DRAFT No. 1

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GENERAL OUTLINE

I SUMMARY AND CONCLUSIONS

This section should provide the reader with a brief summary of the report and the designer's conclusion on the safety of the facility. Major items from Sections I, II, III, etc. below should be included. A summary table of the reactor facility including such as the operating parameters, design data for the reactor and containment building, site data and the accidents considered would be helpful in comprehending the overall system and evaluation. The conclusions on the safety of the facility could also be included in this section.

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II DESCRIPTION OF THE SITE

The material in this section should permit a determination of the adequacy of the proposed site for the reactor facility. The items which permit this determination are: the geographical location, the surrounding population, the use of the surrounding area and the meteorological, topographical, hydrological, geological, and seismological characteristics of the site. The geographical location could be supplemented by two or three maps, each one showing more of the surrounding area. The location, magnitude, and any expected change of the surrounding population could also be shown on a map of the area. The use of the surrounding area such as farming, swimming, flying, etc. could best be described in the text. The meteorological characteristics are used to determine the parameters to be used in the diffusion equation which describes the propagation of any airborne radioactivity which is released from the facility. Also any topographical characteristics of the site which would affect the propagation of airborne radioactivity should be included. The geological information should permit a determination of the compatibility of the facility with the proposed site. The seismology data should give an indication of the degree of protection needed against earthquakes . Any other characteristics of the site which could influence the probability of release of radioactivity or which could influence its propagation once released should also be included in this section.

III DESCRIPTION OF THE FACILITY

The information to be included in this section should give the reader a clear picture of the proposed facility both from the standpoint of what it looks like and from the standpoint of what it can do. A possible breakdown of this section is: reactor core, reactor control, instrumentation, primary and secondary circulating systems, experimental facilities, shielding, auxiliary equipment, and buildings. The reactor core should be described from the standpoint of its nuclear, mechanical, physical, thermal, and hydraulic behavior. The major emphasis should be placed on the dynamic behavior of the core since many accidents involve or lead to a transient of one kind or another. The reactor control could include a description of the control rods, control rod drives, auxiliary control systems, scram systems and interlocks. Description of the instrumentation and its interconnection with the overall control system should be included. The primary and secondary circulating systems should be described with respect to their location and their thermal and hydraulic conditions throughout the system. For some types of reactors the experimental facilities are the center of attention while for other types there are no experimental facilities. The amount and type of information desired on the experimental facilities is dependent on their type, location and number, but in general, a description of the experimental facilities and their expected interaction with the reactor core will suffice. The information on the shields should permit a determination of the adequacy of each shield for the particular application for which it is designed. Auxiliary pieces of equipment which might be described are: water supply system, primary loop clean-up systems, power

supplies, waste disposal systems, monitoring devices, remote reviewing systems, laboratories, fuel storage and handling systems, etc. The description of the building or containment vessel should permit a determination of its adequacy to protect the public from any release of radioactivity from the reactor. This could include a general description, design criteria used, and construction and testing procedures to be followed. Any other part of the facility which is not included above and which could influence the possible release of radioactivity from the facility should be included in this section.

IV ACCIDENT ANALYSIS

This section should give an analysis of the various types of accidents which could occur in the reactor facility. Just about every accident can be divided into two parts: initiating conditions and consequences. Initiating conditions might include the malfunctions of equipment, and/or operators, that are necessary for an accident to occur. The results should indicate the physical damage incurred together with the quantity and quality of radioactive material released to the containment vessel or building. The method and amount of any release of radioactive material outside the containment vessel or building should be included in Section V, Hazards Analysis. The analysis of each accident should give a clear picture of the assumptions and simplifications that were used in calculating the results. Also of interest are the conditions or circumstances which limit the magnitude of an accident. For some types of accidents this will be obvious while in others it will not. The types of accidents which might be considered for a heterogeneous reactor are: reactivity addition, loss of coolant flow, complete coolant loss, chemical reactions, etc. The maximum accident which is considered credible in this facility should be analyzed in much the same way the above accidents are analyzed but in more detail since it may determine the design basis for the containment vessel or exclusion radius. An analysis of the most adverse disturbances in reactivity, coolant flow, etc., which the reactor system could withstand without damage would be valuable in demonstrating the range of inherent safety of the reactor. In summary, the information presented in this section should permit a determination of the types of accidents which could occur, their magnitude, and their results.

V. HAZARDS ANALYSIS

The material which could be included in this section would permit an assessment of the biological damage both internal and external which might be incurred by the general public and operating personnel as a result of the release of either radioactive or toxic materials from the building or containment vessel in the event of an accident particularly the maximum credible accident. Information on the source, mode of transmission, and receptor should be included. The source of the radiation may be the direct gamma radiation from the contained fission products or it may be the airborne radioactive material which has been released from the building or containment vessel. Air, water and direct are the three most common modes of transmission. The location and dose, both internal and external, to the receptor should be given. The type of information desired for any toxic material which might be released is similar to that described above for the radioactive material.

VI. ORGANIZATION, RESPONSIBILITIES, ETC.

The material in this section should permit a determination of the adequacy of the organization to carry out the necessary functions of the reactor facility. In general, information on the structure of the organization, the procedures to be followed and the staff training will be required before this finding can be made. The procedures should include both the normal and emergency procedures.

VII APPENDICES

Any portion of the report that should be included but is too lengthy to put into the main body of the report could be put into the appendices. Calculations, special studies, etc. would fall into this category. The amount of information included in each appendix should be sufficient to permit an independent confirmation of the results.

VIII DRAWINGS, DIAGRAMS, ETC.

see page 37 for this section

I. Summary.

A. General. A brief summary description of the reactor facility should be presented.

B. Summary of Facility Characteristics. This should include the values of the principal design parameters, for example.

1. Site.

a. Location

b. Exclusion distance

c. Prevailing wind direction

d. Population direction

2. Operating Data.

a. Power (thermal, electrical, etc.).

b. Power density

c. Core inlet pressure

d. Core outlet pressure

e. Core inlet temperature

f. Core outlet temperature

g. Maximum fuel temperature

h. Core cycle time

3. Core. (This might best be presented in the form of a diagram as well as a table).

a. Approximate dimensions

b. Number and general configuration of fuel assemblies

c. Number and general configuration of control assemblies

d. Reflector composition and thickness

3. Core. (continued)

   e. Thermal shield composition, thickness, and number

   f. Metal to water ratio

   g. Heat capacity

4. Nuclear Data.

   a. Neutron flux

      (1) Thermal

      (2) Fast

      (3) Maximum to average ratios

   b. Critical mass

   c. Total mass in new core

   d. Neutron lifetime

   e. Temperature coefficient of reactivity

      (1) Prompt

      (2) Equilibrium

   f. Void coefficient

   g. Excess reactivity for:

      (1) Temperature

      (2) Burnup

      (3) Equilibrium xenon and samarium

      (4) Voids (if any)

      (5) Control

      (6) Low cross section fission product poisons

4. Nuclear Data. (continued)

(7) Experiments

(8) Xenon override

(9) Other

(10) Total

h. Maximum reactivity caused by adding a fuel element

i. Fraction of fissions caused by thermal neutrons

j. Neutrons born per neutron absorbed in fuel,

k. Thermal utilization, f

l. Resonance escape probability, p

m. Fast fission factor,

n. Thermal diffusion length, L

o. Fermi Age,

p. Buckling, B

5. Fuel Assemblies.

a. Composition of meat, cladding, and amount of fissionable material per element

b. Approximate dimensions of fuel assemblies

c. Number of plates, pins, etc.

d. Approximate dimensions of plates, pins, etc.

e. Approximate dimensions of coolant passages

6. Control Rods.

a. Composition

b. Approximate dimensions and shape

c. Reactivity worth - individually and collectively

6. Control Rods. (continued)

   d. Maximum possible reactivity insertion rates

      (1) Any single rod

      (2) Any possible combination of rods

      (3) Regulating rods

   e. Scram times

      (1) Dead time

      (2) Total drop time

7. Access Holes. — Size, Number, and Location of Holes in both Core and Reflector.

8. Pressure Vessel.

   a. Dimensions (approximate)

      (1) Height

      (2) Diameter

      (3) Thickness

   b. Design Specifications

      (1) Pressure

      (2) Temperature

   c. Material including cladding

   d. Relief Valves

      (1) Number

      (2) Pressure

         (a) Relief

         (b) Reset

8. Pressure Vessel. (continued)

   e. Weight

      (1) With coolant

      (2) Without coolant

   f. Thermal shields

      (1) Number

      (2) Composition

      (3) Thickness

9. Primary Coolant System.

   a. Coolant

   b. Number of loops

   c. Number of passes through core

   d. Total volume of primary system

   e. Heat transfer area of core

   f. Heat flux

      (1) Maximum

      (2) Average

   g. Coolant volume and mass flow rates

   h. Average velocity in coolant passages

   i. Pressure

      (1) Inlet

      (2) Outlet

   j. Temperature

      (1) Inlet

      (2) Outlet

   k. Maximum fuel surface temperature

9. Primary Coolant System. (continued)

l. Saturation temperature at point of max. surface temperature

m. % steam voids in heated channels

n. % steam voids in total coolant

o. Pumps

(1) Number

(2) Flow rates

(3) Temperature at suction

(4) Saturation temperature at suction

10. Secondary Coolant System.

a. Coolant

(1) Type

(2) Volume flow rate

(3) Mass flow rate

(4) Total volume

b. Heat Exchanger

(1) Type

(2) Pressure

(a) Inlet

(b) Outlet

(3) Temperature

(a) Inlet

(b) Outlet

(4) Heat transfer area

(5) Number of passes

10. Secondary Coolant System. (continued)

c. Pumps

(1) Number

(2) Capacity

(3) Temperature at suction

(4) Saturation temperature at suction

d. Turbine - generator

(1) Speed of rotation

(2) Electrical capacity

(3) Location with respect to reactor building

e. Condenser vacuum

f. Type of cooling tower

11. Containment.

a. Geometry

b. Material

c. Dimensions

d. Thickness

e. Design pressure

f. Total volume

g. Leakage rate at design pressure

h. Frequency and method of testing leak rate

i. Major penetrations

(1) Air locks

(a) Number

(b) Volume

11. Containment. (continued)

(2) Truck doors

(3) Ventilation

(4) Other

j. Missile protection

(1) Composition

(2) Location

12. Summary of Accidents Investigated, such as:

a. Startup

b. Cold water

c. Overloading

d. Others

G. Conclusions. The conclusions regarding the safety of the reactor facility should be presented. The conclusion which is normally reached by the proposer is that the facility is safe.

II. Description of Site.

A. Geographic Location.

1. Map of area showing principal roads, railroads, rivers, lakes, towns, etc., as well as the exact location of the reactor facility.

2. Map of reactor site showing site boundaries, nearest uncontrolled area, nearest residence, etc.

3. Distances to:

a. Nearest site boundaries

b. Nearest uncontrolled area

c. Nearest residence

d. Nearby population centers

B. Population Summary.

1. Population distribution (day and night, public and controlled) as a function of distance and direction from the reactor facility. Either a map or a table will suffice.

2. Anticipated changes in the population

C. Use of Surrounding Area. A brief discussion of such things as industrial or agricultural uses of nearby land, aircraft activity, and use of nearby bodies of water.

D. Meteorology. Enough meteorological data should be included so that one can assess the hazard to offsite personnel in the event of a release of radioactivity to the environs. In particular, one should cite any peculiarities in the local meteorology and determine the parameters necessary for defining average and adverse meteorological conditions. Specific types of information considered desirable are:

D. Meteorology. (continued)

1. Prevailing surface and aloft wind speeds, directions, frequencies, and seasonal variations.

2. Frequency and duration of temperature inversions.

3. Effect of precipitation and associated variations in the wind.

E. Topography. Topographical characteristics of the site which might influence the propagation of airborne activity should be given. This might include:

1. Effects of terrain on local meteorology.

2. Effects of vegetation.

F. Hydrology. This should include an evaluation of the possible extent of radioactive contamination of the soil and water supplies. The amount of information necessary will, of course, depend upon the quantity and quality of radioactive material involved. This information might include:

1. Direction, rate, and nature of underground movement of wastes and water.

2. Elevation of the water table.

3. Surface streams, location, direction and rate of flow, and impoundments.

4. Location of public water sources.

G. Geology. Any geological characteristics of the site which would be helpful in determining the compatibility of the reactor facility with the proposed location should be given. This might include:

G. Geology. (continued)

1. Depth and nature of overburden

2. Location and nature of faults, cavities, and crevices.

3. Stratigraphy of bedrock formations

H. Seismology. Sufficient information to evaluate the degree of protection required against earthquakes should be given. This might include:

1. Earthquake history

a. Intensity

b. Frequency

c. Location of epicenters and faults

2. Earthquake potential

III. Description of Facility.

A. Reactor Core.

1. Nuclear Design. Enough information should be presented to permit a qualitative check of the design parameters. Included should be the mathematical model used, the assumptions made, and the results of the calculations. The information which should be included is:

   a. Thermal neutron flux - maximum and average

   b. Fast neutron flux

   c. Nuclear parameters, such as: η, f, p, ϵ, L, τ, B^2

   d. Neutron lifetime - both with and without the reflector

   e. Metal to water ratio

   f. Critical mass as well as total loading of fuel

   g. Reactivity worths

      (1) Fuel element

      (2) Reflector

   h. Reactivity requirements

      (1) Temperature

      (2) Xenon

      (3) Samarium

      (4) Burnup

      (5) Control

      (6) Low cross section fission product poisons

      (7) Experiments

      (8) Xenon override

      (9) Voids

      (10) Other

      (11) Total

1. Nuclear Design. (continued)

   i. Coefficients of reactivity

      (1) Temperature

         (a) Equilibrium

         (b) Transient - including time constants of the various components

      (2) Void - including an analysis indicating the variation with size and location in reactor.

      (3) Pressure

      (4) Mechanical

      (5) Other

      (6) Power - this coefficient combines the effects of the temperature, void, and pressure coefficients for the whole core. Its calculational difficulty and its wide variability with rate of power level rise may limit its usefullness in some reactors. In many others, however, in which it does not vary so widely, it is a useful parameter in the analysis of power excursions.

   j. Kinetics - an evaluation of the response of the reactor to the various disturbances to which it may be subjected should be given. Such an evaluation should include the case of both the controlled and uncontrolled reactor. Examples of the types of disturbances which should be considered are:

j. Nuclear Design. (continued)

(1) Direct effects on reactivity

(a) Ramp additions

(b) Step additions

(2) Effects on reactivity of coefficients of reactivity

(a) Pressure

(b) Temperature

(c) Flow

(d) Void

(e) Mechanical

(f) Other

(3) Poison effects on reactivity

(a) Xenon and samarium

i. Restart

ii. Redistribution

iii. Instability (burnout)

(b) Chemical poison

k. Fuel cycle

(1) Time between shutdowns

(2) Downtime

(3) Burnup

(4) Rearrangement within the core during shutdown

l. Neutron sources

1. Nuclear Design. (continued)

2. Mechanical and Physical Characteristics. This should include a physical description of the core, including size, shape, location, number, and composition of the various components, such as:

   a. Fuel assemblies

   b. Control rods and drive mechanisms

   c. Reflector

   d. Supports and structural elements

   e. Access holes

   f. Thermal shield

   g. Pressure vessel

   h. Other

3. Heat Transfer and Fluid Flow. An indication of the disposition of the fluid and heat at various points in the core under normal and possible abnormal conditions, should be given. This should include:

   a. Temperatures of fuel, reflector, and coolant, maxima and averages and at significant points in the reactor, maximum to average ratios, indication of any local boiling, etc.

   b. Pressures and pressure drops in various components of the fluid system.

2. Mechanical and Physical Characteristics. (continued)

a. Velocities in the fuel, control, and reflector channels, flow rate through the core, and volume of fluid in the core.

d. Heat fluxes - maximum, average, maximum to average ratios, burnout heat flux, etc.

e. Total heat transfer area of core, reflector, etc.

f. Heat capacity of core both with and without coolant

g. Average steam voids in heated channels, in total moderator; exit steam quality, slip ratio, etc.

h. Power density

i. Power

B. Reactor Control.

1. Control Rods.

a. Composition

b. Dimensions and shape

c. Reactivity worth - individually and collectively

d. Method used, assumptions made, and results of reactivity calculations

e. Maximum possible reactivity insertion and removal rates

(1) Any single rod

(2) Any possible combination of rods

(3) Regulating rods

f. Drop or scram time including delay time

2. Control Rod Drives.

   a. Driving mechanism (including location and rod speed)

   b. Linkages

   c. Latching mechanism

   d. Position indicators

3. Auxiliary Control Systems. -- Including the control system and those for use in emergency only such as fuses.

4. Scrams, Setbacks, Alarms.

   a. Initiating conditions, such as high temperature, high or low pressure, low flow, high voltage, power failure, etc.

   b. Consequences, such as drop rods, dump water, close ventilation ducts, etc.

   c. Scram times

5. Interlocks.

   a. Conditions under which they are effective

   b. Conditions which they are designed to avoid or guarantee

   c. Details of their operation

   d. Possibility of their being bypassed

C. Instrumentation.

1. Sensing Devices. This should include type, location, range, number, sensitivity, etc.

   a. Pressure

   b. Temperature

      (1) Fuel

      (2) Coolant

1. Sensing Devices. (continued)

   a. Flow

   d. Neutron flux

   e. Liquid level

   f. Power

   g. Other

2. Instruments. This should include type, location, range, number, etc.

   a. Meters

   b. Recorders

   c. Indicators

3. Circuitry. A discussion showing how the entire instrumentation system is coupled together, including circuit and block diagrams.

D. Circulating Systems.

1. Primary. Since description of the core appears above, the description here should be directed primarily to that part of the primary system which is external to the core.

   a. General

      (1) Number of loops

      (2) Number of passes through the core

      (3) Total loop volume

      (4) Flow diagram

1. Primary. (continued)

   b. Components. This should include specifications, function, method of operation, location, number, materials (where significant), reliability, etc., of such items as:

      (1) Piping and principal valves

      (2) Pump

      (3) Pressurizer

      (4) Steam generator, heat exchanger, steam flash drum

      (5) Heater

      (6) Decay heat removal system

      (7) Emergency cooling system

      (8) Leak detection system

      (9) Poison injection system

   c. Fluid conditions at significant points in the system — i.e., inlet and outlet to core, pump, heat exchanger, etc.

      (1) Pressure

      (2) Temperature

      (3) Steam conditions

      (4) Concentration and nature of decomposition gases

      (5) Flow rates

2. Secondary.

   a. General

      (1) Total volume

      (2) Number of loops

      (3) Flow diagram

b. Components. This should include specifications, function, methods of operation, material (where significant), reliability, location, number, etc., of such items as:

(1) Piping and principal valves

(2) Pump

(3) Steam generator, heat exchanger, condenser, cooling tower

(4) Turbine-generator

(5) Heater

c. Fluid conditions at significant points in the system

(1) Pressure

(2) Temperature

(3) Steam conditions

(4) Flow rate

E. Experimental Facilities. The interaction of the experiment should be included here. Types of experimental facilities are:

1. Beam tubes

2. Pneumatic tubes

3. Thimbles

4. Thermal columns

5. Other

F. Shields.

1. Thermal.

(a) Number

(b) Composition

(c) Location

(d) Cooling system

2. Biological.

a. Location

b. Composition

c. Dimensions

d. Cooling system

e. Dose rate outside shield under:

(1) Normal conditions

(2) Possible abnormal conditions

3. Shrapnel.

a. Location

b. Composition

c. Dimensions

d. Design specifications and bases thereof

G. Building or Containment. This section should provide information leading to the assurance that the proposed building or containment will adequately protect the public from the effects of any credible accident.

1. General Description.

a. Geometry

b. Dimensions, thickness, volume

c. Materials of construction, insulation

d. Penetrations and access holes

(1) Purpose

(2) Location

(3) Methods of sealing or closing

1. General Description. (continued)

   e. Supporting structure

   f. Heating, cooling, ventilation systems

   g. Drainage systems

   h. Location of principal components in the building

   i. Direct gamma ray shielding

   j. Other

2. Design Criteria.

   a. External forces

      (1) Wind

      (2) Earthquake

      (3) Pressure

   b. Internal forces

      (1) Pressure

      (2) Missile

   c. Leakage rates

3. Construction and Testing Procedures.

   a. Time schedule of construction and testing.

   b. Methods of testing

      (1) Leakage

      (2) Pressure

   c. Frequency of periodic tests

III. Accident Analysis. The analysis of accidents could consist of two parts: (1) Initiating conditions; and (2) Consequences. Initiating conditions should include the malfunctions of equipment, including operators, that are necessary for an accident to occur. The consequences of an accident should indicate the physical damage incurred together with the quantity and quality of radioactive material released to the containment structure. The analysis itself should include a list of all the assumptions and simplifications used in calculating the final results. Unless it is obvious, the conditions or circumstances which limit the magnitude of an accident should be presented. A list of the types of accidents which might be considered are:

A. Reactivity Accidents.

1. Overradiations of Fuel.

2. Addition of Moderator or Reflector.

3. Removal of Poisons.

a. Control rods - (startup accident, uncontrolled rod withdrawal, etc.)

b. Chemical control

c. Fission product poisons - (xenon, samarium, etc.)

d. Burnable poisons

e. Coolant and moderator

f. Experiments

g. Other

4. Effects of Reactivity Coefficients.

a. Changes in temperature, e.g. cold water accidents

b. Changes in void size and location, e.g., void collapse

c. Pressure

d. Power

e. Other

B. Loss of Coolant Flow.

1. Pump failure

2. Valve closure

3. Channel or loop plugging

4. Other

C. Coolant Loss Accidents.

1. Pipe rupture

2. Pressure vessel failure

3. Rupture disk failure

4. Valve failure

5. Pump failure

6. Pressurizer failure

7. Other

D. Miscellaneous Accidents.

1. Chemical Reactions.

a. Metal-water

b. Radiolytic gases

2. Other minor accidents such as; fuel element ruptures, fires, power failure, earthquakes, storms, etc.

E. Maximum Credible Accident. The maximum credible accident is not necessarily a single type of accident but may be a combination of some of the above types of accidents. It is defined as an accident which is highly unlikely but still admitted to be remotely possible. The analysis of the maximum credible accident should

E. Maximum Credible Accident. (continued)

include the same type of information which is included for the above accidents; however, since this accident will most likely be the basis for containments its examination should be done in greater detail than for the other accidents.

F. Maximum Tolerable Disturbances. An analysis of the most adverse disturbances (in reactivity, flow, etc.) which the reactor can withstand without damage would be valuable in demonstrating the range of inherent safety for this reactor.

V. Hazards Analysis.

A. Radioactivity. (fission products, plutonium, etc.)

This should include an assessment of the biological damage both internal and external which might be incurred by the general public and operating personnel as a result of the fission products involved in normal and abnormal operation. The problem can be divided into the following three parts:

1. Source.

a. Contained radio activity - direct gamma radiation

b. Continuous release

(1) Normal release from stack

(2) Leakage from containment vessel

c. Instantaneous release (puff) from containment vessel

2. Mode of Transmission.

a. Air

b. Water

c. Direct

3. Receptor.

a. Location

b. Dose

(1) External - both integrated and as a function of time from both gamma and beta radiation

(2) Internal - total dose received during and after inhalation and/or ingestion of radioactive materials

B. Toxicity. Should the reactor contain significant quantities of toxic materials, an analysis similar to that described above should be included.

VI. Organization, Responsibilities, etc.

A. Structure.

B. Procedures.

1. Initial approach to criticality

2. Summary of normal operating plans

3. Emergency plans

4. Fuel handling

5. Changes in reactor design and operating (or handling experiments)

6. Radioactivity monitoring

7. Other

C. Previous Staff Training.

D. Safety Review Committee.

VII. Appendices. This should include any special studies, supporting information, etc., which may be pertinent to the hazards evaluation, and calculations supporting the results and conclusions presented earlier. Sufficient information should be presented to permit an independent confirmation of these results.

VIII. Drawings, Diagrams, etc. Detailed construction drawings need not be presented; however, sufficient detail should be provided by the drawings to define the layout of the various significant items in the core, building, site, and surroundings and to show the functional relationships in the coolant, control, ventilation and other systems. The placement in the report of the drawings, diagrams, etc. can either be in with the text or at the end of the report.