will be established.

Using the dispersion calculation from Stage 2, demographic information, and the exposure categories, the reviewer can establish populations at risk and — if dose-response relationships are known — can estimate the effect of the proposed facility on the public.

4. Assessment of sites.

(1) Comparison of sites
(2) General discussion of health effects.

The development of the exposure categories or any alternative method of assessing health impacts of emissions will be suggested in the corresponding technology-specific sections (Sections 3.2.1.1.3, 3.3.1.1.3, and 3.4.1.1.3). Any further considerations in evaluating or comparing the proposed sites, with respect to emissions, will be included.

3.1.1.2 Other Considerations

In this section, any other matters for consideration regarding the health and safety impact (detrimental of beneficial) of a particular facility will be treated. (See Sections 3.2.1.2, 3.3.1.2, and 3.4.1.2.)

3.1.2 Emergency Situations—General Considerations

Emergencies are highly technology specific, and are treated in detail only in the technology-specific sections. Both internal and external emergencies will be considered. Internal emergencies are those occurring within the plant caused by a plant malfunction, such as fire, explosion, or core melt. External emergencies are caused by natural or man-made circumstances outside the plant, earthquakes or air pollution episodes etc., which affect the operation of the plant.

It will be necessary for the reviewer to consider not only the hazard presented by an emergency, but also the actual probability of its occurrence. The hazard presented by a nuclear accident is high, but the probability of one occurring is low. The probability of a geothermal accident is much higher, but its effect on the public considerably less.

SECTION 3.2 FOSSIL FUEL PLANTS

3.2.1 Routine Operation

3.2.1.1 Emissions

3.2.1.1.1 Specific Pollutants of Major Importance

a. Coal. Some of these pollutants may be emitted into air or water

Particulates:

- dust
- visibility reducing particles (VRP)
- sulfates
- nitrates
- polyaromatic hydrocharbons (PAH), such as benzo(a)pyrene
- hazardous trace metals—Hg, Pb, Se, etc.

Gases:

- sulfur dioxide
- nitrogen oxides

Radioactivity

Electromagnetic Emanations:

- electric field gradient
- magnetic fields

Thermal Pollutants

Sludge Runoff to Aquifiers

Noise

b. Oil. As for coal, although most emissions are decreased in importance, relative to coal.

c. Gas. Many emissions are reduced in importance relative to oil; those remaining important are (which may be emitted into air or water):

Particulates

Gases:

nitrogen oxides

hydrocarbons

Electromagnetic Emanations

Thermal Pollution

Noise

3.2.1.1.2 Regulatory and Monitoring Problems

- Pollutants for which there are no regulations:

  Electric fields, 60 Hz

  Magnetic fields

- Pollutants for which there are possibly inadequate regulations:

  Particulate Matter:

  The standard is given in terms of total suspended particulate (TSP) mass, without adequate specification of physical and chemical characteristics.

  Sulfates:

  This standard is new and is not as yet well established.

  Carcinogens:

  PAH (notably benzo(a)pyrene) — is a particulate and governed by that regulation, which may not be adequate since it was initially established on the basis of particulate studies.

  Nitrates and Nitrites — Research Developments on the effects of these agents and their byproducts in the biota are too recent for adequate standards to have been established.

  Noise:

  See the discussion in Section 3.2.1.1.3.

- Monitoring Problems

  Monitoring problems are closely related to inadequacies in pollutant characterization and related standards. See Section 5 of Ref. 4.

3.2.1.1.3 Health and Safety Considerations

Since the data necessary to establish chronic, low-level exposure categories is presently insufficient, judgment must be exercised in assuring the importance of the health and safety impact of fossil fuel emissions. Using the dispersion calculations performed or measurements made in Sections 2.1.2 (air), 2.2.1 (water), and 2.3.2 (noise) and the demography of the proposed site, potential population exposures can be characterized. Both the current and projected populations should be considered as to:

size
density (and distribution)
age
health
% urban
% Agricultural

A judgment of health impact must be made on the basis of the important emissions for which there are standards and the adequacy of those standards, and the emissions for which there are no standards, in order to determine the relative and absolute suitability of the proposed sites. This task will be considerably easier when even crude exposure categories have been established. Those will constitute an index to health risks. In this case the methodology of Section 3.1.1.1.3 may be employed.

3.2.1.2 Other Considerations

a. Coal

Although the major consideration, with regard to public health and safety, of any fossil fuel plant are the emissions, there is one further consideration regarding coal plants. This is the sheer volume of coal being burned, which makes even the most minor trace contaminants of much greater importance. The reviewer must then keep in mind pollutants such as Hg, which enters the food supply through surrounding water, and radioactivity, even though the percentage present is seemingly inoccuous. Hence they and other trace pollutants are included in the list of specific pollutants of major importance in emissions Section 3.2.1.1.1.

b and c. Oil and Gas

No additional considerations. Establishment of this type of plant to replace a coal burning or out-dated facility may actually improve the air quality of an area.

3.2.2 Emergency situations

Emergency situations involved in fossil fuel operations are not of major importance. They can, however, present problems if not handled properly. The reviewer should therefore determine that the applicant has thoroughly considered the following situations.

3.2.2.1 Internal Emergencies

a. Coal

Fires and Boiler Explosions — The effect of either of these would be minimal to the public. Facility control of such situations should be considered in the AFC portion of the review.

Slurry Line Breakage — See below under Oil Spillage.

b. Oil

Oil Spillage — While the primary effect of an oil spill tends to be environmental, its impact on the food chain can be considerable. The reviewer should then consider:

(1) Measures the applicant plans to take to prevent such spillage
(2) Measures the applicant plans to take to clean up
(3) Proximity of biota which might be endangered by such an accident.

Fires and Explosions Within the Facility--As under Coal, except that the petroleum at an oil-fired facility has its characteristic potential for explosion.

c. Gas

Pipeline Leaks→Potential Explosions—This situation can be most hazardous to the public. Gas mains can develop leaks, and with every leak is the potential of an explosion. Since the pipeline may extend through heavily populated areas, the public could be placed in danger.

The reviewer should consider carefully:

(1) The measures the utility plans to take to control leaks and prevent explosions.
(2) The measures the utility plans to take to protect the public after the leak has been detected, but before it is repaired.
(3) The routes the gas lines will take, in order to minimize their proximity to population centers.

Fires and Explosions Within the Plant—See above under Coal, the gas presents a characteristic potential for explosion.

3.2.2.2 External Emergencies

Natural Disasters—Natural disasters such as earthquakes, or meteorological events, could cause power outage. The reviewer should consider therefore: probability of outage occurrence and the population affected by the outage. If the potential for power outage is too great or the effect of the power outage too hazardous to the population, the proposed site may not be acceptable.

Earthquakes also have a potential for inducing fire and explosion of the type discussed in Section 3.2.2.1.

Air Pollution Episodes — The net effect, however unlikely, of an air pollution episode might be to close the plant down. The reviewer should then make the same considerations as he did when considering the potential effects of power outages due to natural disasters.

SECTION 3.3 GEOTHERMAL PLANTS

Section 3.3.1 Routine Operation

Section 3.3.1.1 Emissions

3.3.1.1.1 Specific Pollutants of Major Importance

a. Vapor-Dominated Resources

hydrogen sulfide
noise

b. Liquid-Dominated Resources

Open cycle: (flashed or binary)

H_2S
noise
radon
heavy metal
noise

3.3.1.1.2 Regulatory or Monitoring Problems

- Pollutants for which no regulations exist:

  none of the above

- Pollutants for which the regulations may be inadequate:

  H_2S — Russian studies indicate that the current standard, 30 ppb, may not be sufficient to safeguard the population. They note effects at >8 ppbv,[17] such as headache, nausea, and impairment of vision.

  Noise — Recent studies indicate that noise levels as low as 35 dBA can disrupt the sleep, which can have grave psychological impact.[18] Currently, there are only recommended ambient noise standards of ca.55 dBA at the property line.

- Monitoring Problems

  H_2S — arguments exist as to the best technique, and placement of monitoring equipment.

  Noise — The suitability of the dBA scale for measuring geothermal noise is questionable. Geothermal noise is weighted toward the lower frequencies, while the dBA scale is weighted toward the higher frequency.[19]

3.3.1.1.3 Health and Safety Considerations

3.3.1.2 Other Considerations

3.3.1.2.1 Subsidence

a. Vapor-Dominated Resources

Subsidence does not appear to be a problem at the Geysers.

b. Liquid-Dominated Resources

Depending upon the cycle chosen, there may be either a localized or more general subsidence problem. Localized subsidence can occur even when reinjection is being practiced. Some liquid areas may have more general subsidence problems if the ground is not sufficiently stable.

3.3.1.2.2 Field Variance

The quantities of various pollutants emitted by the wells and consequently by the plant varies sometimes by orders of magnitude from field to field, so that pollutants which are considered of major importance at the Geysers, the geothermal facility operating in California, may not be as important elsewhere. Pollutants which are of only minor consequence at the Geysers may become much more important at another field or well. They are:

Radon
Trace Metals (Hg, Pb, As, etc.)

3.3.1.2.3 Scale

Currently, the size of the operation at the Geysers allows the facility to ignore certain of the pollutants. When the operation is considerably increased in size, or larger operations are developed certain pollutants may become more important. They are:

Radon
Trace Metals (Hg, Pb, As, etc.)

3.3.2 Emergency Situations

Geothermal emergencies, as discussed below, are rarely serious problems since (1) with proper preparation they are containable or (2) the plants are usually far removed from most population centers, so the effect is small and for only short duration.

3.3.2.1 Internal Emergencies

a. Vapor

Blown Wells, Steam Line Breakage, Direct Venting of Steam on Shut-Down. The primary hazard from these events is the direct venting of H_2S into the atmosphere. All these emergencies occur not infrequently, and could present a health hazard to surrounding communities. The reviewer should examine the measures the applicant proposes to take in event of such an emergency.

Plant Fires and Boiler Explosions. These are not of great import to the public at large except in so far as they might force a shut down of the plant, causing direct venting of the well steam into the atmosphere. See above.

b. Liquid — as above in Vapor, plus:

Escape of Geothermal Liquid. This could present a serious problem to the water supply. The reviewer should consider the reliability of the methods the applicant proposes to control this problem.

3.3.2.2 External Emergencies

a. Vapor and b. Liquid

Natural Disasters (Earthquakes, Meteorological Events) — These are likely to cause the same sorts of problems as considered in Internal Emergencies. See above 3.2.2.1.

Air Pollution Episodes — not currently applicable.

SECTION 3.4 NUCLEAR PLANTS

Section 3.4.1 Routine Operations

3.4.1.1 Emissions

3.4.1.1.1 Specific Pollutants of Major Importance

tritium (^{3}H)
carbon (^{14}C)
iodine (^{119}I, ^{131}I, ^{133}I)
krypton (^{85}Kr)
xenon (^{133}Xe)

3.4.1.1.2 Regulatory or Monitoring Problems

All the radioactive species of importance are regulated, particularly since the regulations are not based on specific substances, but on "dose equivalent" from all substances emitted.

- Monitoring problems — Emergency monitoring instrumentation is somewhat primitive.
- Particular care must be exercised in monitoring for iodine releases in a manner that is consistent with its uptake and concentration via the food chain (grass, cow, milk, human, thyroid).

3.4.1.1.3 Health Considerations

- Establishment of Exposure Categories

For routine emissions, only low levels (as opposed to acute) exposures are caused by the operation of the plant. Exposure categories are effectively not required because, the health effects can be assessed on the basis of a linear dose-response function. On the other hand, specific information is required to convert exposure to differing radioactive species into "dose equivalent." However, on the basis of available information and dosimetric models, tables for such conversions have been constructed, so that the conversion is trivial, once ambient levels are known (from Stage 2).

Although the actual number used may vary by a factor of 2, fatalities induced by exposure to radiation may be estimated assuming that an increase in the summed dose to a population group of 10,000 rem will induce one cancer fatality. Similar statements may be made about illness and genetic effects. Although, such estimates are not precise, they may be used for the assessment of this section.

However, it will normally be found that the potential impacts from routine emissions are not important compared with other considerations, including the impact of accidental releases (see 3.4.2).

3.4.1.2 Other Considerations

Some assessment of the impact of the public perception of nuclear power plants may be appropriate.

3.4.2 Emergency Situations

3.4.2.1 Internally-Caused Emergencies

a. On-Site Emergencies

The primary concern is exposures to radiations. Possibilities for on-site exposures are reviewed by the Nuclear Regulatory Commission as a fundamental part of its licensing procedures. It is the potential for such emergencies to develop into off-site emergencies that is the primary consideration in the present review.

b. Major Radioactive Releases

In principle, the potential for occurrence of nuclear accidents may be analyzed using techniques such as those of WASH-1400. However, these techniques require adaptation to a form appropriate for site-specific analysis. See References 20 and 21.

Presuming accident probabilities and release characteristics are available, the consequences may be calculated. The exposure categories are well-defined:

early effects (from large radiation doses)
latent effects (from smaller doses as under Section 3.4.1.1.3.)

Either category includes both illnesses and deaths.

Regulatory needs

1. Assessment criteria for risk—a judgment of acceptability must be made
2. Criteria for emergency planning (see Ref. 22)
3. Criteria for population density control (see Ref. 21).

These three items are closely related to one another and to the ability to analyze the risk in a site specific manner. The tools for such analysis and the criteria given above must be specified.

3.4.2.2 Externally-Caused Emergencies

Natural events—the events of most concern are seismic disturbances. These may affect not only the operation of the plant (i.e., induce a shutdown), but could—in principle—so severely disturb the plant as to induce a major release of radioactivity. Such a possibility is mitigated by proper assessment of the potential for earthquakes and corresponding incorporation of seismic design features in the plant.

Sabotage—consideration must be given to the possibility that terrorists might, for their own reasons, attempt to provoke a nuclear accident. To some extent the ordinary safety systems would tend to prevent any series of events leading to a large release. Moreover, specific measures to prevent sabotage are incorporated into the design and operational plans for a nuclear power plant. However, the overall potential for releases due to sabotage is difficult to assess because it depends on the number, intent, and ingenuity of saboteurs.

For either case, natural events or sabotage, the effects of any releases may be analyzed in the same manner as in Section 3.4.1.2. However, for these cases, it is possible that the severity of the release could be increased by the peculiarity of the initiating event. For example, either earthquake of sabotage could not only provoke a release, but also prevent effective emergency responses from occurring.

AFC
INTRODUCTION

The purpose of the Application for Certification review is to examine the detailed plans for a facility which is proposed for construction on a site which has previously been approved at the Notice of Intention stage. The basic focus of this "health and safety" methodology is assurance that the facilities as proposed will have satisfactory safeguards for the protection of the health and safety of the public and facility employees. However, because the primary emphasis of the State health and safety review — as envisioned in this study — is the site-specific impact, a large portion of the AFC effort would be a review to assure that the presumptions of the NOI are actually fulfilled in the plant as designed, constructed, and operated. As a result, the AFC review places a heavy emphasis on monitoring of emission control technology performance and on oversight of safety-related design areas.

The AFC methodology is divided into five stages. The first reviews the matters considered during the NOI review. The second, third, and fourth treat the plant design. The fifth is intended to reach a final judgment on the health and safety aspects of the proposed sites and facilities. In somewhat more detail, these stages are:

Stage 1. Review of the NOI treatment

The purpose of this stage is to determine whether the validity of the NOI review may have been affected by any changes in the data or regulations. Basically, three possible areas of change need to be considered: applicable standards or criteria, the characteristics of the site itself, and the characteristics of the facility. Any changes in the applicable review methodologies could be considered part of the first area. At this stage, if the information has changed significantly, reconsideration of related requirements must take place. If the information changes very substantially, the validity of the earlier NOI review may be questionable.

Stage 2. Emission control equipment

The NOI review, and also the AFC stage 1, were predicated on the ability of the proposed facilities to meet applicable emission limitations. In examining the actual design of the facility, an important area to consider is the emission control equipment. This equipment plays a large role in mitigating potential impacts of power plant operation on the public. This examination extends to equipment for controlling emissions into both air and water, including even noise. Review can be divided into three possible levels: performance characteristics, the monitoring which assures this performance, and equipment design.

Stage 3. Safety design

Stage 3 would determine the compliance of the plant design with applicable safety design criteria. Two generic areas can be identified: occupational safety and health, and operational safety systems. For the first, the applicable criteria are either OSHA requirements, generally suitable for any type of power plant, and Nuclear Regulatory Commission regulations, which apply to nuclear power plants. With regard to operational safety systems, a large body of criteria are applicable to nuclear power plants, those of the Nuclear Regulatory Commission. For fossil-fuel and geothermal plants, the comparable criteria might again be OSHA regulations, which cover the most important safety-related systems of conventional industrial facilities.

Stage 4. General facility design

Review of the facility design may proceed to other systems, which do not have direct emissions or safety significance. This would require identification of standards for use and determination of the approach used in the ERCDC review. Should substantial design areas become subject to review, close collaboration with professional societies or the utilities would be necessary to determine suitable standards for review. In many cases, these could be selected from the large body of standards already developed by professional societies.

Stage 5. Overall assessment of site and facility AFC introduction acceptability

After completion of the NOI review process and the specific areas covered in the first four AFC stages, a final determination of site and facility suitability will have to be reached. This stage would serve to assemble the results of the earlier portions of the health and safety review into a form that can be used in this final determination. Because this judgment cannot be reached independently of other considerations, it is not to be expected that stage 5 can itself reach any conclusion in this matter. However, it would serve as the connection with the overall AFC decision process.

STAGE 1. REVIEW OF THE NOI TREATMENT: SITE-SPECIFIC IMPACTS

The purpose of this level is to check whether new data or regulations can affect the validity of the NOI review. If changes can affect the conclusions significantly, the reviewer should repeat the methodology of the NOI in those areas unless that the changes are so significant that the NOI review is invalidated. This review can also serve to check for the possibility of error in earlier calculations and situations which required judgmental decisions.

SECTION 1.1 EMISSIONS AND SITE CHARACTERISTICS

This stage should determine whether the proposed facility still agrees with the directly applicable standards. It also allows reconsideration of the geological stability of the proposed site.

1.1.1 Emissions Characteristics

This section checks the comparisons made in the NOI review in Sections 1.1, Air Emissions, 1.2, Water Emissions, and 1.3, Noise Emissions, with regard to plant emissions.

Methodological Approach

1. Determine any changes in the data collected at Stage 1, Sections 1.1, air emissions; 1.2, water emissions and 1.3, noise emissions.

   Data Required

   Plant specific information:

   - plant emissions - supplied by the applicant using calculations based on the specific control equipment that he intends to use.

     or

   - uncontrolled plant emissions - supplied by applicant, predicted from the specific plant he now intends to build.

- control equipment and data - latest available information regarding the equipment that the applicant intends to use.

  and

- availability of appropriate fuels

Regulatory:

- changes in old regulations
- new regulations

2. Determine emissions as in the NOI.

3. Compare the new projected emissions with the current standards.

If there have been no changes in the emissions or the standards, the reviewer can proceed to Section 1.1.2 Site Characteristics. If there are new or changed regulations, the reviewer must determine compliance with them. If the proposed facility does not now comply, the applicant may need to consider:

Changing his control equipment.

Attempting to obtain a variance, depending on the extent of the violation and the regulation violated.

Cancelling the project.

Moving to one of the other acceptable sites.

Special Considerations

At this time if the plant has passed the review the applicant should obtain, or have obtained permits to operate from the EPA or local water resources board, which will designate the amount of effluent he may discharge into the neighboring waters. AFC Stage 2 will deal with assurances that the control equipment he proposes to use comply with the regulations and the methods that will be used to assure compliance.

1.1.2 Site Characteristics

In this section, the reviewer must determine if there have been any changes in site geophysical or developmental characteristics that would effect the construction of the proposed facility.

Methodological Approach

1. Determine if there have been any changes in the data collected in Stage 1, Sections 1.4, Solid Waste Disposal, 1.5, Site Geophysical Characteristics, and 1.6, Site Developmental Characteristics.

Data Required

Facility-related information:

- Net solid wastes – supplied by the applicant, using calculations based on the specific control equipment that he intends to use;

OR {
- Uncontrolled plant emissions — supplied by applicant, predicted from the specific plant he now intends to build.
- Control equipment and data — latest available information.

AND
- Method of and place of disposal — any changes.

Site-related information:

- changes in seismic, ground stability hydrological information
- changes in population, land use availability regulations
- new regulations
- changes in availability of transportation and other utilities.

2. Determine the effect of any changes in the above information on the analysis performed in Stage 1, NOI, Sections 1.4, Solid Waste Disposal, 1.5, Site Geophysical Characteristics and 1.6, Site Developmental Considerations.

If there have been no changes in either the site, the planned facility or the regulations and populations, the reviewer will be able to proceed to Stage 2 NOI review. If there have been significant changes, the reviewer should return to the NOI sections 1.4 - 1.6 and repeat the pertinent review with the new information.

Special Considerations

In conducting this review of Sections 1.4 - 1.6, the reviewer should take particular care in assuring himself that rights of way have been adequately established for all parts of the facility including:

basic generation unit
transmission lines
supply lines
access roads
disposal sites
storage units

SECTION 1.2 BASIC IMPACT ANALYSIS

In this section, the reviewer will check the analysis performed in NOI, Stage 2, to determine if there have been any changes which would affect the conclusions of the NOI, Stage 2 review.

1.2.1 Ambient Environmental Considerations

This section determines the effect that any changes in the ambient air, water and noise regulations and any changes in the projected emissions will have on the decisions made in NOI Stage 2, Sections 2.1, Air Emissions, 2.2 Water Emissions, and 2.3 Noise.

Methodological Approach

1. Determine changes in the input data as required in NOI Stage 2, Sections 2.2.1, 2.2.1 and 2.3.1.

Data Required

Model - was the one chosen in the NOI review acceptable, providing extensive enough information?

Results desired - have circumstances changed enough to require more or less extensive analysis?

Input data:

- emissions, net - calculated from AFC (or NOI Stage 1 if still appropriate) Stage 1.
- competing sources - are there any changes regarding:

  new plants
  closing of previously extant plants
  other new sources (roads, agricultural users, population centers)
  meteorological and topographical data - any changes, new information

- chemical and physical processes - any new information regarding the parameters which are required by the model.

Standards:

- changes in old regulations
- new regulations - see NOI Stage 3 for possible areas where new regulations might be established.

Interactive Information:

- new ecological information
- new or changed biota in the area
- new or changed water in the area

2. Determine compliance with current regulations;

If there have been no substantial changes in the analytical model or in the projected emissions, this can be a comparison of the ambient levels calculated in the NOI, Stage 2, Sections 2.1.1, 2.2.1, and 2.3.1. If there has been a change, the corresponding NOI review section must be repeated.

If for some reason the plant does not now comply with existing regulations the applicant has the same options as listed in AFC Section 1.1.1.

1.2.2 Site Characteristics

The purpose of this section is to determine the effect of any changes in site characteristics or relevant standards on the review performed in NOI Sections 2.4 - 2.6.

Methodological Approach

1. Determine any changes in the information considered in NOI, Stage 2, Sections 2.4, 2.5, 2.6 has changed.

Data Required

New information regarding aggravation of subsidence or ground stability problems.

New information or regulations regarding emergency plans or population protection during an internal or external emergency.

2. Determine compliance with new regulations

As in Section AFC 1.1.1 and 1.1.2, the applicant has the option of changing the site, adapting his plant to the new regulations, obtaining a variance or abandoning the project if he is unable to pass this stage of review.

SECTION 1.3 ASSESSMENT OF PUBLIC IMPACTS

This section will be used to reassess the health and safety impacts of the projected facility upon the populations surrounding it. Any decisions that were made in the NOI review should be reconsidered at least cursorily, since they had to be based largely on judgement of a very complex system.

Methodological Approach

1. Determine variables which may have changed.

Data Required

Regulatory:

- new standards may have been established, either where none existed before or in place of older standards which had been based on earlier information; in addition, still existing standards may have been called into question. How to deal with such interim changes will require a policy decision.
- new monitoring equipment may have been developed, or new controversies on monitoring methods may have arisen.
- new equipment may remove a major portion of the troublesom emissions, or the old equipment may have been found to be less efficient than was previously supposed.

Facility-related changes:

- control equipment changes
- fuel reliability predictions
- plant reliability predictions
- fuel composition
- emergency control
- technology advances - relating to the means of power generation.

Site-specific changes:

- seismic activity, ground stability, hydrology
- land availability/use
- meteorological
- population character
- utility availability
- competing sources

Health-related changes:

- dose response curves may have been established for some of the major pollutants, allowing establishment of exposure categories
- questionable pollutants may have been found to be innocuous (or regulations established, see above)

Safety-related changes:

- questions regarding the effect of the plant on fault aggravation, ground destabilization, subsidence aggravation may have been further resolved
- methods of protecting existing structures, or building new ones, which are impervious to some of the interactive effects mentioned in NOI, Sections 2.1.2.2.1 and 2.1.2.2.2, have been developed.

2. Return to NOI Stage 3 with the new parameters to consider the acceptability of the projected facility and site.

STAGE 2. EMISSION CONTROL EQUIPMENT

In examining the actual design of the proposed facility, the first area to be examined is the emission control equipment. The reviewer must consider equipment for controlling air, water and noise emissions. Review must also consider both conventional and radioactive pollutants from all aspects of any generation facility. There are three possible levels of examination:

- performance characteristics - the expected pollutant removal efficiency and reliability of the proposed control equipment must be examined for suitability
- performance monitoring - proposed monitoring systems for guaranteeing compliance with either emissions limitations or equipment performance standards must be examined for suitability
- design and quality assurance - the equipment design itself may be examined to determine whether efficiency and reliability requirements will be met.

SECTION 2.1 PERFORMANCE CHARACTERISTICS

In this section of the review, we suggest sources of information on various control techniques for conventional and radioactive pollutants. In cases where the control equipment is suggested or required by law, reference is given to the pertinent regulation. Before discussing particular emissions, we suggest a general methodology.

Methodological Approach

1. Establish the sources of emissions into the environment.

This was done in the NOI review, Stage 1, Sections 1.1, 1.2, and 1.3, or AFC, Section 1.1.1.

2. Determine the control equipment proposed by the applicant, and its operating efficiency, reliability, and cost.

This will have been supplied by the applicant in AFC, Stage 1, Section 1.1.1. The reviewer should consider using staff analysis or an expert opinion to explore the previous operating record of such equipment, not necessarily relying on either the applicant or the manufacturer.

If the efficiency is not as high as predicted by the applicant or manufacturer, it may be worthwhile to suggest resubmission for other equipment, which may be an economically feasible solution to a control problem. Many of the regulations are based on just such a requirement (radioactive and conventional water, see below).

3. The projected performance of the control equipment should be compared with any performance standards which have been derived from applicable emission limitations.

Determination of such performance standards will constitute the major effort for development of this section of the review methodology. In certain cases, performance may be legally specified independently of ERCDC review. Performance standards may pertain either to control efficiency or to reliability.

2.1.1 Conventional Pollutants

These considerations may be applied to the operations of fossil-fuel and geothermal plants, and to some of the peripheral operation of a nuclear facility.

2.1.1.1 Air

Basic Generation Facility - a good general reference with extensive bibliography concerning the control techniques available for fossil fuel and geothermal emissions is Reference 4.

Petroleum Storage - the new source performance standards specify certain equipment or its equivalent (see Ref. 1 Appendix, Table A-1). Certain localities require operating efficiencies of vapor recovery systems employed.

2.1.1.2 Water

Direct Discharge

Effluent guidelines and standards were established by the EPA in 40 CFR Chapter 1, Subchapter N, Part 423.15. Previous to this the EPA published a "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Steam Electric Power Generating Point Source Category."[9] It carefully discusses the proposed guidelines and how to achieve them, including information on control and treatment of chemical wastes, describing the techniques used for control, reduction possible, actual usage, and costs.

The development document covers most of the problems concerning conventional water effluents of fossil-fuel fired and nuclear plants and some found in geothermal facilities (although not specifically considered). One area which is somewhat neglected is control of effluents into ground waters.

Fossil Fuel Facilities: effluence should only reach ground water through leaching form storage piles or solid waste disposal areas, and is more a consideration of proper engineering design, see guarantees and review in Section 1.1.2 or the NOI review, Section 1.4, if the AFC review has not been extensive. Engineering design may be considered further in Stage 4 of the AFC review.

Geothermal: effluence to the ground waters in this case may be direct. Prevention of pollution of the aquifers depends often on proper reinjection of the geothermal fluids. In this case an excellent source of information is GRID[28] (National Geothermal Information Resource) of Lawrence Berkeley Laboratory which can provide quick access to the latest references concerning geothermal operations, including reinjection engineering information. Currently, federal regulations have been proposed which would regulate reinjection (40 CFR 146).

2.1.1.3 Noise

Noise abatement procedures are essentially design specifications. Such design is often simple implementation of concepts from prototypes intended to achieve certain acoustical effects. See Ref. 4 for a brief discussion of techniques which includes muffling and landscaping.

2.1.2 Radioactive Pollutants

For nuclear power plants, review of the equipment for controlling both routine and accidental releases of radioactivity is performed by the Nuclear

Regulatory Commission, in accordance with 10 CFR 20 and 10 CRF 50, supported by Regulatory Guides, and as described more fully in the Standard Review Plan (see Stage 3). See Reference 13 for further discussion, including a brief description of control systems. (However, note that review of equipment for controlling accidental releases properly belongs in Stage 3 of this review.)

For fossil-fuel and geothermal plants, radioactive effluents are effectively controlled, in some degree, by the conventional effluent control systems, such as the particulate control devices at a coal-fired plant. However, equipment for specific control of radioactive materials emanating from fossil-fuel or geothermal plants is not required.

SECTION 2.2 PERFORMANCE MONITORING

This section of the AFC review is to establish that the monitoring equipment and programs suggested by the applicant meet with established standards and are adequate to assure compliance with both emissions regulations and any equipment performance standards which have been formulated. From the monitoring point of view, the distinction between these two categories is that emissions monitoring implies instrumentation for monitoring the pollutant output of the plant, whereas performance monitoring requires instrumentation for verifying that the control equipment itself operates as expected.

Methodological Approach

1. Determine the sources of emissions which are to be monitored, the monitoring equipment the applicant proposes to use and his monitoring program.

The sources of emissions would have been established previously; the monitoring equipment and program would be supplied at this time by the applicant. See also Section 2.1.

2. Determine that the monitoring equipment and program meet all pertinent regulations, standards, and requirements.

Regulations exist at both the state and federal levels concerning the methods of analysis and programs used for emission monitoring equipment. Sources of this information are listed in the discussion of the sources of emissions, below Sections 2.2.1 (Conventional) and 2.2.2 (Radioactive). Performance monitoring instrumentation is not as thoroughly specified.

3. Determine that the monitoring equipment and programs will be able to verify compliance with emissions standards and requirements.

This step requires that the staff examine the monitoring program and assure itself that the program suggested will in fact guarantee that the regulation, standards, and requirements established on all levels state, federal, local, and those established within the NOI and AFC review will be met, throughout the operating life of the plant.

2.2.1 Monitoring Equipment

The best source for information regarding many types of instrumental monitoring equipment is:

Survey of Instrumentation for Environmental Monitoring[23]

vol. 1, Air (also includes information on Noise)
vol. 2, Water
vol. 3, Radiation

2.2.2 Monitoring Requirements

The monitoring equipment and programs must meet regulatory standards (see the following discussion) and requirements associated with monitoring of equipment performance that the ERCDC may specify.

Air

Current federal regulations regarding monitoring programs and equipment are outlined in "Inspection Manual for the Enforcement of New Source Performance Standards."[24] The instrumentation required has been compiled in Ref. 1. However, because of the on-going nature of regulation it would be wise to check with the local APCD, the Air Sources Board and the local EPA office for any new regulations.

Water

Federal regulations are found in the Water Pollution Control Act, amended by P. L. 92-500.

The regulations regarding permits and the interpretation of the act have not been finalized. It will be necessary then to be aware of the procedures to be followed under Title 40, "Code of Federal Regulations", Part 125 for acquiring permits, and then to check with the regional EPA office regarding interpretation.

The EPA also approves analytical methods which are listed in 40 CFR 136. The best descriptive source of these methods is Standard Methods for the Examination of Water and Waste Waters.[25] Other sources are found in Ref. 26, 27.

Noise

Since the noise regulations are rather difficult to establish and enforce, the manner of monitoring is made even more difficult. The problems involved have been discussed earlier (NOI, Stage 3). Local regulations should be determined.

Radiation

Monitoring requirements are closely connected with the emissions limitations and performance requirements which, as discussed in Section 2.1, arise from 10 CFR 20, 10 CFR 50, and related regulatory procedures. See Reference 13 for a brief discussion of these review procedures.

SECTION 2.3 CONTROL EQUIPMENT/DESIGN AND QUALITY ASSURANCE

How to treat matters of design and quality assurance is considered primarily in AFC Stage 4, General Facility Design. That section emphasizes the difficulty of conducting a review program in areas where standards are not well specified. However, for emission control systems, the goals are well defined, so that institution of a compliance program as discussed in section 2.2 is not as difficult as carrying out an actual design review. Since monitoring of plant emissions and/or of control equipment performance serves directly to protect the public large part, a full design review and associated quality assurance program may not be appropriate. An oversight function may be considered to be sufficient. See section 4 for discussion of alternative approaches to a design review.

STAGE 3 SAFETY DESIGN

Stage 3 would determine compliance with applicable safety criteria, including those which apply to occupational health and safety systems and those which apply to operational* safety systems. Specific information on these areas is given below, in sections 3.1 and 3.2, respectively. More general considerations, which apply to all design areas, including those of this stage, are set forth in Stage 4, General Facility Design.

Because the bulk of "occupational health and safety" standards are developed for conventional industrial facilities, section 3.1 emphasizes the safety considerations appropriate to geothermal and fossil-fuel power plants, only briefly mentioning those which pertain to nuclear power plants. On the other hand, section 3.2 emphasizes nuclear power plants and, in the course of considering the Nuclear Regulatory Commission safety review procedures, includes those aspects of nuclear power plants which pertain to occupational health and safety.

---

*In the present context, "operational safety systems" are those which monitor and control the basic processes at the facility to assure that it operates in a controlled and safe manner. As an example, the pressure control system associated with a pressure vessel could be construed to be such a system. (However, it would also be included in the third category of occupational safety and health review discussed in section 3.1.) Another example is the reactor shutdown control rod system of a nuclear power plant.

SECTION 3.1 OCCUPATIONAL SAFETY AND HEALTH

3.1.1 Areas of review

Three general areas may be included in this section. They are:

- control of hazardous substances
- equipment and design for protection of workers
- prevention of explosion, fire, extraordinary releases, etc.

These areas are closely related, but it is practical to distinguish between them. Specific regulations apply to each of these areas. Occupational Safety and Health Administration regulations (either Federal or State) may be applied to any type of facility. In California they are contained in Title 8 of the California Administrative Code (CAC), Chapter 4 on Industrial Safety Orders. Specific portions of the Code apply to each of the categories just mentioned. However, the Code is primarily directed to conventional facilities, not nuclear plants. Although the CAC mentions control of radiation exposures, the criteria it refers to are based principally in Federal criteria, as specified by the Federal Radiation Council (and now the Environmental Protection Agency). In most respects, these are identical to the provisions applicable to facilities under the control of the Nuclear Regulatory Commission, at least as far as occupational protection is concerned. The latter type of provision is contained in 10 CFR 20, although the provisions of 10 CFR 50 are also relevant. See section 3.2 for discussion of the review of nuclear power plants.

The remainder of section 3.1 treats the three areas specified above, emphasizing the extent to which they are covered by the California Administrative Code's Industrial Safety Orders. Stage 4, General Design Review, discusses more general bases for review which might be implemented for specific areas not covered by existing regulations.

3.1.2 Bases for occupational safety and health review

3.1.2.1 Control of hazardous substances

Of occupationally related considerations, protection of workers from hazardous materials (in which we include noise, for the sake of simplicity) bears greatest similarity to the protection of the public from the health and safety impacts of power plants. However, although the health related considerations are in principle the same for workers and for the public, in practice they differ considerably. This difference arises from the fact that workers may be subject to a wider range of substances and at a higher exposure level than the public is likely to encounter. Without explicit safeguards, workers may encounter levels which are "toxic", whereas the public is more often exposed to lower levels which - over the long term - may induce disease. Moreover, the philosophy of protection of workers differs somewhat from that for the public, since the worker may be expected to assume some higher occupationally-related risk than would be appropriate for large segments of the public.

Standards for protection of workers from hazardous substances are embodied in the California Administrative Code's "General Industrial Safety Orders," i.e., subchapter 8.4.7. Of particular interest are:

Group 14: Radiation and radioactivity
Group 15: Noise control safety orders
Group 16: Control of hazardous substances.

Group 14 is of little interest in this section since - for the case of nuclear power plants - it is the Nuclear Regulatory Commission review (described in section 3.2) with its much more extensive treatment, that is the primary assurance of worker (and public) protection from exposure to radiation.

In the present section, the view is taken that - since the CAC provision cited apply to any industrial facility - they should be applied to power plants in a manner consistent with their application to other facilities. (But where a special danger exists because of the particular character of a power plant, greater attention is appropriate.)

For the areas considered below, regulations exist, in the CAC, which must serve as a design basis. It is, moreover, to be expected that their implementation would be assured in some way. This assurance may be limited to an expectation that the plant operator will freely comply, particularly in the face of possible inspection. On the other hand, a stricter program of quality assurance at the design, construction, and operation stages may be instituted, in which the ERCDC monitors a quality assurance program carried out by the utility or its agents. While it seems probable that the second approach would offer a level of protection to workers that is superior to the first, it is by no means clear that the increased protection is great enough to warrant the greater investment in review, monitoring, and compliance procedures that is required by a formal QA program. A comparison of costs and benefits should be made prior to any decision in these matters. Active involvement of the ERCDC in these design areas would require substantial efforts, both by the ERCDC and by the applicants.

Group 15 (noise) is a matter to be considered in this section. However, it consists largely of a reiteration of the federal standards for occupational noise protection. In view of the fact that the noise levels encountered in a power plant are not substantially different than those encountered in other industrial facilities (except perhaps for venting of geothermal fluids), it does not appear that review and inspection programs different from that of general industrial facilities is warranted. Therefore, any action of the ERCDC in this area would presumably be taken as part of a wider effort for noise control.

Group 16 contains extensive material on protection of workers from hazardous chemical substances. To indicate the areas covered, we list the articles of group 16:

107: Dusts, fumes, mists, vapors, and gases
109: hot, flammable, poisonous, corrosive, and irritant substances
110: special hazardous substances and processes
111: fumigation
112: labeling of injurious substances.

For the most part, these categories represent - as in the case of noise - no greater danger in a power plant than in other industrial facilities. Often the danger is less. However, conventional power plants do handle large amounts of flammable materials, and the potential for explosion and fire must be carefully controlled. (See section 3.1.2.3.) Moreover, power plants chemicals other than fuels in a secondary capacity, i.e., for cleaning, water treatment, and other procedures; however, in these respects, review and inspection procedures which are satisfactory for other industrial facilities will be satisfactory for power plants.

3.1.2.2 Equipment and design for protection of workers

This section emphasizes those aspects of plant design and operation which physically protect workers. These include, for example

- railings, ladders, etc.
- emergency equipment, such as respirators, medical supplies
- work practices

Regulations for these areas are contained largely in California Administrative Code 8.4.7, as were the regulations discussed in the previous section.

As for hazardous substances, regulations for physical protection of workers should be enforced in a manner consistent with practice pertaining to other industrial facilities.

3.1.2.3 Prevention of explosion, fire, extraordinary releases

Substantial portions of CAC 8.4 consist of regulations for prevention of explosion, fire, etc. We do not cite all of them here, but note three subchapters which are particularly applicable to conventional power plants:

- 8.4.1: Unfired pressure vessel safety orders - includes air pressure tanks, low-pressure gas tanks and cylinders, underground and above-ground storage tanks
- 8.4.2: Boiler and fired pressure vessel safety orders - has direct application to the major steam generating and handling components of power plants
- 8.4.15: Petroleum safety orders - treats handling both as a hazardous substance and as an initiator of fire and explosion.

For many of these areas, the utility will - in any case - carry out a substantial program of inspection and testing. It may be appropriate for the ERCDC to devote the time of a staff member to the monitoring of this program. On the other hand, the direct interest of the utility (and its insurer) in preventing explosions and fires is probably a much more substantial incentive to compliance with the regulations than efforts of the ERCDC in this area. As a result, these efforts may be restricted to that of a low-level oversight role.

Note that the subject of this section may be considered to overlap substantially with the next section, operational safety systems. This occurs because such systems, intended to assure smooth operation of the basic plant fucntions, also serve to prevent the safety-related occurences of the present section.

For the case of nuclear power plants, however, a large amount of effort is devoted to operational safety systems, primarily to assure the safety of the public. For this reason, section 3.2 is used as the opportunity to discuss areas of review for nuclear power plants.

SECTION 3.2 OPERATIONAL SAFETY SYSTEMS

3.2.1 Areas of review

This section would treat areas of plant design which have a direct influence on the safe operation, and indeed the integrity, of the major plant systems. To some extent these areas are included in section 3.2.1.3 on explosion, fires, etc. The OSHA codes, for example, include provisions applicable to pressure vessels, fire and electrical safety, petroleum handling, etc. However, these apply particularly to conventional facilities. They fail to include many areas of great importance for nuclear power plants, largely because of the extensive effort expended to prevent any radioactive releases from these plants. For this reason, this section is devoted primarily, although not exclusively, to specific areas of design for nuclear power plants.

For nuclear plants, three levels of safety systems are utilized:

1. The basic system design should minimize the probability of component or systems failure. This level of design is comparable with OSHA provisions for pressure vessel integrity, and is therefore analogous to the subject of section 3.1.2.3. However, unlike the case of conventional power plants, a nuclear plant expends considerable efforts on additional layers of safety systems, as noted in items 2 and 3, to prevent releases should the basic systems fail.

2. To take account of the possibility of such failures, auxiliary systems are provided to prevent serious damage to the nuclear fuel, since it is the radioactive material in that fuel that poses the greatest danger to the public and to workers.

3. For any case where severe damage to the fuel occurs, systems are available to prevent large releases to the atmosphere. These systems include, for example, containment spray systems and the containment itself; these are systems for control of accidental releases, as distinguished from systems for control of routine emissions (discussed in stage 2).

As discussed in section 3.2.2, these arease are subject to review by the Nuclear Regulatory commission. The ERCDC might consider a coordinated effort in these areas, both to prevent duplication of review effort and to avoid the overwhelming cost of an independent comprehensive review.

For any kind of power plant, whether nuclear, geothermal, or fossil-fuels if it is determined that - for an area requiring review - usable standards do not exist, then the ERCDC may have to adopt the procedures outlined in Stage 4, for the case where standards are lacking. For the most part, though, such regulatory criteria do exist, as OSHA standards for conventional plants and as a very large body of criteria for nuclear plants.

3.2.2 Review of nuclear power plants: the Standard Review Plan

The Nuclear Regulatory Commission reviews the safety aspects of proposed nuclear power plants on the basis of a Safety Analysis Report that is supplied by the applicant. This report is expected to contain information and analysis which is reviewed in accordance with a review procedure that has been constructed by the staff of the NRC to assure that the proposed plant meets regulatory requirements, particularly those specified in Title 10 of the Code of Federal Regulations, parts 20, 50, and 100. For the convenience of all concerned, the NRC has published a "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants". In addition, the NRC has published, as one of its Regulatory Guides, a "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants." These documents serve as a substantial basis for understanding the current review procedure of the Nuclear Regulatory Commission. The purpose of this section is to summarize that review procedure with a view to identifying those areas in which the ERCDC can fruitfully become involved. We will not attempt to mention here all of the criteria, regulatory guides, and standards which are employed in that review. These have been collected into a separate document[29] which has been supplied to the ERCDC staff.

The NRC review plan treats a broad variety of areas deemed pertinent to the public and worker health and safety. In this sense, the Standard Review Plan (SRP) included the equivalent content of both the NOI and AFC stages of ERCDC review. This is, it includes both site-specific considerations and the detailed character of the power plant design. The structure of the NRC and ERCDC reviews may become more similar if the NRC relies on site pre-approval.

However, even then, the ultimate emphasis will differ, because - at the State level - it is the site-specific character of the proposed facility that merits the greatest attention, while - at the Federal level - it is the detailed plant design.

The summary given below includes all of the areas considered during the NRC safety review. It is extremely unlikely that the ERCDC would attempt a comparable effort for all of these areas. On the other hand, certain areas which are specifically related to siting power plants in California would be appropriate areas on which to concentrate ERCDC efforts. These include much of the material under site characteristics (Chapter 2), and some of the subjects under radioactive waste management (Chapter 11) radiation protection (12) and conduct of operations (13, which includes emergency planning). Some of the material under quality assurance may be of interest, if only as a guide to possible approaches in quality assurance programs for conventional facilities. It is likely that the ERCDC would be able to exercise only oversight in many of the other areas summarized below.

The Safety Analysis Report submitted by the applicant is divided conventionally into a number of chapters, and the NRC review follows this order. In the discussion below, for each subject, we begin by summarizing the coverage of the Safety Analysis Report, then comment on the manner in which the NRC reviews this material and on possible involvement by the ERCDC. The first chapter is simply an introduction (similar orientation material will have been included in the NOI) and is not subject to review.

NRC Standard Review Plan - based on Safety Analysis Report

Chapter 1. INTRODUCTION AND GENERAL DESCRIPTION OF PLANT - presents an introduction to the report and a general description of the plant. This chapter should enable the reader to obtain a basic understanding of the overall facility without having to refer to the subsequent chapters. Review of the detailed chapters that follow can then be accomplished with better perspective and with recognition of the relative safety importance of each individual item to the overall plant design.

Chapter 2. SITE CHARACTERISTICS - provides information on the geological, seismological, hydrological, and meteorological characteristics of the site and vicinity, in conjunction with present and projected population distribution and land use and site activities and controls. The purpose is to indicate how these site characteristics have influenced plant design and operating criteria and to show the adequacy of the site characteristics from a safety viewpoint.

This portion of the review examines the suitability of the site from a safety viewpoint. Many of the matters treated here would have been treated in the Notice of Intention. The major subjects of review are:

- Geography and demography - this includes examination of: the site location; the exclusion area, low population zone, and population center distance; population distribution. These are matters of direct interest to the ERCDC in connection with power plant siting and population density controls.

- Nearby industrial, transportation, and military facilities - these facilities are examined to determine whether accidents at their locations can affect the nuclear plant.

- Meteorology - this section reviews the meteorological information provided by the applicant, the site meteorological monitoring program, and the diffusion estimates for accidental and routine releases, with a view to determining whether the information is adequate for purposes of the safety review.

- Hydrologic engineering - the general hydrology of the site is examined; in addition specific attention is given to the potential for flooding (and to related design bases) and to dispersion of accidental releases.

- Geology, seismology, and geotechnical requirements - after examining the basic geologic and seismic information, the review explicitly examines the potential for vibratory ground motion, the existence of local surface faulting, the stability of subsurface materials and foundations and of slopes (including embankments and dams).

As is clear, much of this examination would take place at the NOI stage, as a prelude to detailed examination of the facility during the AFC.

Chapter 3. DESIGN OF STRUCTURES, COMPONENTS, EQUIPMENT, AND SYSTEMS - should identify, describe, and discuss the principal architectural engineering design of those structures, components, equipment, and systems important to safety; discusses the seismic and quality group classifications, then the criteria for qualifying various components and systems.

This is a major portion of the review and is appropriately considered part of the AFC review. In large part, this could be conducted by overseeing the review carried out by the NRC.

The proposed facilities must meet the NRC "General Design Criteria for Nuclear Power Plants" (10 CFR 50, Appendix A). The specific areas given attention during the review are:

- Classification of structures, components, and systems (seismic classification and system quality group classifications)
- Wind and tornado loadings
- Water level (flood) design
- Missile protection
- Protection against dynamic effects associated with the postulated rupture of piping
- Seismic design
- Design of Category I structures
- Mechanical systems and components
- Seismic qualification of seismic Category I instrumentation and electrical equipment
- Environmental design of mechanical and electrical equipment.

In these matters, it would be useful to establish liaison with the NRC staff. For matters of special interest in California - particularly those related to the potential for earthquakes - it would be appropriate to build up in-house staff competence, particularly on the geophysical aspects of the questions.

Chapter 4. REACTOR - provides evaluation and supporting information to establish the capability of the reactor to perform its safety functions throughout its design lifetime under all normal operational modes, including both transient and steady-state, and accident conditions. Should include information to support the analyses presented in Chapter 15 Accident Analyses. The major topics to be considered in Chapter 4 are fuel system design, nuclear design, thermal and hydraulic design, reactor materials, and the design of the reactivity control systems.

This portion of the review examines the safety design of the reactor itself, including the nuclear core (and its interaction with the reactor coolant system) and reactivity control systems. Because of the highly specialized nature of this examination, it is not to be expected that the ERCDC staff would participate actively. The major areas treated are:

- Fuel system design - the mechanical, thermal, and chemical design of the fuel assembly and its constituents is examined.
- Nuclear design - operation of the core itself is examined; specific attention is given to the core power distribution, to reactivity and control questions, and to pressure vessel irradiation.
- Thermal and hydraulic design - basically examines the rate at which heat is generated in the core and the capacity for the coolant system to carry off this heat under normal operation and anticipated transients, and accident conditions.

Chapter 5. REACTOR COOLANT SYSTEM AND CONNECTED SYSTEMS - provides information on the reactor coolant system and systems connected to it, making a point to include information on the entire "reactor coolant pressure boundary" as defined in 10 CFR 50.2(v). Topics included are a summary description, the integrity of the reactor coolant pressure boundary, the reactor vessel, and component and subsystem design.

The purpose of this review is to verify that the reactor coolant system is adequate to accomplish its intended objective and to maintain its integrity under conditions imposed by all foreseeable reactor behavior, including both normal and accident conditions. Even an ERCDC oversight role in this aspect of the review would require staff with specific experience in reactor coolant system design. The main areas considered are:

- Integrity of reactor coolant pressure boundary - compliance with applicable codes is checked. Specific attention is given to overpressurization protection to boundary materials and fabrication to inservice inspection and testing, and to leakage detection.

- Reactor vessel - the reactor vessel itself is given special attention; vessel materials, fabrication, and testing are reviewed, as well as the vessel's pressure-temperature limits and the overall question of vessel integrity.

- Component and subsystem design - examines safety aspects of components within the reactor coolant system and associated systems. Included are reactor coolant pumps, steam generators, piping, main stream line flow restrictions and isolation system, reactor core isolation cooling system, residual heat removal system, reactor water cleanup system, valves, and component supports.

Chapter 6. ENGINEERED SAFETY FEATURES - provides enough information on features designed to mitigate the consequences of postulated accidents that an adequate evaluation of their performance is permitted. The information includes experience and testing, consideration of component reliability and system design, provisions for inservice test and inspection, and evidence that materials will stand the accident environment. Systems to be considered may include containment systems, emergency core cooling systems, habitability systems, fission product removal and control systems, and others.

Whereas the previous two review sections examine the "intrinsic" safety features of the reactor and coolant system, this section examines the "engineered" safety features, intended to mitigate the effects of possible failures in the basic system. Although these systems are extremely important, much as in the case of the previous two sections, the ERCDC staff can exercise no more than oversight in these areas. The specific topics considered by the NRC staff are:

- Engineered safety feature materials - examines materials selection and fabrication (including composition of spray coolants), evaluates suitability of organic materials (paints) for accident conditions, reviews control of post-accident chemistry within containment.

- Containment systems - the design and accident response of the containment (and associated systems) is examined in detail. The review areas are: containment functional design, heat removal systems, secondary containment functional design, containment isolation system, combustible gas control in containment, and containment leakage testing.

- Emergency core cooling system (ECCS) - at this stage of the review, the ECCS information is reviewed for adequacy of design bases, design, test program, and proposed technical specifications. A major effort is devoted to evaluation of ECCS performance, but this is deferred until Chapter 15 below.

- Habitability system - examines adequacy of the equipment, supplies, and procedures to assure that control room operators can remain in the control room during accident conditions; these systems are to protect the operators from radioactivity, toxic gases, smoke, and steam.

- Fission product removal and control systems - examines engineered safety feature filter systems, containment sprays, basic fission product control systems, and any ice condensers to determine effectiveness of fission product removal during accident conditions.

- Inservice inspection of class 2 and 3 components - reviews the inspection program of these components; examines component classifications, accessibility, manner of inspection, how the results are evaluated, pressure testing.

- Main steam isolation valve leakage control system (BWR) - the control system is examined to assure adequacy of radioactivity control during accident conditions.

Chapter 7. INSTRUMENTATION AND CONTROLS - provides information on the reactor instrumentation which senses the various reactor parameters and transmits appropriate signals to the regulating systems during normal operation, and to the reactor trip and engineered safety feature systems during abnormal and accident conditions; emphasizes those instruments and associated equipment which constitute the reactor protection system.

This portion reviews safety-related instrumentation, control, and supporting systems, including alarm, communication, and display instrumentation. The review emphasizes conformance with IEEE standard 279-1971. Moreover, many of the systems listed below are expected to be standardized or compared in detail with recently approved power plants:

- Reactor trip system - examines instrumentation reactor trip system and supporting systems.
- Engineered safety feature systems - analyzes instrumentation and controls for behavior for various accidents and failures.
- Systems required for safe shutdown - reviews instrumentation for various plant systems required for safe shutdown of the reactor.
- Safety-related display instrumentation
- Other instrumentation systems required for safety
- Control systems not required for safety - these systems are examined to assure that they cannot impair the effectiveness of the protection systems.

Chapter 8. ELECTRIC POWER - provides information directed toward establishing the functional adequacy of safety-related electric power systems and ensuring that these systems have adequate redundancy, independence, and testability in conformance with current criteria.

Reviews adequacy of plant electric power systems, since these are the sources of power for the reactor coolant pumps and other auxiliaries during normal operation and for the protection system and engineered safety features during abnormal and accident conditions. The basic systems examined are:

- Offsite power system - examines the layout and design of the offsite power system, with particular attention given to the existence of two independent paths from the offsite source of power to the onsite power distribution system.

- Onsite power system - examines the AC onsite power system, including the onsite sources (typically diesel generator sets), distribution system, and supporting system. Checks redundancy requirements, independence from offsite power, details of the distribution components, testing, etc. The DC power system is also evaluated for redundancy and other criteria. Fire protection for cable systems would also be reviewed at this point.

Chapter 9. AUXILIARY SYSTEMS - provides information on auxiliary systems including fuel storage and handling, water systems, process auxiliaries (such as air handling, water drainage, etc.), ventilation systems, and others (such as fire protection, lighting, etc.). Systems that are essential for safe plant shudown or for the protection of the public health and safety should be identified and discussed in detail (design bases, safety evaluation, etc.).

This section examines many of the plant systems which, while not central elements in the reactor, steam supply system, or generator system, serve important plant functions which are safety-related. Many of these systems are similar in principle, to systems at other types of power plants, but have increased significance because they handle radioactive materials. The systems considered are:

- Fuel storage and handling - examines out-of-core storage and handling, including: facilities for the dry storage of new fuel, facilities for the wet storage of spent fuel (with an emphasis on maintaining subcriticality), the cooling and cleanup system associated with the spent fuel pool, and the fuel handling system (for both new and spent fuel).

- Water systems - examines the plant water systems, including (as appropriate): station service water system, cooling system for reactor auxiliaries, demineralized water system, potable and sanitary water systems, ultimate heat sink, and condensate storage facilities.

- Process auxiliaries - examines systems associated with the reactor process system, including (as appropriate): compressed air system, process sampling system, equipment and floor drainage system, chemical and volume control system, and standby liquid control system.

- Air conditioning, heating, cooling and ventilation systems - examines the ventilation system for: control room area, spent fuel pool area, auxiliary and radwaste area, turbine area, and engineered safety features.

- Other auxiliary systems - safety aspects of the following are examined: fire protection system, communications systems, lighting systems, and diesel generator fuel oil systems, cooling water system, starting system, lubrication system, and air intake and exhaust system.

Chapter 10. STEAM AND POWER CONVERSION SYSTEM - provides information on the steam system and turbine generator units, as defined by the secondary coolant system in a PWR or by the system beyond the reactor steam isolation valves in a BWR. Information should be broadly descriptive, with emphasis on those aspects of design or operation which might affect the reactor and its safety features or contribute toward the control of radioactivity.

This portion of the review examines the capability of the secondary (steam and power conversion) system to function without compromising directly or indirectly the safety of the plant under both operating conditions or transient situations. (Radiological aspects are summarized here and treated in more detail in chapters 11 and 12, below.) The major systems considered are:

- Turbine-generator - examined primarily with a view to limiting the possibility of overspeed and possible generation of turbine missiles; for this same reason, materials and fabrication for turbine components are examined.

- Main steam supply system - the system for transporting steam from the generation system to the power conversion system and to various auxiliaries is examined for safety significance and adequate design, including proper materials and fabrication.

- Other features of the steam and power conversion system - the following additional features are examined: main condensers (including evacuation system), turbine gland sealing system, turbine bypass system, circulating water system, condensate cleanup system, condensate and feedwater system, steam generator blowdown system, auxiliary feedwater system.

Chapter 11. RADIOACTIVE WASTE MANAGEMENT - describes 1) the capabilities of the plant to control, collect, handle, process, store, and dispose of liquid, gaseous, and solid wastes that may contain radioacitve materials, and 2) the instrumentation used to monitor the release of radioactive wastes; information covers normal operation, including anticipated operational occurrences. Radwaste systems should be capable of complying with 10 CFR 20 and 50, Appendix I.

The radioactive waste management system is analyzed for conformance with rather detailed expectations of operational requirements and performance. This analysis includes establishing the sources of radioactivity, examining the capabilities of the various radwaste systems, and reviewing the monitoring systems:

- Source terms - establishes the sources of radioactivity that will serve as design bases for the radwaste systems. Includes consideration of leakage of radioactivity from the fuel into the coolant,then elsewhere.

- Liquid waste management systems - examines the design bases for systems for controlling the release of radioactivity in liquid effluents, gives attention to the detailed systems design, to leakage, to methods for volume reduction, and - ultimately - to capability for complying with 10 CFR 50, Appendix I. (A typical radwaste system diagram is given in Figure 3-3 of Ref. 13.)

- Gaseous waste management systems - examines gaseous effluent control systems in a manner similar to that for liquid. The radioactive species of particular interest are nobles gases, iodine, and particulates. (A typical gaseous radwaste system diagram is given in figure 3-2 and Ref. 13.)

- Solid waste management systems - examines methods for handling various solid wastes, such as sludges, resins, evaporator bottoms, and dry materials, such as contaminated tools, equipment and clothing. Attention is given to solidification processes, where appropriate, to container design, and to design of the in-plant waste handling systems.

- Process and effluent radiological monitoring and sampling systems - examines the systems that monitor and sample the process and effluent streams in order to control releases of radioactive materials. The location, type, redundancy, range, alarm capability, and calibration of continuous monitors is reviewed; for routine sampling, the location, type of sample, frequency and analytical procedure are reviewed.

The performance of these systems is closely connected with the NOI review and AFC Stage 2.

Chapter 12. RADIATION PROTECTION - provides information on methods for radiation protection and on estimated occupational exposure of operating and construction personnel during normal operation and anticipated operational occurrences; should describe facility and equipment design, the planning and procedures programs, and the techniques and practices employed to meet 10 CFR 20.

This section reviews the provisions for radiation protection, primarily for workers at the site. The review proceeds in the following stages:

- Assuring the occupational radiation exposures are as low as is reasonably achievable - devoted primarily to examination of the procedural aspects of assuring that this criterion is met. Reviews the management, organizational, and training structures; examines design considerations, including dose assessment, comparison with past designs; reviews operational plans, specifically procedures for assuring adequately low exposures.

- Radiation sources - establishes the sources of radiation which must be considered in the occupational radiation protection program, including: contained sources, for which shielding may be required; and airborne radioactive material sources, for which ventilation and other measures must be considered.

- Radiation protection design features - examines the design measures taken to limit exposures, including general facility design features and layout, shielding ventilation, and area radiation and airborne radioactivity monitoring instrumentation.

- Dose assessment - in order to assess the expected occupational exposures, examines: the expected occupancy of plant radiation areas, the design dose rates for both onsite and offsite areas, the estimated annual man-rem dose associated with various operations, the estimated annual dose at the plant boundary, and measures taken to limit what appear to be excessive doses associated with particular operations.

- Health physics program - examines suitability of the health physics program for monitoring and controlling occupational exposures. Subjects reviewed include: organization, including health physics personnel qualifications; equipment, instrumentation, and facilities; and procedures for monitoring and controlling exposures.

Chapter 13. CONDUCT OF OPERATIONS - provides information relating to the preparations and plans for operation of the plant; the purpose is to provide assurance that the applicant will establish and maintain a staff of adequate size and technical competence and that operating plans to be followed by the licensee are adequate to protect the public health and safety.

In order to assure that the plant will be operated in a manner consistent with the public health and safety, the following areas related to planning are examined:

- Organizational structure of applicant - the management and technical support organization of the applicant itself is reviewed.

- Operating organization - the staff proposed for actual operation of the plant is reviewed, including qualification for various positions and training anticipated.

- Emergency planning - examines provisions for mitigating the effects of onsite and offsite emergencies. See Ref. 22 for detailed description. This planning is of particular interest to the ERCDC.

- Review and audit - reviews the applicant's plans for conducting review and audit of matters important to safety.

- Plant procedures - reviews procedures to be used by the operating organization to assure the safe operation of the plant.

- Industrial security - examines the industrial security plan for the plant, including personnel screening and the layout and design of security design features. Also examines communications, both in plant and with law enforcement agencies.

Chapter 14. INITIAL TEST PROGRAM - provides information on the initial test program for structures, systems, components, and design features for both the nuclear portion of the plant and the balance of the plant. The information provided should address major phases of the test program, including preoperational tests, initial fuel loading and initial criticality, low-power tests, and power-ascension tests.

The plans for initial testing of the power plant systems are examined:

- Information to be reviewed in the Preliminary Safety Analysis Report: scope of test program; plant design features that are special, unique, or first-of-a-kind; applicable regulatory guides and industry standards; utilization of plant operating and testing experience at other reactor facilities; test program schedule; trial use of plant operating and emergency procedures; augmenting of the applicant's staff during the test program.

- Information to be reviewed in the Final Safety Analysis Report: test program and objectives; organization and staffing; test procedures; conduct of test program; review, evaluation, and approval of test results; test records; test programs' conformance with regulatory guides; utilization of reactor operating and testing experience in the development of the test program; trial use of plant operating and emergency procedures; initial fuel loading and initial criticality; test program schedule; individual test descriptions.

Chapter 15. ACCIDENT ANALYSES - includes analyses of the response of the plant to postulated disturbances in process variables and to postulated malfunctions or failures of equipment. Previous SAR chapters evaluated structures, systems, and components important to safety for their susceptibility to malfunction or failure. In this chapter, the effects of anticipated process disturbances and postulated component failures should be examined to determine their consequences and to evaluate the capability built into the plant to control or accommodate such failures and situations; analysis should include anticipated operational occurrences, off-design transients that induce fuel failures above those expected from normal operational occurrences, and postulated accidents of low probability.

This section reviews the applicant's analysis of a large spectrum of transients and accidents. For each such event, the cause and frequency of occurrence is evaluated, the sequence of events and systems operations are given in detail; where appropriate, the core and system performance is evaluated, often with mathematical models, the effectiveness of barriers to release of radioactivity is evaluated, and the radiological consequences both on and offsite are calculated, using appropriate models, consistent with the requirements of 10 CFR 100 and of applicable Regulatory Guides. The classes of events which must be analyzed are simply listed below, along with the specific initiators which should be considered:

- Increase in heat removal by the secondary system (causing a decrease in moderator temperature, an increase in reactivity, and hence in power level, and reactor trip) - may be caused by: malfunctions which lead to decrease in feedwater temperature, increase in feedwater flow, or increase in steam flow; inadvertant opening of a steam generator relief or safety valve; system piping failures inside and outside of containment (PWR).

- Decrease in heat removal by the secondary system - may be caused by loss of external electric load, turbine trip, loss of condenser vacuum, closure of main steam isolation valve (BWR), steam pressure regulator failure, loss of non-emergency AC power to the station auxiliaries, loss of normal feedwater, and feedwater piping break.

- Decrease in reactor coolant system flowrate - may be caused by reactor coolant pump trips, flow controller malfunction (BWR), or coolant pump rotor seizure or shaft break.

- Reactivity and power distribution anomalies - may be caused by: uncontrolled control rod assembly withdrawal from a subcritical or low power startup condition; uncontrolled control rod assembly withdrawal at power; control rod maloperation (system malfunction or operator error); startup of an inactive coolant or recirculation loop at an incorrect temperature; flow controller malfunction causing an increase in BWR core flow rate; chemical and volume control system malfunction that results in a decrease in boron concentration in PWR coolant; inadver tant loading and operation of a fuel assembly in an improper position; control rod ejection or drop accidents.

- Increase in reactor coolant inventory - may be caused by inadvertant operation of ECCS, chemical and volume control function malfunction, and by other events above.

- Decrease in reactor coolant inventory - may be caused by: inadvertant opening of a safety or relief valve; failure of small lines carrying primary coolant outside containment; steam generator tube failure (PWR); main steam line failure outside containment (BWR); loss-of-coolant accidents resulting from pipe breaks in the reactor coolant pressure boundary (requiring analysis in accordance with rather detailed criteria).

- Radioactive release from a subsystem or component - may be caused by: waste gas system failure; liquid waste system leak or failure; liquid-containing tank failures; fuel handling accidents; dropping of spent fuel cask.

- Anticipated transients without scram - occur when an anticipated transient occurs, but is not followed by an automatic reactor shutdown, possibly resulting in unacceptable coolant system pressures and fuel damage. Events which may have such consequences, in the absence of scram, are: loss of feedwater, loss of load, turbine trip, inadvertant control rod withdrawal, loss of AC power, loss of condenser vacuum, and (BWR) closure of main steam line isolation valves.

Chapter 16. TECHNICAL SPECIFICATIONS - the applicant proposes Technical Specifications that set forth the limits, operating conditions, and other requirements imposed on the facility operation for, among other purposes, the protection of the health and safety of the public.

The proposed technical specifications are reviewed for conformance with generic standard technical specifications. Where there are differences, they must be justified on the basis of uniqueness in plant design or other considerations.

CHAPTER 17. QUALITY ASSURANCE - provides a description of the applicant's quality assurance program to be established during design, construction, preoperational testing, and operation.

The quality assurance program of the applicant and its contractors is reviewed for adequacy in assuring conformance of the power plant with applicable regulatory requirements and with the design bases specified in the license application. The following areas are reviewed for the quality assurance programs to be implemented both during the design and construction stage and during actual plant operation:

- Organization - relationship between various parties (applicant, vendor, etc.).
- Quality assurance program - reviews coverage, overall procedures, applicable Regulatory Guides, etc.
- Design control - assurance of design as indicated in the licensing application.
- Procurement document control - assuring applicable requirements are in procurement documents.
- Instructions, procedures, and drawings - assures quality-related activities will be carried out in accordance with instructions.
- Document control - assures control and distribution of documents.
- Control of purchased material, equipment and services - assures that suppliers comply with requirements.
- Identification and control of materials, parts, and components.
- Control of special processes.
- Inspection - includes inspection organization and program.
- Test control - the test program of Chapter 14.

- Control of measuring and test equipment - assures reliability of test equipment.
- Handling, storage, and shipping.
- Inspection, test, and operating status - assurance that required testing is performed.
- Nonconforming materials, parts, or components - handling to prevent their inadvertant use.
- Corrective action - determination of need for corrective actions; measures for carrying them out.
- Quality assurance records - record maintenance program.
- Audits - the system for verifying compliance with the quality assurance program.

This summary of the Nuclear Regulatory Commission safety review has only pointed out the major subject areas for review. Much more detail is contained in the Standard Review Plan. Moreover, the criteria used during various phases of the review have been collected into a separate informal report.[29]

It is not to be expected that the ERCDC can participate actively in all phases of this review. Certain site-related areas that would be particularly appropriate for ERCDC action have been indicated above. In the other areas, a minor liaison effort with the NRC staff would not be difficult to initiate.

STAGE 4. GENERAL FACILITY DESIGN

This stage of review can be utilized to examine more general aspects of facility design than are treated in Stages 2 and 3. The purposes of such review are discussed in Section 4.1; general approaches to such review are treated in Section 4.2 (and it is pointed out that these approaches may also be employed, in part, for review of matters included at Stages 2 and 3); general safety aspects of a facility are indicated in Section 4.3.

SECTION 4.1 PURPOSES OF REVIEWING THE GENERAL FACILITY DESIGN

The purpose of this stage is to treat the hypothetical situation in which one or more safety-related design areas were not included in the review of Stages 2 and 3. Section 4.2 outlines general approaches to review of such areas, explicitly considering courses of action which may be adopted. Approaches to review are considered for cases where regulatory standards are specified but are not included in AFC Stages 2 and 3, or for areas where there are no regulatory requirements. Substantial effort may have to be devoted to review if the ERCDC staff attempts to perform any detailed analysis of proposed design.

Stages 2 and 3 are intended to treat design areas with specific health and safety significance: monitoring systems and safety system design. If other areas are to be considered during the AFC review, review criteria would have to be specified. Since these may be areas for which health and safety significance has not been clearly recognized, existing practice or standards may not have been formulated as regulations. Nevertheless, there may be reason for review of such areas. Such bases for review may include:

- the broad safety implications of general plant systems, an area which may also be included in Stage 3

- the efficiency and reliability of the plant
- plant costs.

The last two of this list are not directly pertinent to a health and safety review, but might prompt review of areas which could be included for convenience in the same review structure. Generally, regulatory requirements for these areas will not exist. As noted, the first item of the three can be regarded to be included in Stage 3. However, for practical purposes we will consider it to indicate safety-rèlated areas for which standards have not been specified by a regulatory authority. For this reason, the design areas identified on these bases will have the common feature that, prior to ERCDC involvement, a method for proceeding in the absence of regulatory standards will have to be adopted.

Many of the considerations underlying choice of a course of action are suggested in this report and treat explicitly in the Overview Report. The final choice must be made considering the benefits to be gained by involvement of the ERCDC in these design matters and the costs of this involvement to both the ERCDC and the applicants.

SECTION 4.2 GENERAL APPROACHES TO AN ENGINEERING DESIGN REVIEW

The effort needed to establish an engineering design review depends on the design area of interest. Areas of special interest have been discussed in earlier sections of this report, particularly in AFC Stages 2 and 3. In addition, the possibility of broader, safety-related areas has been indicated in Section 4.1. However, two generic situations may be identified: that where regulatory standards or criteria have been specified by other agencies; and that where previous specification has not taken place or where it is judged inadequate. In the latter type of area, a basis for review must be established, after which the review process may be similar to that for cases where applicable standards have already been determined. Possible courses of action for unregulated areas are the subject of Section 4.2.1. Possible review procedures for areas where regulations apply, such as the design areas of Stages 2 and 3, are outlined in Section 4.2.2.

4.2.1 Review of unregulated areas

For areas where standards have not been specified, but for which the ERCDC considers them necessary, the ERCDC may either encourage other agencies to formulate such standards, which may then be used in the context discussed in Section 4.2.2, or it may undertake one of the following approaches:

1. For certain areas, the review may only be cursory.

It is to be expected that the ERCDC would, in any case, broadly examine the features of the proposed facility, if only to familiarize itself with the overall design. However, such oversight may also be applied simply to verify that the design includes features which have been determined to be necessary for protection of the public or for occupational health and safety. Such overview would also serve to prevent obvious, but unaccountably unnoticed, flaws in the design. Depending on the particular area, the ERCDC may limit its review to such oversight, or this may only be a prelude to the determination of standards considered in the following approaches.

An alternative and more comprehensive approach to this oversight may include submission by the applicant of its plan for inspection and testing in areas that are determined to be critical. The utility or its agents would normally have such a program in any case, and it should be relatively straightforward to involve the ERCDC staff in an oversight capacity without the formal submission of a set of standards and a corresponding quality assurance program (such a QA program is possibility 2, discussed below).

It appears that this oversight approach is the one which is most likely to be adopted for those areas lacking regulatory requirements, since for these areas - even if determined to have safety implications - such a low-level effort, without the large administrative overhead of a formal quality assurance program, would probably be a more effective utilization of effort. Furthermore, it would avoid the rather odd state of affairs, implicit in possibility 2, in which a utility specifies its own standards.

Implementation of this oversight role, as regards both general design review and involvement in the applicant's inspection program, would require 1) ERCDC staff familiar with the design areas of interest, and 2) coordination with the applicant's inspection plans and efforts. This matter is discussed in Section 4.2.2.

2. For areas where the ERCDC considers greater regulatory involvement appropriate, the applicant may be required to submit formally the standards which were used in preparation of the submitted design.

Depending on the area, the ERCDC may then adopt one of the three approaches discussed in Section 4.2.2 for areas where standards have been specified; i.e., a simple monitoring or inspection program may be established (as above), a formal quality assurance program may be required and monitored, or the ERCDC may undertake a design review based on these standards.

These possibilities are discussed in more detail in Section 4.2.2 At this point, though, it is worth mentioning the difficulty, as a matter of practice, of basing any formal review procedure on a set of standards submitted by the applicant. An informal program, with its relatively small commitment of time and effort on the part of the ERCDC and the applicant, could easily be implemented. A formal program, as set forth in possibilities 2 and 3 of Section 4.2.2, discourage submission of comprehensive standards. Furthermore, a decision to proceed in these more comprehensive and costly manners would have to be preceded by examination of the attendant benefits of the program.

3. As a last alternative, the ERCDC may undertake to select or develop the necessary standards. The distinction between selection and development is important because, for many areas, applicable industry standards have been developed, but have not been adopted for use in a regulatory framework. Often these standards are developed for voluntary use; many such standards have been collected in a separate informal report[30] - see Section 4.3. (On the other hand, these voluntary standards are often incorporated into regulatory codes. The OSHA pressure vessel standards are one important example.)

One course of action for the ERCDC would be to specify how certain of these industry standards are to be used for power plant design. However, such specification ought only to be done on the basis of expert knowledge of each design area of interest. It does not appear likely that the ERCDC will assemble a large enough staff to conduct the substantial work necessary for selection of standards. Should the ERCDC choose to make such selections, the advise of a standing advisory committee should be taken; in any case, such selection should not take place hurriedly. Standards, and particularly regulatory standards, must be developed with great care. (In fact, should the ERCDC constitute an advisory panel, it would not be surprising if their most urgent advice were to be that the ERCDC decline to select standards.)

A second course of action, even more ambitious than the above, would be for the ERCDC to actually develop design standards. This appears highly unlikely for plant engineering design. The ERCDC <u>has</u> undertaken to develop certain standards. However, these have been performance standards (such as for appliances) and more easily specified design standards (such as for insulation or windows). As we have noted in the discussion of emission control equipment (Stage 2), performance standards are more easily specified than design standards; even these, however, should be very carefully chosen, probably with the advice of specialists.

Standards for the design of structures and equipment are appropriately developed by specialized professional societies. For areas of particular interest to the ERCDC, the Commission could encourage such societal development, establishing a staff liaison with societal standards committees. Should the ERCDC independently attempt to develop design standards internally or through contractors, a much larger effort would be involved, and their acceptability to the engineering community would not be automatic. Except for rare instances, it would be surprising for the ERCDC to adopt such a course.

For areas where standards are selected, by whatever means, a design review may proceed as in Section 4.2.2.

Section 4.2.2 Design review for regulated areas

For areas where determination of standards has already been made, either by the ERCDC or by other agencies, the ERCDC may use these standards in several possible ways, which are listed in the order of their commitment of ERCDC staff effort:

1. The staff may simply determine that the applicant has agreed to comply with the required standards on the basis of a checklist.

The ERCDC may also, sometimes in conjunction with other agencies, institute a program of inspection and monitoring to verify that the facility, as actually built and operated, complies with these standards. As an example, for applicable OSHA standards the applicant would normally specify compliance, in any case, and the ERCDC may participate or initiate corresponding inspection of facilities for compliance.

This approach may be extended to the oversight role discussed as the first approach under Section 4.2.1. That is, the ERCDC staff may conduct a broad, but cursory, review of plant function and design, largely to verify that the design includes features determined to be necessary for the protection of workers and the public. This role may include involvement of the ERCDC staff in oversight of the applicant's program of inspection and testing (without the formal quality assurance program discussed below). These inspection and test programs are often specified in the standards, in any case.

Even for areas with regulatory standards, this less formal approach to design and construction verification may be advantageous, because it may afford substantial benefits without going to the extent of requiring the rigor of a quality assurance program.

2. For certain areas, in addition to agreeing to comply with applicable standards, the applicant may be required to submit a corresponding quality assurance program, specifying a management structure and inspection procedure.

In this case, ERCDC would presumably monitor the results of the QA program. It should be noted that, to some extent, the applicant will have, for its own purposes, instituted inspection programs in important areas. Whether formal QA programs should be implemented for these or other areas must be determined from a comparison of the additional costs and the increased benefits.

For nuclear power plants, of course, extensive quality assurance programs are required and are monitored by the Nuclear Regulatory Commission. In fact, the very criteria used by the NRC in its safety review often specify associated components of a quality assurance program. The aspects of a QA program that the NRC reviews are listed in Section 3.2.2 (part 17). For these plants, therefore, QA programs already exist, and the ERCDC could - if it chooses - monitor that program.

For other types of plants, such programs do not typically exist, at least not as a requirement of regulatory agencies. As noted previously, programs of inspection and testing do exist and, in some cases, these may take on the character of a quality assurance program; informally monitoring already existing programs should not be difficult, as indicated in approach 1 of this and the previous section.

Should the ERCDC require a formal QA program, which it would monitor, more extensive preliminary efforts would be required. The character of such a program should be determined after careful consideration of the specific design area, probably with the advice of expert groups. It is likely that - to some extent - programs could use the nuclear case as a model. Moreover, the inspection requirements specified as part of many standards will be helpful.

In any case, formal QA programs require substantial effort on the part of both the applicant and the monitoring agency. These efforts are clearly worthwhile in cases, such as nuclear, where a failure can lead to large consequences. For cases of less consequence, simpler inspection programs may be more appropriate.

3. On the basis of the standards for specific areas, the ERCDC staff may actually review these areas of design.

This would require a correspondingly large staff commitment and, again, the costs and benefits have to be compared. This approach would, of course, include the first approach noted above, but it may or may not include a quality assurance program (i.e., the second approach just cited).

Design review can only proceed with staff of a size and competence capable of performing the review. The size of this commitment can only be determined case by case. Should the ERCDC choose this approach for any areas of design, it should be done with the advice of those with experience specific to those areas.

If standards are available, they may be employed in any of the three review procedures considered above. The choice of review procedure and of a method for determining standards will depend on the particular area being considered. The approach chosen may clearly vary from one area to another. In each case, the decision will be based on the needs of the particular area and on consideration of the comparative costs and benefits of alternative approaches.

It is beyond the scope of this work to determine the adequacy of existing standards. In the next section, we briefly consider the extent to which standards exist for a number of important areas.

SECTION 4.3 SAFETY-RELATED DESIGN AREAS

The purpose of this section is to indicate briefly the extent to which bases exist for the review of a number of areas important to safety. We identify nine broad areas, applicable to nuclear, geothermal, or fossil-fuel power plants, for which review might be considered appropriate. Many of these areas have been treated in the discussion of Stage 2 and 3; it is nevertheless useful to include them here, if only to indicate the extent to which safety is assured by the reviews suggested for those stages. Four of the areas are primary aspects of facility design:

1. Operational safety systems
2. Seismic design

3. Pressure vessels and piping

4. Explosion and fire

Two others support these and, indeed, all aspects of design and operation:

5. Quality assurance and monitoring

6. Safety equipment and training

Three areas tend to be closely related to emissions and site characteristics, although they are also aspects of plant design and operation:

7. Site geophysical characteristics (seismology, soil stability, hydrology and meteorology.

8. Fuel handling and waste disposal, including transportation

9. Emission control equipment.

Many of these areas have been considered explicitly either in the NOI or in AFC Stages 2 and 3. Furthermore, an attempt has been made to collect standards generally applicable to design of power plants; this collection[30] has been communicated separately to the ERCDC staff. (A subject outline is given in Table 4-1.) For each of the nine areas given above, we indicate the extent to which current regulatory review and standards apply:

1. Operational safety systems: these are of primary importance for nuclear power plants and may be considered to include the systems for normal operation, including basic control and instrumentation systems, as well as "engineered safety features," such as the emergency cooling systems and the containment, with its various subsystems. For all these, the NRC has recommended engineering standards and, in many cases, developed Regulatory Guides. Many of the standards applicable to the systems for normal operation may also be applied to fossil-fuel and geothermal plants. However, for such plants, the systems do not assume a safety significance comparable to the case of nuclear.

Table 4-1. Generally Applicable Engineering Standards

1. GENERAL
2. STRUCTURAL
    - 2.1 - General
    - 2.2 - Concrete
    - 2.3 - Steel
    - 2.4 - Welding
    - 2.5 - Painting
    - 2.6 - Screws, Bolts, Nuts
    - 2.7 - Testing
    - 2.8 - Safety
    - 2.9 - Others
3. BOILERS AND PRESSURE VESSELS
4. GENERATORS, MOTORS, TURBINES, ETC.
5. PIPING SYSTEMS, AND RELATED ITEMS
    - 5.1 - General
    - 5.2 - Pipes and Fittings
    - 5.3 - Valves and Flanges
    - 5.4 - Welding and Supports
6. ELECTRICAL SYSTEMS
    - 6.1 - General
    - 6.2 - Storage Batteries and Auxiliary Power Systems
    - 6.3 - Cables, Wires, and Insulators
    - 6.4 - Conduits, Ducts, and Trays
    - 6.5 - Circuit Breakers, Switch Gears, Fuses, and Relays
    - 6.6 - Transformers and Capacitors
    - 6.7 - Transmission Lines, Substations, and Busways
    - 6.8 - Control Apparatus
    - 6.9 - Motors and Other Equipment
    - 6.10 - Safety and Protective Devices
    - 6.11 - Test
    - 6.12 - Measurement
7. COOLING TOWERS, EQUIPMENT
8. MISCELLANEOUS EQUIPMENT
    - 8.1 - Pumps and Water Treatment Equipment
    - 8.2 - Air Handling Systems
    - 8.3 - Lighting
    - 8.4 - Hoists and Cranes
    - 8.5 - Industrial Trucks
9. FUELS, STORAGE, ETC.
10. FIRE
    - 10.1 - General
    - 10.2 - Extinguishing Devices
    - 10.3 - Flammable Materials
    - 10.4 - Fire Prevention and Detection
    - 10.5 - Doors, Windows, Walls, and Roofs
11. WASTES
12. SAFETY (OCCUPATIONAL)

The standards applicable to pressure vessels and piping and to explosion and fire are considered below.

2. Seismic design: for nuclear power plants, where seismic events have the potential for inducing large radioactive releases, the need for plant designs that prevent such occurrences has led to the formulation of Regulatory Guides for categorizing plant equipment, for specifying the seismic response spectra to be considered, and for selecting damping values for seismic design. Making a comparable effort for fossil-fuel and geothermal plants might be excessive, considering the lesser potential for harm to the public. The independent question of determining the potential for seismic events at a specific site is considered under site characteristics.

3. Pressure vessels and pipings: for all types of plants, standards have been formulated for these components. Of particular importance are the (ASME) Boiler and Pressure Vessel Code (BPVC) and related standards, which have especially stringent specifications for fabrication and inservice inspection of vessels for nuclear service, since these vessels operate under unusual pressure and radiation conditions. The BPVC is effectively a regulatory standard, due to its incorporation into both NRC and OSHA regulations. Similarly, such standards exist for use with piping components.

4. Explosion and fire: specific NRC Regulatory Guides apply to design areas with a potential for explosion and fire; attention to these matters is intense, primarily because of possible effects on reactor operation and ultimate integrity, rather than because of direct effects of explosion or fire. OSHA requirements, applicable to any industrial facility, are directed toward the latter effects.

5. Quality assurance and monitoring: nuclear plants have stringent quality assurance programs applied to them. The NRC Regulatory Guide on QA is based on industry standards (ANSI N45.2-1971) for nuclear plants. In addition, Regulatory Guides 1.70 and supporting documentation provide more specific guidance. These same techniques may be applied to other types of facilities, but - as for any generally applicable engineering standard - would not specify what areas quality assurance would be applied to or who shall create the require management and inspection structure. As to less rigorous monitoring and inspections, in most design areas for which standards exist, the standards specify monitoring and inspection needs.

6. Safety equipment and training: the NRC has primary responsibility for specifying requirements for radiological safety and related equipment. Regulatory Guides (Division 8) are a guide to implementing 10 CFR 20. OSHA performs the corresponding task for conventional hazards. The NRC Regulatory Guides (Division 1) also specify qualifications for reactor operators.

7. Site geophysical characteristics: for nuclear power plants, the information required for analyzing site suitability are specified in a number of Regulatory Guides (especially 1.70 and 4.7 for general seismic and stability requirements, 1.23 for meteorology, 1.59 for hydrology, and 1.76 for tornado). These site characteristics must be considered in connection with the actual design of the plant, such as the seismic response. Typically, such a detailed analytical program has not been formulated for fossil-fuel and geothermal plants and it can therefore be said that comparable standards do not exist. In principle, though, the NRC approach may be adapted to other types of plants to the extent considered necessary.

8. Fuel handling and waste disposal; transportation: for nuclear plants, fuel handling is carried out in a manner consistent with the safety of workers, and fuel storage requirements are specified in Regulatory Guides. Radioactive waste disposal does not occur on the site, and off-site disposal is a matter of controversy. A specific set of Regulatory Guides (Division 7) is devoted to transportation. For fossil-fuel and geothermal plants, no standards are explicitly formulated for these areas, even though they would be useful, primarily because of the large bulk of material handled and stored or disposed, and the associated potential for leaching harmful chemicals into water resources.

9. Emission control equipment: in order to meet the specifications in 10 CFR 20 and 50, the NRC gives rather detailed guidance on the design, fabrication, testing, inspection, and operation of radioactive emission control systems. Such detailed guidance is not typically available for the comparable control equipment at fossil-fuel and geothermal facilities, although it is to be expected that such guidance will develop as the control equipment sees expanded use. It should be noted that the NRC guidance extends both to operational parameters for the control equipment and to design bases, materials, and other standards for the equipment.

The choice of standards and of review procedures are extremely important. A final determination in these matters must depend on their consideration by the ERCDC in conjunction with a broader community, including both the public and the utilities. Ultimately, the choices will have to balance the cost of implementation to the utilities and to the ERCDC, the increased protection afforded members of the society, and the benefits accruing to the public from the individual technologies.

It is useful to point out, too, that this final determination need not occur at once. The alternatives listed above for selection of standards or for review procedures represent, in each case, a logical progression which may occur in various areas as the review process is more fully developed. At any given moment, the best available course should be taken with due consideration to the needs of the public. The fact that a complete review methodology is not available (and never will be) should not, of itself, bring a halt to the review and construction of power plants.

As is usual in such matters, a conservative approach should be taken. The ERCDC should only undertake a review of those areas for which a need is demonstrated. General aspects of plant design should not be reviewed only for the sake of completeness.

STAGE 5. OVERALL ASSESSMENT OF SITE AND FACILITY ACCEPTABILITY

Stages 1 to 4 actually perform the detailed AFC health and safety review. Stage 5 would assemble the results of that review into a form suitable for final consideration of the acceptability of the proposed site and facility. For areas where specific criteria apply, this section would identify those specific respects in which the proposal fails to meet these specifications. For areas where a more general assessment of impacts was performed, the results of the analysis would be summarized. This information would then be available for the final AFC determination of acceptability, which would include consideration of other factors than the health and safety implications of the proposed site and facility.

REFERENCES

1. G. Palo, R. Peter, D. Woo, S. Leung, and F. Hahn, "Compilation of Air Pollution Control Regulations and Standards", ERCDC Staff Draft, Updated Version (updated by T. Choy, M. S. Quinby-Hunt), Energy Resources Conservation and Development Commission, Facility Siting Division, June 8, 1976, update, Jan. 1, 1977.

2. Nuclear Regulatory Commission, Regulatory Guide 1.109 "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50, Appendix I" (3/76).

3. Bonneville Power Adminstration, "Electrical Effects of Transmission Lines", Sept. 15, 1975.

4. G. D. Case, T. A. Bertolli, J. C. Bodington, T. A. Choy, and A. V. Nero, "Health Effects and Related Standards for Fossil-Fuel and Geothermal Power Plants", Lawrence Berkeley Laboratory Report, LBL-5287, 1977.

5. California State Water Resources Control Board, "Water Quality Control Plan: Ocean Waters of California," Adopted and Effective, July 6, 1972.

6. California State Water Resources Control Board, "Water Quality Control Policy for the Use of Inland Waters Used for Powerplant Cooling", June, 1975.

7. California State Water Resources Control Board, "Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California", June 5, 1972.

8. E. Piekarz, S. Leung, and F. Hahn, "Compilation of Water Quality Standards Applicable in California", Energy Resources Conservation and Development Commission, Facility Siting Division, Staff Draft.

9. U. S. Environmental Protection Agency, "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Steam Electric Power Generating Point Source Category", EPA 440/1-74 029-a, Group I, October, 1974.

10. A. J. Haagen-Smith and L. G. Wayne, "Atmospheric Reactions and Scavenging Processes", Air Pollution, Vol. I, Air Pollutants, Their Transformation and Transport, ed. A. C. Stern, 3rd ed., Academic, New York, San Francisco, London, 1976, pp. 274-279.

11. S. P. Sander and J. H. Seinfeld, "Chemical Kinetics of Homogeneous Oxidation of Sulfur Dioxide", Environ. Sci. Tech., 10, 1114 (1976).

12. L. C. Rosen, "A Review of Air Quality Modelling Techniques", Lawrence Berkeley Laboratory Report, LBL-5988, 1977.

13. A. V. Nero and Y. C. Wong, "Radiological Health and Related Standards for Nuclear Power Plants", Lawrence Berkeley Laboratory Report, LBL-5285, 1977.

14. D. C. Brady and J. C. Geyer, "Development of a General Computer Model for Simulating Thermal Discharges in Three Dimensions", EEI Publication No. 72-902, 1972.

15. W. L. Graves and J. C. Geyer, "Cooling Pond Temperature Models", EEI Publication, No. 73-900, 1973.

16. Nuclear Regulatory Commission, Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I", May, 1976.

17. O. Weres, L. Vallentine, K. Tsao, and B. Wood, "Hydrogen Sulfide Toxicology, Chapter IX, Environmental Aspects of the Geysers Geothermal Development", Lawrence Berkeley Laboratory Report LBL-5231, Draft.

18. U. S. Environmental Portection Agency, "Public Health and Welfare Criteria for Noise", EPA Document No. 550/9-73-002, July 27. 1973, Refs. 114-117.

19. R. R. Illingworth, "Factors Contributing to the Annoyance by Geothermal Steam Well Venting at the Geysers".

20. A. V. Nero and M.R.K. Farnaam, "A Review of Light-Water Reactor Safety Studies", Lawrence Berkeley Laboratory Report LBL-5286, 1977.

21. A. V. Nero, C. Schroeder, and W. W. S. Yen, "Control of Population Densities Surrounding Nuclear Power Plants", Lawrence Berkeley Laboratory Report LBL-5921, 1977.

22. W. W. S. Yen, "Radiological Emergency Response Planning for Nuclear Power Plants in California", Lawrence Berkeley Laboratory Report LBL-5920, 1977.

23. Environmental Instrumentation Group, Survey of Instrumentation for Environmental Monitoring, Vols. 1, Air; 2, Water; 3, Radiation; Lawrence Berkeley Laboratory Report, LBL-1, June 1976.

24. "Inspection Manual for the Enforcement of New Source Performance Standards: Fossil-Fuel-Fired Steam Generators," U.S. Environmental Protection Agency, Office of Enforcement, 1975.

25. American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 14th Ed. New York, N.Y., 1976.

26. American Society for Testing and Materials, "ASTM Standards, Part 23, Water; Atmospheric Analysis," 1972, Philadelphia.

27. U. S. Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes, Water Quality Office, Analytical Control Laboratory, NERC, Cincinatti, Ohio, 1974.

28. An early reference is: T. Trippe, V. White, F. Henderson, and S. Phillips, "GEODOC-The GRID Document File, Record Structure and Data Element Description," Lawrence Berkeley Laboratory Report LBL-4432, 1975.

29. "Criteria, Regulatory Guides, and Standards Applicable to the Safety Engineering of Light-Water Reactor Power Plants," LBL informal report supplied to the ERCDC staff, January 1977.

30. "Generally Applicable Engineering Standards," LBL informal report supplied to the ERCDC staff, January 1977.