Newport News Industrial Corporation

Controlled Copy #44

REPORT NO. EI/NNI-77-7-NP

JUNE 24, 1977

TOPICAL REPORT
RWR-1™ RADWASTE
VOLUME REDUCTION SYSTEM

PREPARED FOR:

UNITED STATES NUCLEAR REGULATORY COMMISSION

WASHINGTON, D.C.

ENERGY INCORPORATED

7811220191

NOTICE

ABSTRACT

This document describes the RWR-1™ volume reduction system for application to radioactive waste produced at nuclear electrical generating stations. This process utilizes a fluidized-bed to calcine liquids and incinerate solids within a common chamber but with separate modes of operation. Volume reduction is projected to vary from 5 to 1 for filter sludges to 80 to 1 for compacted combustible solid waste.

Typical waste stream data from Boiling Water Reactors and Pressurized Water Reactors are examined. Decontamination factors (DFs) across similar systems are reviewed and DFs for the RWR-1™ System are developed. Anticipated releases to the atmosphere are computed for normal and abnormal operations and shown to be within the prescribed limits.

The RWR-1™ System components, instrumentation and controls, materials of construction, and operating characteristics are described. It is shown that the components and controls have been chosen on the basis of operating reliability and safety.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

This document is the Generic Licensing Topical Report for the RWR-1™ System. The RWR-1* System provides a new method of radwaste management and disposal which results in improvements in the cost and effectiveness of radwaste disposal for light water power reactors. The RWR-1™ System has been designed and developed to be capable of dealing with the nuclear power industry's problems of increasing waste volumes, greater activity levels, and more stringent regulations regarding containerization, transportation, and disposal.

The RWR-1™ System is being developed jointly by Energy Incorporated and Newport News Industrial Corporation. The RWR-1™ System incorporates a proprietary design that combines a single-chamber fluidized-bed incinerator and calciner that can substantially reduce the volume of both liquid and solid radwastes such as concentrated chemical wastes, filter sludges, spent ion exchange resin beads, rags and other similar materials. Operation of the RWR-1™ System reduces all liquid and combustible solid radwaste to anhydrous granular solids. This residue is compatible with existing solidification agents as well as many agents currently under study.

The RWR-1™ System capabilities result in several benefits for the nuclear power industry which include cost savings for containers, transportation, and disposal as well as an extension of available space at disposal sites. From human engineering considerations, it results in increased safety in handling, transportation and disposal, and in reduced radiation exposure to operating and maintenance personnel.

1.1 Purpose

The purpose of this Generic Licensing Topical Report is to provide specific design bases, system descriptions, and an Environmental Impact Analysis of the RWR-1™ System to allow generic licensing of the system by the Nuclear Regulatory Commission. The RWR-1™ System is capable of

---

*RWR-1™ is a trademark of Newport News Industrial Corporation and Energy Incorporated.

meeting the current public and governmental standards on radwaste disposal methods and is capable of dealing with more stringent regulations regarding containerization, transportation, and disposal.

1.2 Scope

This Generic Licensing Topical Report deals with those overall issues of licensing a solid waste processing system which are not specific to the location of the system. Applications for specific plants shall be submitted dealing with plant-specific issues. The report is designed in such a manner that plant-specific applications will only have to ascertain compliance to the generic design basis and confirm the generic safety analyses.

1.3 Applicability

This report, being generic in nature, is intended to apply to all light water reactors. For this reason an extensive effort has been expended to develop source term design criteria for the RWR-1™ System in such manner that all present and future designs of the light water reactor will generate radioactive waste at rates which will be less than those used for the present analysis of the RWR-1™ System. Moreover, the RWR-1™ System is applicable to other forms of low-level and intermediate level wastes not necessarily generated by the LWR. However, for the purposes of the licensing effort, only the applicability to the LWR will be discussed in this generic report.

1.4 History and Background

The basic processes of liquid calcination and combustible waste incineration which are used in the RWR-1™ System have been used in industrial plants for decades.(1) Fluidized bed calcination of radioactive wastes was developed during the period 1952-1959 at the Idaho National Engineering Laboratory. Use of calcination for liquid radwaste reduction was first demonstrated in an engineering scale facility, the Waste Calcining

Facility (WCF), at the Idaho Chemical Processing Plant in 1963.(2) The successful operation of the WCF has demonstrated that liquid wastes can be routinely calcined into a granular free-flowing powder which can subsequently be handled in a simplified manner. Since 1963, the WCF has handled over 2.5 million gallons of radioactive aqueous wastes which were calcined to approximately 4[illegible] cubic feet of solids.(3)

A batch operated fluidized bed calciner was designed and built as part of the Midwest Fuel Recovery Plant (MFRP) at Morris, Illinois, for General Electric Company.(4) The plant did not go into operation, but this was not due to radioactive waste concerns. Another batch calcination process, the Potcal process, was demonstrated on a fully radioactive basis in the WSEP program from 1966-1970. This process was developed at ORNL for the specific purpose of solidification of high level liquid wastes, although it did not use a fluidized bed process.(4)

Incineration of combustible radioactive wastes has been in use as a disposal technique since 1948 when a pilot plant incinerator and off-gas cleanup system were built at Mound Laboratory.(5,6,7) Early systems were adaptations of standard refuse incinerators and did show that considerable volume reduction in waste handling was possible. Data taken in the early 1960's at the General Electric Atomic Power Equipment Department in San Jose, California, showed that ~99% of the activity of the incinerated wastes remained in the ash.(5) Similar data are reported from an incinerator at Pratt and Whitney Aircraft where approximately 99.1-99.98% of the activity remained in the ash.(6)

Various methods have been utilized in off-gas treatment systems including very simple dry scrubber systems and very complex arrangements having both wet and dry scrubbers, water sprayed filters, and HEPA filters.

The RWR-1™ System has been designed to utilize the most proven components and a general arrangement that experience has shown to be effective and relatively maintenance free.

2.0 DESIGN BASES

The design bases of the RWR-1™ System can be considered to be of three distinct types. The first type relates to system location and interfaces with the commercial nuclear power installation. The second type relates to system operation, which includes not only types of wastes processed, but also expected volumes of wastes, flows of different categories of wastes, and the associated configuration and through-put. The third type is related to the legal regulations placed on the function, operation, and hardware configuration.

2.1 General

The RWR-1™ System is designed to meet the needs of utilities operating nuclear power reactors. Radwaste handling is becoming an increasing burden at these installations, and a system which reliably and safely reduces the volume of waste to be handled, shipped, and buried offers significant advantages over current practices. The RWR-1™ System is designed to reduce the volume of radwaste by incineration of the combustible waste and calcination of the liquid non-combustible waste. Spent fuel rods and hardware items such as broken control rods and contaminated tools are, of course, not amenable to treatment by the RWR-1™ System.

Progress in fluidized-bed technology now allows both incineration and calcination to take place in the same vessel. This is one of the design bases of the RWR-1™ System and is described in Section 3.2. The other generic design bases relate to the types and amounts of waste which the system must handle and the requirements for safe and reliable operation. Insuring that personnel operating the RWR-1™ System receive minimal occupational doses is also a primary consideration in design of this system. Finally, the system is designed to satisfy all the applicable requirements and regulations of the U.S. NRC and other governmental agencies.

2.2 Light Water Reactor Wastes Which Are Volume Reducible

Data are available from operating light water reactor systems to characterize the types, volumes, and activities of radwaste which is volume reducible.

2.2.1 Types of Waste

The solid waste generated at a nuclear power plant has been classified as "wet" waste or "dry" waste.[8] The "wet" wastes result from treatment processes which remove radioactive contaminants in cooling system and fuel storage pool water, from decontamination, and from other sources of contaminated water. This type of waste generally contains at least some water and consists mainly of spent demineralizer resins, evaporator bottoms and filter sludges.

The "dry" waste consists of ventilation air filters, contaminated clothing, cleaning swipes, paper, miscellaneous hardware and laboratory wastes. This type of waste normally has a much lower specific activity than the wet waste and it is generally combustible, if hardware items are removed. Hardware items, such as contaminated equipment, tools, and other metal items are generally excluded from this discussion.

The methods of processing these wastes with the RWR-1™ System are discussed in Section 3.2 of this report.

2.2.2 Maximum and Expected Volumes and Activities of Waste

The characteristics of radioactive waste from light water power reactors can be described within reasonable generic ranges, although they vary between plants. Volumes and radioactivity content of radwaste have been estimated by two recent reports on radioactive wastes: WASH-1258[8] and ERDA-76-43.[9] Table 2-1 summarizes the volumes and maximum specific activities estimated by WASH-1258 for a typical 3500 MWt BWR and for a typical 3500 MWt PWR. The BWR volumes apply to case 3 in WASH-1258 and are intermediate estimates. The PWR volumes apply to cases 4, 5, and 6 in WASH-1258 and are the largest volumes estimated.

Tables 2-2 and 2-3 contain estimates of solid waste activity, listed by nuclide. WASH-1258 assumed 180 days decay prior to shipment, which allowed many of the short-lived radionuclides to decay away. With the RWR-1™ System, storage of radwaste for a period on the order of a year before processing is not likely, so the 180 day decay period is not appropriate. For the purposes of this report, it is assumed that the radwaste is processed by the RWR-1™ System every four weeks, so that the average decay period before processing would be 14 days.

The final column in both Tables 2-2 and 2-3 contains the activity for each nuclide adjusted for 14 days decay. This adjustment is easily made since radioactive decay is described by an exponential relation:

$$A_{180} = A_{14} \exp[-\lambda(180 - 14)]$$

where

A_{180} = generation rate with 180 days decay (Curies/year)

A_{14} = generation rate with 14 days decay (Curies/year)

λ = $\frac{\ln(2)}{HL}$ = decay constant (1/days)

HL = half life (days)

As an example, consider Sr-89 in Table 2-2: A_{180} = 49 Ci/yr, HL = 52.7 days, and $A_{14} = \frac{49 \text{ Ci/yr}}{\exp[(-\ln(2)/52.7)\ (180 - 14)]}$ = 435 Ci/yr.

ERDA-76-43[9] distinguishes between reactors with deep-bed condensate clean up and those with powdered resin condensate cleanup. The ERDA-76-43 estimates are given in Figures 2-1 through 2-4. The WASH-1258 estimates are for a 3500 megawatt thermal (MWt) reactor while those of ERDA-76-43 are for a 1000 megawatt electric (MWe) reactor. Since a 1000 MWe plant is approximately equal to 3200 MWt, the values from ERDA-76-43 must be multiplied by a factor of 35/32 before a valid comparison can be made. WASH-1258 provides an analysis by nuclide but ERDA-76-43 does not. Therefore, only the data from WASH-1258 are used in this section. Radwaste generation rates throughout this report are normalized to 3500 MWt. For example, if an 1825 MWt plant shipped 1036 Curies in a certain year, the rate is given as 1986 Ci/yr = 1036 (3500/1825).

Five different cases for radwaste generation rates are considered herein. They are listed in Table 2-4. Case A is based upon WASH-1258, adjusted for 14 days decay. Cases B, C and D are based upon a survey of the semi-annual operating reports of nuclear power reactors. The data through the end of 1972 has been analyzed in ORNL-4924.[10] This early data was not particularly helpful in the preparation of this report since the 1500 MWt to 3300 MWt reactors, which comprise almost all the reactors currently operating, had accumulated very little operating time by the end of 1972. Therefore, cases B, C and D are based upon radwaste shipment data primarily from 1975 and the first half of 1976. The material available on microfiche from the U.S. NRC Public Document Room was examined for all operating commercial reactors in the U.S. from the beginning of 1975 onward. Data for the second half of 1976 was generally not available, and some data for 1975 was also unavailable. For Monticello, Nine Mile Point, Oyster Creek, Pilgrim and Point Beach, which all had relatively high shipment rates, data for a year or two prior to 1975 was obtained to insure that the shipment rates for 1975 were not atypical. This radwaste shipment data is summarized in Tables 2-5 and 2-6. These tables contain data from only those reactors which had received their operating licenses before 1975. Examination of semi-annual reports shows that the radwaste shipment rate increases with time during the first few years of the reactor's operation. Thus, the data from the first year or two of operation was not considered to be significant.

For Case B, all the reactors in Tables 2-5 and 2-6 for which there was data are considered, with three exceptions (see Table 2-7). The exceptions are Big Rock Point, Humboldt, and LaCrosse. These three reactors are relatively old, are less than 250 MWt, and were considered to be a special case. They are listed in Tables 2-5 and 2-6 for completeness, but are not considered further.

Because most reactors ship much less solid radwaste during their first year or two of operation, Case C excludes those reactors which received their operating licenses in 1973 or later. The reactors considered in constructing the averages for Case C are listed in Table 2-8. The Surry and Turkey Point reactors are borderline cases, which might well have been included. However, the data concerning volume shipped from Surry appears to be inconsistent for May 1975, so it was decided to exclude the data from all four reactors. Had the data Surry 1 and 2 been included, the activity rate would have been slightly higher (1830 Ci/yr), but if the data from Surry 1 and 2 and the data from Turkey Point 3 and 4 had been included, the rate would have been considerably lower (1600 Ci/yr). A comparison of cases B and C in Table 2-4 indicates that excluding data from the newer reactors results in a significant increase in the average amount of radwaste shipped.

Case D is the maximum amount for each category, as shown by Tables 2-5 and 2-6. The reactor site for each category is given in Table 2-4.

A comparison of Cases B, C and D with Case A indicates that the volume estimates of WASH-1258 are rather low. This may be due to the fact that the data upon which WASH-1258 is based was preliminary in some respects, or it may be due to radwaste practices which differ from those assumed in WASH-1258. These reasons, plus the variability in cladding integrity, may explain why WASH-1258 appears to have underestimated the activity in BWR radwaste and overestimated the activity in PWR radwaste. In comparison to both the WASH-1258 and the ERDA-76-43 estimates, the PWRs have shipped considerably less radwaste, both in volume and in activity, than the BWRs. It should be noted that Case A assumes a uniform 14-day delay between time of production and the time of assessment. On the other hand, cases B, C and D are not generation rates but shipment rates from the site, and the delay between production and shipment is not known.

Case E has been selected as a worst case for use in computing site boundary doses and concentrations resulting from normal operations. The highest annual rate of activity generation, 9500 Ci/yr, has been taken from Cases A, B, C and D and applied to both BWRs and PWRs. The volume rate is the maximum for each type of reactor.

The nuclide composition of the 9500 Ci/yr is given in Table 2-9. It represents a compromise between the nuclide composition of WASH-1258 (Tables 2-2 and 2-3) and the reported compositions of actual shipments (Table 2-10). Unfortunately, the BWR (Monticello) and the PWR (Point Beach) which shipped the most activity did not report solid radwaste composition by nuclide in their semi-annual reports. Table 2-10 indicates that the nuclide composition of solid radwaste varies considerably from reactor site to reactor site.

The volumes shown for Case E are worst case (maximum) volumes. For a given total activity, the minimum volume will obviously correspond to the maximum specific activity. Thus, Case E is not the worst case from the standpoint of specific activity. The specific activity is not so important for the solid radwaste as a whole as it is for each individual type of waste, so maximum specific activities are considered for each type of radwaste in Section 4.3.

2.2.3 Specific Activities

Specific activities are given in Tables 2-5 and 2-6. Some sites listed wet and dry wastes separately, and some identified only resin shipments, while others did not identify the specific type of waste at all. Therefore, the survey of the specific activies of radwaste shipped from operating reactors was necessarily incomplete. The highest specific activities are found in resins and other types of wet waste. The information for resins and wet waste is summarized in Table 2-11. Shipments with specific activities greater than 1000 Ci/m^3 do not constitute a great deal of volume. The Pilgrim shipment with a specific activity of at 1434 Ci/m^3 consisted of only 0.38 m^3 (13.6 ft^3) of sludge containing 553 Ci, and the Point Beach shipment with a specific activity of 1168 Ci/m^3 consisted of only 2.1 m^3 (73 ft^3) of resin containing 2415 Ci. Therefore, it is not reasonable to consider that the feed to the RWR-1™ System is comprised of material at a very high specific activity for more than a very short time, if at all, since different batches of the same type of waste may be mixed in the holding tank before incineration. Further, if station radwaste personnel know that a batch of waste has a high specific activity, they may elect not to process it in the RWR-1™ System in order to keep the surface radiation levels from the radwaste containers below some desirable level. Even if a batch of high specific activity waste were reduced in volume with the RWR-1™ System, it would be very unlikely that the residue from this batch alone would fill up the product container. Since radwaste with specific activity greater than a few hundred Curies per cubic meter comprises only a small portion of the solid radwaste, the material filling up the remainder of the product container would probably be fairly low in specific activity and the total activity in the container might well fall within acceptable limits. If a product container receives so much activity that it cannot be shipped as low-level waste after the usual storage period, it must either be stored for a longer period or shipped in a shielded cask.

2.3 RWR-1™ System Sizing

2.3.1 Introduction

The RWR-1™ System has been designed so that it can process the wastes from a typical reactor by operating less than 75% of the time on an around the clock basis. Extra capacity is included to permit time for system maintenance and to ensure sufficient capacity for periods of abnormally high waste generation. This section discusses the basis for the selected throughput rates which in turn determine the size of the RWR-1™ components.

2.3.2 Waste Generation Rates

The principle documents used in this report for determining the activities of the expected waste feed to the RWR-1™ System were WASH-1258[8] and ERDA-76-43.[9] The total waste volumes reported in WASH-1258 were 225-325 m^3/yr (for 3500 MWt reactors, see Table 2-4). ERDA-76-43 reports somewhat higher volumes: 371-684 m^3/yr (for 1000 MWe reactors, see Figures 2-1 through 2-4). These "generic" estimates of volumes may be compared with the actual volumes shipped from reactor sites as listed in Tables 2-5 and 2-6. The rates at which volumes have been shipped vary from 77 m^3/yr to 3538 m^3/yr (normalized to 3500 MWt). It would not be prudent to base the size of the RWR-1™ System on a volume generation rate as high as 3000 m^3/yr. In the first place, few of the operating reactors are as large as 3500 MWt. Secondly, plants which generated much smaller volumes of radwaste would be forced to consider systems which would stand idle too much of the time to be economically feasible. The ERDA-76-43 radwaste volume generation rates have been selected as the basis for determining the size of the RWR-1™ System. The volume through-put rates which result from designing the RWR-1™ System on this basis are such that the majority of nuclear power plants can process their waste by operating less than three fourths of the hours in the year.

2.3.3 Selected RWR-1™ Capacity

The tabulation of waste generation rates by type of waste in ERDA-76-43 is adequate to determine time of operation of the RWR-1™ System required in each mode. The wastes from a BWR using deep-bed condensate cleanup represent the highest volume generation rate of the four cases presented in ERDA-76-43:[9] 684 m^3/yr. If the RWR-1™ System is sized so that it can process these 684 m^3/yr in 184 (24-hour) days of operation (50% capacity), waste processing for the other three cases in ERDA-76-43 requires from 93 to 137 (24-hour) days per year as shown in Table 2-12.

Two hundred and sixty-four days of operation per year is considered to be maximum for the RWR-1™ System. The capacity of the RWR-1™ System operating 264 days per year is 1230 m^3/yr for a PWR with deep-bed condensate cleanup. The maximum operating capacities for the RWR-1™ System with wastes from all four cases considered in ERDA-76-43 are given in Table 2-12.

2.4 RWR-1™ System Performance and Operating Conditions

The RWR-1™ System is designed to incinerate and calcine in the same single-chamber vessel with the same inert bed. It has been sized to incinerate 91 kilograms (200 pounds) per hour of combustible dry waste or 68 kilograms (150 pounds) per hour of resins and sludges, or to calcine 132 liters (35 gallons) per hour of liquid waste. Processing reduces these wastes to a dry, granular solid product. An effluent containing a very small amount of radioactivity is released in gaseous form to the atmosphere. The resulting concentrations at the site boundary are shown in Section 4.2 to be much less than the limiting concentrations.

During incineration the fluidized bed operates at about 1000°C and during calcination it operates at about 400°C. The hot off-gas passes through the dry cyclone at temperatures slightly below the bed temperature. In the quench tank the off-gas is cooled to about 70°C. The off-gas remains between 40°C and 70°C throughout the remainder of the off-gas cleanup system.

The pressures in the incinerator/calciner and the off-gas cleanup system are maintained below ambient pressure in all operating modes. The pressures range from 29 kPa (4.2 psig) below ambient at the inlet to the off-gas blower (the exit of the off-gas cleanup system) to near atmospheric in the fluidized bed.

The RWR-1™ System volume reduction factors are estimated to be:

Compacted dry combustible solids	80
Spent resin	18
Concentrated liquids	8
Filter sludge	5

Decontamination factors used for computing emissions are 4×10^4 for particles and 1×10^4 for iodine. Estimates of the decontamination factors expected to be observed in operation are considerably higher than these very conservative values used for computing emissions.

2.5 Seismic Classification of the RWR-1™ System

The RWR-1™ System will be designed, fabricated, erected, and tested in such a manner that it will meet the seismic design standards of the U.S. Nuclear Regulatory Commission. The RWR-1™ System is capable of satisfying all the applicable regulations and guidelines for radioactive waste management systems located in light-water-cooled nuclear power plants. A primary design basis for the RWR-1™ System is to minimize the exposure of operating personnel and the general public to radiation in the event of a natural disaster such as an earthquake.

The U.S. NRC document which determines the seismic design classification is Effluent Treatment Systems Branch Technical Position ETSB No. 11-1 (Rev. 1).[11] ETSB No. 11-1 states in Part B, Sections I and III, that "Equipment and components used to collect, process or store liquid (or solid) radioactive waste need not be designed to the seismic criteria given in Section V." Section II of Part B requires that "Those portions of the gaseous radwaste treatment system which by design are intended to store or delay the release of gaseous radioactive waste, including portions of structures housing these systems should be designed to the seismic design criteria given in Section V." While the RWR-1™ System will handle radioactive waste in solid, liquid, and gaseous form, storage vessels will contain only liquids and solids. There is no gaseous holdup or storage capability in the system. Therefore, the equipment and components of the RWR-1™ System will not be designed to seismic criteria.

ETSB No. 11-1, Part B, Sections I and III do require that "The foundations and adjacent walls of structures that house the liquid or solid radwaste system should be designed to the seismic criteria described in Section V to a height sufficient to contain the liquid inventory in the building." Section V, Paragraph b defines the seismic design requirements for buildings housing radwaste systems. However, Section V, Paragraph c allows an optional construction method:

> "In lieu of the requirements and procedures defined above, optional shield structures constructed around and supporting the radwaste systems may be erected to protect the radwaste systems from effects of housing structural failure. If this option is adopted, the procedures described in Section V.b only need to be applied to the shield structures while treating the rest of the housing structures as non-seismic Category I."

In conclusion, the RWR-1™ System will not be designed to seismic criteria; however, the foundations and adjacent walls that house the RWR-1™ system must be designed and constructed to the seismic criteria given in Section V.b of ETSB 11-1 (Rev. 1) to a height sufficient to contain the liquid inventory of the storage tanks within the building, or optional shield structures surrounding and supporting the RWR-1™ System must be erected to protect the system from housing structural failure as described in Section V.c of ETSB 11-1 (Rev. 1).

2.6 Quality Group Classification

In accordance with NRC Branch Technical Position ETSB No. 11-1 (Rev. 1)[11] the following Quality Assurance Program will be implemented for the RWR-1™ System.

2.6.1 Scope

Design, fabrication, inspection, and testing of the RWR-1™ System will be accomplished in accordance with the codes and standards listed in

Table 1 of ETSB 11-1. To assure that all requirements promulagated for the system are met, a quality assurance system has been established in accordance with ASME Section VIII, Division 1.[12] This system is maintained by each department assuming responsibility for quality - subject to control and audit by quality assurance personnel.

2.6.2 Description of Quality Control System

Operation of the quality control system for the RWR-1™ System is the responsibility of the Quality Assurance Department.

2.6.2.1 Authority and Responsibility

The Quality Assurance Manager has overall responsibility for coordination and implementation of the QA system. He has the authority to identify and resolve quality control problems. He is independent of any other activity and reports directly to the Vice-President, Engineering.

2.6.2.2 Organization

An organization chart which shows relationships between management and the Quality Assurance Department and all areas concerned with the quality system is a part of the detailed quality assurance procedure. Departments implementing the quality system are Purchasing, Engineering, Design, Manufacturing, Field Installation, and Inspection and Testing.

2.6.2.3 Drawings, Design Calculations and Specification Control

All design calculations, procedures, and drawings are subject to review by a person or persons other than the preparer. The reviewer verifies incorporation of comments by his signature. All documents must be approved and signed by management.

The records control system precludes possession of an incorrect revision of internal documents or customer specifications by any individual. All recipients of documents are recorded and must verify, by their signature, receipt of each subsequent revision.

2.6.2.4 Material Control

Purchase orders are all subject to review by the Quality Assurance Department to ascertain incorporation of quality requirements. Material certification and test reports are also reviewed by QA prior to issue of material. Material or items which require traceability are assigned a unique number applied at receipt. All incoming material is inspected by a qualified inspector and inspection results are reported to Quality Assurance.

Material is stored and handled in a manner to prevent damage or deterioration. Special storage and handling instructions are furnished by Engineering when required.

Cleaning and preservation is in accordance with requirements of design specifications.

2.6.2.5 Examination and Inspection Program

Instructions on drawings and in procedures specify inspections, tests, and examinations to be performed and refer to detailed procedures which must be followed in performance of inspections and examinations. All inspections, tests and examinations are documented by reports which are reviewed by Quality Assurance.

2.6.2.6 Correction of Nonconformities

Nonconformities are reported by inspectors using a Nonconformity Report form. These reports are submitted to the Engineering Department for resolution. If it is determined that evaluation by another department is required, that department will be consulted by Engineering. Nonconformity Reports are reviewed by Quality Assurance to ascertain adequacy of the resolution and are signed by Inspection and Quality Assurance when all corrective action has been completed.

Nonconforming material is tagged to indicate that it is in a hold status and is physically isolated from satisfactory, in process material.

2.6.2.7 Calibration of Measurement and Test Equipment Controls

Controls governing calibration examinations of measuring and test equipment are provided in a written procedure. All tools and equipment requiring calibration are periodically recalled, calibration is recorded, and items are labeled with the next calibration due date. Calibration is to standards traceable to the National Bureau of Standards.

2.6.2.8 Records Retention

Quality documentation is maintained by the records control center for a length of time determined by customer specifications.

Documentation retained is that indicated in the next paragraph and as follows:

(1) Design Specifications

(2) Design Calculations

(3) Certified Material Test Reports

(4) Radiographic Film

(5) Heat Treatment Records

(6) Test Reports

(7) Drawings

(8) Data Reports

2.6.2.9 <u>Sample Forms</u>

Sample forms are included in the detailed quality assurance procedure with requirements for their use. These forms include but are not limited to the following:

(1) Personnel and Procedure Qualification Forms

(2) Inspection Reports

(3) NDE Reports

(4) Purchase Order Form

(5) Job Order Form

(6) Tags

(7) Material Issue Records

(8) Nonconformity Report

(9) Documented Distribution Record

2.6.2.10 <u>Shipment</u>

All shipments are inspected by Quality Assurance to ensure the adequacy of packaging and secureness.

2.7 Compliance With Federal Regulations

The RWR-1^{TM} System will be in compliance with federal regulations concerning protection of personnel against radiation and other technical and legal licensing requirements for production and utilization facilities. These regulations are promulgated by the Nuclear Regulatory Commission and other agencies of the federal government.

2.7.1 10CFR20 - Standards for Protection Against Radiation

The RWR-1^{TM} System design results in very low radiation levels. When RWR-1^{TM} is operated in accordance with prescribed procedures, at no time will the limits of 10CFR20 Appendix B be exceeded. The dose rates to personnel operating the RWR-1^{TM} System cannot be computed on a generic basis, but the individual cells formed by the concrete shield walls and the operation of the System at less than atmospheric pressure facilitate keeping the operational dose rate below the levels required by 10CFR20. The emissions from operation of the RWR-1^{TM} System result in concentrations and dose rates at the site boundary which are well below the limiting values for concentrations and dose rates as set by 10CFR20 for unrestricted areas. The maximum concentrations and dose rates are presented in Section 4.2 of this report.

2.7.1.1 10CFR20.101 - Exposure of Individuals to Radiation in Restricted Areas

To allow compliance with this regulation, the components of the RWR-1^{TM} System shall be placed behind concrete walls to attenuate the radiation which may be emitted from these components. The modular design of the RWR-1^{TM} System allows the components of the system to be placed in cells. The shield walls of the cells minimize the radiation exposure of operating personnel both during operation at the remote console and during maintenance. Figure 2-5 shows a typical arrangement of the components and the shielding walls.

2.7.1.2 10CFR20.103 - Exposure of Individuals to Concentrations of Radioactive Material in Restricted Areas

Concentration limits for radioisotopes in restricted areas are listed in 10CFR20, Appendix B, Table I. Compliance with these limits will be achieved by minimizing leakage rates from the RWR-1™ System to surrounding areas during operation. Storage hoppers, feed systems, product transfer mechanisms, etc., will be isolated by equipment air seals. In addition, the RWR-1™ System is designed to operate at a negative pressure with respect to its surroundings; thereby, further reducing the possibility of leakage of radioactive material to restricted areas. Area radiation monitors are intended to continuously monitor the room air.

2.7.1.3 10CFR20.105 - Permissible Levels of Radiation in Unrestricted Areas

This regulation specifies the following dose rate limits in unrestricted areas:

(1) 2 millirem per hour,

(2) 100 millirem in any seven consecutive days, and

(3) 0.5 rem per calendar year.

The RWR-1™ System can be located and operated so that the dose rate in the closest unrestricted area will be less than these limits.

2.7.1.4 10CFR20.106 - Radioactivity in Effluents to Unrestricted Areas

Radioactivity in effluents released to unrestricted areas from the operation and maintenance of the RWR-1™ System will be limited to concentrations "as low as is reasonably achievable." The concentrations at the site boundary will be below these specified in 10CFR20, Appendix B,

Table II. Section 4.2 of this report provides an analysis of the concentrations at a site boundary from the normal operation of the RWR-1™ System. Concentrations due to anticipated transients and postulated accidents are considered in Section 4.3. These analyses confirm this design basis.

2.7.2 10CFR50 - Licensing of Production and Utilization Facilities

The RWR-1™ System will be installed at a facility meeting the requirements of 10CFR50 and will itself meet all applicable requirements.

2.7.2.1 10CFR50 Appendix A - General Design Criteria for Nuclear Power Plants

The System principle design criteria are listed in Section 2.0 of this document. Certain plant specific considerations will be covered on an individual basis by the plant owner.

2.7.2.1.1 Criterion 60 - Control of Releases of Radioactive Materials to the Environment

The concentrated liquid waste storage tank, the resin storage tank, the sludge storage tank, and the dry combustible waste hopper all are usually part of the reactor plant radwaste system. They shall be designed to accommodate anticipated operational occurrences, such as unscheduled demineralizer changeouts. The high treatment efficiency of the RWR-1™ off-gas cleanup system minimizes the release of gaseous effluents to the atmosphere. In case a portion of the off-gas cleanup system should fail, the RWR-1™ System has the capability of recirculating the off-gas through the cleanup system instead of releasing it to the atmosphere. The only significant solid effluent is the product which is removed from the dry cyclone to the plant radwaste system for immobilization or storage. Purged scrub liquid returns to the plant liquid radwaste system. Condensate from the condenser which is not needed to maintain the volume of the scrub liquid is returned to the plant water system.

No liquid releases from the RWR-1™ System directly to the environment are envisaged. The RWR-1™ System includes an internal holdup tank for scrub liquid.

2.7.2.1.2 Criterion 63 - Monitoring Fuel and Waste Storage

Appropriate instrumentation will be provided to detect conditions that may result in excessive radiation levels within the RWR-1™ System. The RWR-1™ System will be equipped with controls designed to sense and activate an alarm upon the occurrence of a wide variety of off-normal operational conditions. A part of the controls will be an annunciator panel which will provide identification of the causes of any alarm. Corrective action will be taken either automatically or manually, depending on the potential seriousness of the occurrence.

2.7.2.1.3 Criterion 64 - Monitoring Radioactivity Releases

Off-gas from the RWR-1™ System is routed to the plant stack. Therefore, the plant monitoring system will be used to monitor these releases. In addition, a separate RWR-1™ System radioactivity monitor will be located in the off-gas exhaust line to the plant stack.

2.7.2.2 10CFR50 Appendix B - Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants

The RWR-1™ System is designed to permit compliance with these criteria. The quality assurance criteria for the RWR-1™ System have been established in accordance with U.S. NRC ETSB 11-1 (Rev. 1).[11] This quality assurance program is presented in Section 2.6 of this report.

2.7.2.3 10CFR50 Appendix I - Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criteria "As Low As Is Reasonably Achievable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents

The RWR-1™ System design results in very low releases to the atmosphere. The dose rates, as shown in Section 4.2, are well below, and should be maintainable below, the limits set in Appendix I. The radioactive effluents produced by the RWR-1™ System during normal operations will be so small that their addition to other effluents from a nuclear power plant should have no significant effect upon the ability of the plant to satisfy the requirements of Appendix I. Specific compliance will be addressed on a plant by plant basis.

2.7.3 10CFR71 - Packaging of Radioactive Material For Transport and Transportation of Radioactive Material Under Certain Conditions

It is expected that the solid residue(s), or product(s), of the RWR-1™ System will be packaged and transported to a licensed disposal site. The responsibilities for this belong to the user (owner/licensee). The specific compliance shall be discussed on a plant by plant basis in individual applications.

2.7.4 NRC Regulatory Guides

2.7.4.1 Regulatory Guide 1.21 - Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants

The specific compliance to this guide shall be discussed on a plant by plant basis in individual applications. Provisions shall be made to monitor and to limit the radiation from each package of solid waste in order to permit the operator to control radiation exposure to personnel and to meet the regulatory requirements of 10CFR71 and of 49CFR.

2.7.4.2 Regulatory Guide 1.110 - Cost-Benefit Analysis for Radwaste Systems for Light-Water-Cooled Nuclear Power Reactors

The RWR-1™ System is an addition to a nuclear power station radioactive waste handling system, the purpose of which is to reduce handling and disposition costs. An ecological benefit is the fact that the land required for isolation of the wastes is reduced by at least a factor of ten. The radiological dose effects resulting from the addition of RWR-1™ to a radwaste facility are complex. The gaseous emissions to the atmosphere are insignificant, therefore no cost is realized from that source. A cost benefit results from the reduced number of shipments.

U.S. NRC Regulatory Guide 1.110 sets forth guidelines for preparation of cost/benefit analyses for radwaste systems. This guide, however, does not lend itself well to radwaste systems of this type which do not directly change the dose to the population in the immediate vicinity of the station. As a result, no dose credits result from reduced radwaste shipments and reduced repository land commitments.

Direct costs include the fixed costs associated with purchasing the RWR-1™ System and the construction of a building and support equipment. Any increase of maintenance costs as compared with the previous system must also be included.

"Benefit" is more difficult to quantify than cost. The most obvious item is reduced cost of operation. This results from the reduced annual volume of radioactive waste that must be handled and shipped and the reduction in space required for storage. A less tangible benefit of the RWR-1™ System is reduced radiation exposure of operating personnel.

2.7.4.3 Regulatory Guide 8.8 - Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable

The RWR-1™ System equipment design is consistent with the guidelines set forth. Means of interior surface decontamination will be provided via a separate spray system in larger components which handle radioactive materials. The overall design includes considerations of equipment location, shielding, personnel access, etc., which should permit the operation and maintenance of the RWR-1™ System with a minimum of occupational radiation exposure. The design criteria incorporated in the RWR-1™ System will permit the operator to effectively implement the philosophy of NRC Regulatory Guide 8.8.

TABLE 2-1

ESTIMATED ACTIVITY, VOLUME, AND SPECIFIC ACTIVITY OF RADWASTE ACCUMULATING IN ONE YEAR*

Type of Waste	Characteristic	Units	BWR	PWR
Wet	Volume	m^3	166	125
		ft^3	6000	4500
		55-gal drums	800	600
	Specific Activity	Ci/m^3	<14	<75
		Ci/ft^3	<0.4	<2
Dry	Volume	m^3	125	94
		ft^3	4500	3300
		55-gal drums	600	450
	Activity	Ci/m^3	<<.03	<<.03
	Activity	Ci/ft^3	<<1	<<1
Total	Volume	m^3	291	219
		ft^3	10500	7800
		55-gal drums	1400	1050
	Activity	Curies	2900	9500

*These values are for a 3500 MWt reactor and are based on WASH-1258.(8) The BWR volume estimates are for case 3; taken from Table 2-47, p. 2-157. The PWR volume estimates are for cases 4, 5, and 6; taken from Table 2-49, p. 2-159. The specific activity limits for wet wastes (as a whole) are from the same tables, and apply to all cases for the BWR and to all cases except Case 1 for the PWR. The total activity is from Tables 2-2 and 2-3 and has been adjusted for 14 days decay.

TABLE 2-2

ESTIMATED NUCLIDE CONTENT OF BWR SOLID WASTE*

Nuclide	Half Life	Generation Rate Ci/yr (180 days Decay)	Generation Rate Ci/yr (14 days Decay)
Sr-89	52.7 d	49	435[2]
Sr-90	27.7 y	90	91
Zr-95	65 d	1.1	6.5
Ru-103	368 d	2.1	2.9
Te-127m	109 d	1.6	4.6
Cs-134	2.0 y	130	152
Cs-137	30.0 y	120	121
Ce-141	32.5 d	0.25	8.6
Ce-144	284 d	5.1	7.6
Cr-51	27.8 d	0.60	37.6
Mn-54	303 d	13	19
Fe-55	2.6 y	800	903
Fe-59	45.6 d	6.6	82.3
Co-58	71.4 d	130	651
Co-60	5.3 y	200	212
		(no days decay)	
I-131	8.065 d	442	133
I-133	20.8 h	275	0.004
			2867

*The values for 180 days decay are from WASH-1258,[8] Table 2-46, p. 2-156. The values for 14 days decay have been computed from the 180 days decay values explained in the text. The iodine values have been computed by the method explained in Appendix A.

TABLE 2-3

ESTIMATED NUCLIDE CONTENT OF PWR SOLID WASTE*

Nuclide	Half Life	Generation Rate Ci/yr (180 days decay)	Generation Rate Ci/yr (14 days decay)
Sr89	52.7 d	2.0	17.8[2]
Sr90	27.7 d	2.7	172
Zr-95	65 d	0.64	3.8
Ru-103	39.5 d	0.10	1.8
Ru-106	368 d	1.7	2.3
Te-127m	109 d	11	31.6
Te-129m	34.1 d	1.3	38.0
Cs-134	2.0 y	2800	3278
Cs-137	30.0 y	2700	2729
Ce-144	284 d	4.2	6.3
Cr-151	27.8 d	0.35	22.0
Mn-54	303 d	22	32.2
Fe-55	2.6 y	200	226
Fe-59	45.6 d	1.8	22.4
Co-58	71.4 d	120.	601
Co-60	5.3 y	280	297
		(no days decay)	
I-131	8.065 d	6803	2044
I-133	20.8 h	1037	.0142
			9525

*The values for 180 days decay are from WASH-1258,[8] Table 2-48, p. 2-158. The values for 14 days decay have been computed from the 180 days decay values as explained in the text. The iodine values have been computed by the method explained in Appendix A.

TABLE 2-4

ESTIMATES OF SOLID RADWASTE GENERATION RATES, NORMALIZED TO 3500 MWt

Case	Description	Generation Rates from a 3500 MWt BWR		Generation Rates from a 3500 MWt PWR	
		Ci/yr	m^3/yr	Ci/yr	m^3/yr
A	Values from WASH-1258 corrected for 14-day rather than 180-day decay. See Tables 2-1, 2-2, and 2-3.	2875	375	9500	225
B	Average of available data on radwaste shipped for all reactors except three early small reactors (Big Rock Point, Humboldt Bay, and LaCrosse). See Tables 2-5, 2-6, and 2-7.	1750	1300	1150	750
C	Average of available data on radwaste shipped for all reactors which are greater than 500 MWt and which had their operating license prior to 1973. The Surry and Turkey Point sites have been excluded because each second unit received its operating license in 1973. See Tables 2-5, 2-6, and 2-8.	2875	1850	1825	750
D	Maximum site. For each type of reactor and each category (activity or volume) the site which ships the maximum has been chosen. See Tables 2-5 and 2-6.	Monticello 8575	Dresden 3550	Point Beach 4950	Yankee Rowe 1525
E	Selected worst case. See Table 2-7.	9500	3600	9500	1600

TABLE 2-5

SOLID RADWASTE SHIPMENT RATES FOR BWRs

Site	Unit	NSSS Supplier	MWt	Date of Op. Lic.	Radwaste Shipment Rate* Ci/yr	Radwaste Shipment Rate* m^3/yr	Specific Activity Ci/m^3 Total	Specific Activity Ci/m^3 Wet	Specific Activity Ci/m^3 Dry	Specific Activity Ci/m^3 Resin Only	Time Period Used for Data	Notes
Arnold		GE	1593	2-74	173	571	.30				1975	
Big Rock Point		GE	240	8-62	14,800						1975	No volumes given.
Browns Ferry	1 2 3	GE GE GE	3293 3293 3293	6-73 6-74 7-76	717	679	1.06	3.5	.10	55	1975	Resin density is for "high resin" only. Unit 3 not considered for normalization.
Brunswick	2	GE	2436	12-74	292	1489	.20	.30	.04		July 1975 -June 1976	
Cooper		GE	2831	1-74	550	407	1.35	1.60	.01		July 1976 -June 1976	
Dresden	1 2 3	GE GE GE	700 2527 2527	9-59 12-69 1-71	658	3538	.19	.34	.05		Jan. 1975 to June 1976	Extraordinary shipment of 6300 Ci in August 1975 has been excluded.
Fitzpatrick		GE	2436	10-74	2[illegible]	835	.29	.34	.03		July 1975 -June 1976	
Hatch		GE	2436	8-74	208	329	.63	.86	.02		June 1976 -July 1976	
Humboldt Bay		GE	220	8-62	686	2014	.34	.08	.45			
Millstone	1	GE	2011	10-70	3669	2645	1.39	3.51	.02		Jan-June 1975 +Jan-June 1976	
Monticello		GE	1670	9-70	8578	700	12.25				Jan. 1974 -June 1976	[1]
Nine Mile Point		GE	1850	8-69	4848	906	5.35	7.62	.04		1974 - 1976	[2]
Oyster Creek		GE	1930	4-69	2853	1869	1.53			104	July 1973 -June 1976	[3]

TABLE 2-5 (Contd.)

Site	Unit	NSSS Supplier	MWt	Date of Op. Lic.	Radwaste Shipment Rate* Ci/yr	m³/yr	Specific Activity Ci/m³ Total	Wet	Dry	Resin Only	Time Period Used for Data	Notes
Peach Bottom	1 2	GE GE	3293 3293	8-73 7-74	115	310	.37				1975	
Pilgrim		GE	1998	6-72	5940	900	6.6	13.1	1.96		July 1973 -June 1976	[4] Wet and Dry density based on July 1975-June 1976
Quad Cities	1 2	GE GE	2511 2511	10-71 3-72	1840	906	2.0				Jan. 1975 -June 1976	
Vermont Yankee		GE	1593	3-72	77	880	.08	.23	.02		June - Dec. 1975	Only one Semi-annual Report found.

[1]Monticello: If only July 1974 - June 1976 data are used, normalized rates are 10355 Ci/yr and 729 m^3/year.

[2]Nine Mile Point: If 1970 - 1976 data are used, normalized rates are only 2474 Ci/yr and 773 m^3/year, but operating licence was received in August 1969.

[3]Oyster Creek: If only January 1975 - June 1976 data are used, normalized rates are 3647 Ci/yr and 2213 m^3/yr.

[4]Pilgrim: If only July 1975 - June 1976 data are used, normalized rates are 13604 Ci/yr and 1633 m^3/yr.

*Normalized to 3500 MWt.

TABLE 2-6

SOLID RADWASTE SHIPMENT RATES FOR PWRs

Site	Unit	NSSS Supplier	MWt	Date of Op. Lic.	Radwaste Shipment Rate* Ci/yr	Radwaste Shipment Rate* m^3/yr	Specific Activity Ci/m^3 Total	Specific Activity Ci/m^3 Wet	Specific Activity Ci/m^3 Dry	Specific Activity Ci/m^3 Resin Only	Time Period Used for Data	Notes
Arkansas		B&W	2568	5-74								No information found.
Calvert Cliffs	1	CE	2560	7-74								Does not appear to have shipped anything yet.
	2	CE	2560	8-76								
Conn Yankee		W	1825	6-67	1986	1333	1.49	12.3	.01		1975, 1976	
Cook		W	3250	10-74								No information found.
Fort Calhoun		CE	1420	5-73	132	1046	.12	.106	.16		Jan 1975-June 1976	
Ginna		W	1520	9-69	267	963	.28					
Indian Point	1	B&W	615	3-62	2080	645	3.22	4.69	.04		1975	
	2	W	2758	10-71								
	3	W	3025	12-75								Unit 3 not considered for normalization.
Kewaunee		W	1650	12-73								Very few shipments so far.
La Crosse		A-C	165	7-67								No data.
Maine Yankee		CE	2440	9-72	1892	309	6.12	9.63	.13		Jan. 1975 -June 1976	
Millstone	2	CE	2560	8-75	3	550	.005				Jan.-June 1976	
Oconee	1	B&W	2568	2-73								
	2	B&W	2568	10-68	865	771	1.12			120	Jan.-June 1975 Jan.-June 1976	
	3	B&W	2568	7-74								
Palisades		CE	2000	3-71	259	1276	.20			4	1975	

TABLE 2-6 (Contd.)

Site	Unit	NSSS Supplier	MWt	Date of Op. Lic.	Radwaste Shipment Rate*: Ci/yr	Radwaste Shipment Rate*: m^3/yr	Specific Activity Ci/m^3: Total	Specific Activity Ci/m^3: Wet	Specific Activity Ci/m^3: Dry	Specific Activity Ci/m^3: Resin Only	Time Period Used for Data	Notes
Point Beach	1	W	1518	10-70	4927	235	21.0			343	Jan. 1974 -July 1976 Excluding July-Dec. 1975	
	2	W	1518	11-71								
Prairie Island	1	W	1650	8-73	78	248	.32				Jan. 1975 -June 1976	
	2	W	1650	10-74								
Rancho Seco		B&W	2772	8-74								No data found.
Robinson	2	W	2200	7-70	1446	521	2.8	4.8	.25		Jan. 1975 -June 1976	
San Onofre		W	1347	3-67	117	338	.35				1975	
Surry	1	W	2441	5-72	1895						1975	Suspicious volume data.
	2	W	2441	1-73								
Three Mile Island		B&W	2535	4-74	356	632	.56				1975	
Turkey Point	3	W	2200	7-72	108	794	.14				Jan. 1975 -June 1976	
	4	W	2200	4-73								
Yankee-Rowe		W	600	7-60	19	1534	.01	.02	.002		1975	
Zion	1	W	2760	4-73	25	1075	.02				Jan. 1975 -June 1976	
	2	W	2760	11-73								

*Normalized to 3500 MWt.

TABLE 2-7

REACTOR DATA USED IN OBTAINING THE AVERAGES
FOR CASE B (SEE TABLE 2-4)

BWR	PWR
Arnold	Connecticut Yankee
Browns Ferry 1 & 2	Fort Calhoun
Brunswick 2	Ginna
Cooper	Indian Point 1 & 2
Dresden 1, 2 & 3	Maine Yankee
Fitzpatrick	Oconee 1, 2 & 3
Hatch	Palisades
Millstone 1	Point Beach 1 & 2
Monticello	Prairie Island 1 & 2
Nine Mile Point	Robinson 2
Oyster Creek	San Onofre
Peach Bottom 1 & 2	*Surry 1 & 2
Pilgrim	Three Mile Island
Quad Cities 1 & 2	Turkey Point 3 & 4
Vermont Yankee	Yankee - Rowe
	Zion 1 & 2
20 Units	*24 Units

*Due to apparently inconsistent data for the volumes shipped from Surry, the Surry data has been used only for computing the average activity shipped.

TABLE 2-8

REACTOR DATA USED IN OBTAINING THE AVERAGES
FOR CASE C (SEE TABLE 2-4)

BWR	PWR
Dresden 1, 2 & 3	Connecticut Yankee
Millstone 1	Ginna
Monticello	Indian Point 1 & 2
Nine Mile Point	Maine Yankee
Oyster Creek	Palisades
Pilgrim	Point Beach 1 & 2
Quad Cities 1 & 2	Robinson 2
Vermont Yankee	San Onofre
11 Units	Yankee - Rowe
	11 Units

TABLE 2-9

NUCLIDE COMPOSITION OF TOTAL SOLID RADWASTE FOR CASE E (SEE TABLE 2-4): A SELECTED WORST CASE FOR A 3500 MWt REACTOR

	BWR		PWR	
	Ci/yr	%	Ci/yr	%
CR-51	2000	21.1	100	1.1
MN-54	800	8.4	400	4.2
FE-55	100	1.1	100	1.1
FE-59	300	3.2	100	1.1
CO-58	1800	18.9	2700	28.4
CO-60	1300	13.7	1800	18.9
ZN-65	400	4.2	100	1.1
SR-89	80	0.8	20	0.2
SR-90	20	0.2	80	0.8
I-131	300	3.2	2000	21.1
CS-134	700	7.4	700	7.4
CS-137	1400	14.7	1300	13.7
CE-141	300	3.2	100	1.1
TOTAL	9500		9500	

TABLE 2-10

NUCLIDE COMPOSITION (%) OF WET RADWASTE SHIPPED FROM ELEVEN NUCLEAR REACTOR SITES*

	BWRs							PWRs				
Nuclide	Brunswick	Cooper	Hatch	Millstone #1	Nine Mile Point	Pilgrim	Vermont Yankee	Conn Yankee	Indian Point	Maine Yankee	Prairie Island	Robinson
CR-51	37	39	40				17					
MN-54	5	10		31	3	16			2		9	3
FE-59	3											
CO-58	35	20						10	22	20	64	11
CO-60	4	20	Both Co=31	49	22	52	29	80	4	7	22	34
ZN-65	2	1	27				24					
TC-99M	5											
CS-134				6	25	6		5	29	28		18
CS-137				9	47	15	14	5	43	45		24
CE-141	8											

*The data is for the same periods shown in Tables 2-5 and 2-6. Since the bulk of the activity is in the wet waste, these compositions apply to the total radwaste as well (excluding spent fuel, control rods, structural components and similar hardware items).

TABLE 2-11

ESTIMATES OF SPECIFIC ACTIVITIES OF WET WASTES AND RESINS

Description of Source	BWR Ci/m^3	PWR Ci/m^3
Maximum for all wet wastes from WASH-1258	30	100
Maximum for all wet wastes for ERDA-76-43 (including non-combustible slurries)	7.3	17
Maximum class of resin from ERDA-76-43	229	647
Average wet waste from Tables 2-5 and 2-6	2.5	5.2
Average of resin shipments (site with maximum)	Oyster Creek 104	Point Beach 343
Maximum found for any single shipment*	Pilgrim (Clean-up Sludge) 1434	Point Beach (Resin) 1168

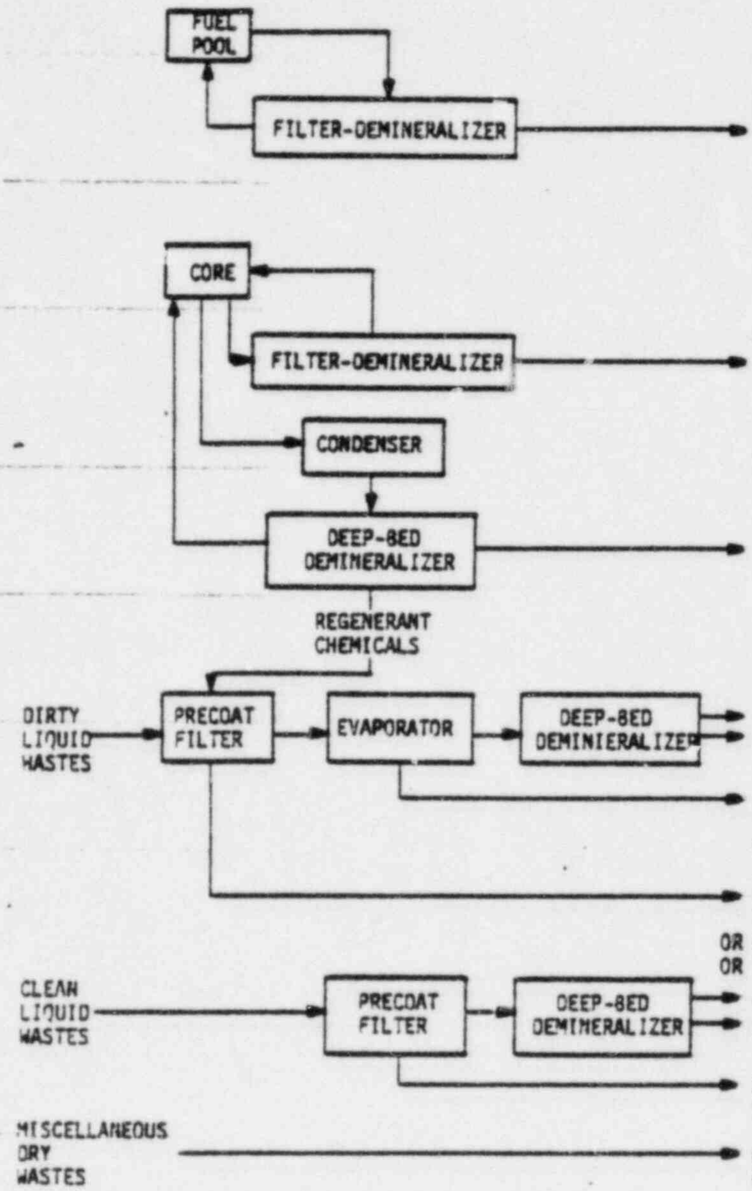
*Only those reactors which listed activity and volume for each shipment could be examined.

TABLE 2-12

RWR-1™ CAPACITY*

Reactor Type	Condensate Cleanup Method	Waste Generation from ERDA-76-43 (m^3/yr)	Days per year Required to Process ERDA-76-43 Wastes	RWR-1™ Capacity at 264 day/year (m^3/yr)
BWR	Deep Bed	684	184	980
BWR	Powdered Resin	445	120	980
PWR	Deep Bed	586	137	1230
PWR	Powdered Resin	371	93	1050

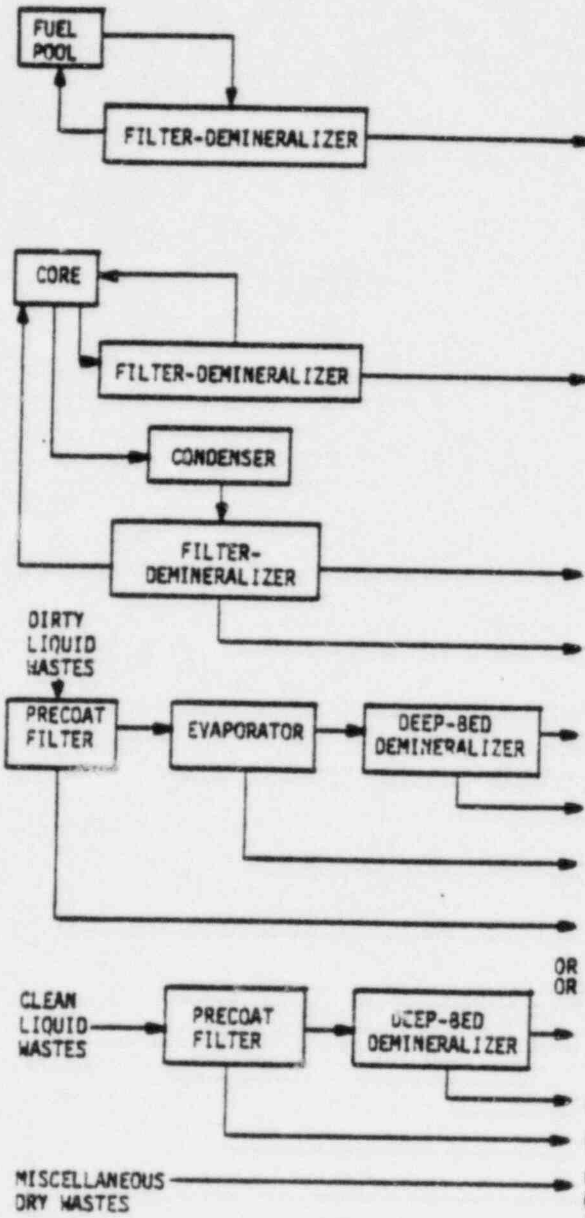
*The volumes generated for the different types of waste are those presented in ERDA-76-43.(9) It is assumed that the RWR-1™ System operates three shifts (24 hours) per day, and that the distribution of the total volume among the various types of waste does not vary with the total volume.



PRIMARY WASTE PER GWe-year			
FORM	UNCOMPACTED VOLUME M^3	RADIO-ACTIVITY Ci	TYPE
POWDERED RESINS	2.8	<10	COMBUST. By
BEAD RESINS	4.8	1000	COMBUST. By
BEAD RESINS	9.9	5.0	COMBUST. By
PURIFIED LIQUID BEAD RESINS	2.8	5.0	COMBUST. By
SLURRY ~25% DISSOLVED SOLIDS, MOSTLY Na_2SO_4	280	40	NON-COMBUST. LIQUID By
PRECOAT SLUDGE, DIATOMACEOUS EARTH OR CELLULOSIC FIBERS OR POWDERED RESINS	42	30	COMBUST. By
PURIFIED LIQUID BEAD RESINS	5.7	10	COMBUST. By
PRECOAT SLUDGE POWDERED RESIN	57	10	COMBUST. By
HEPA FILTERS, CHARCOAL, PLASTIC, PAPER, WOOD, METAL, RUBBER	280	<5.0	COMBUST. By and NON-COMBUST. SOLID By

FIGURE: 2-1* Non-Gaseous Wastes From a BWR with Deep-Bed Condensate Cleanup

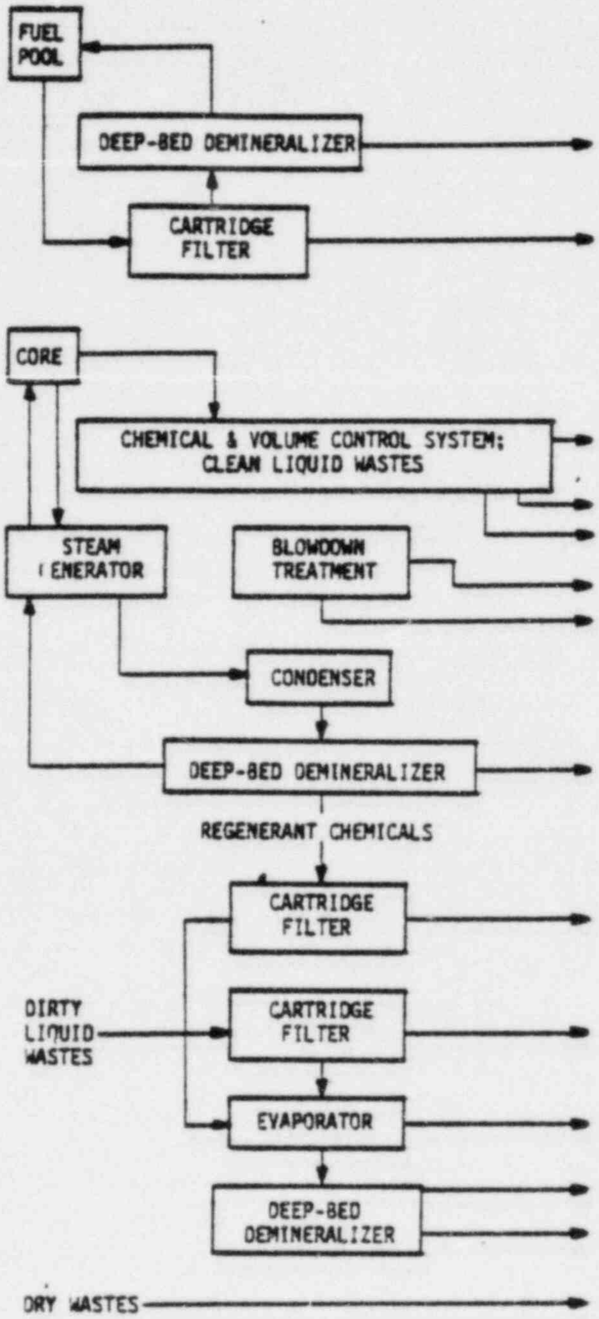
* (This figure is drawn from ERDA-76-43 (9), Vol. 1, Fig. 2.7. p. 2.22. The total waste for this case amounts to 684 m^3 containing 1115 Ci.)



PRIMARY WASTE PER GWe-year			
FORM	UNCOMPACTED VOLUME M^3	RADIO-ACTIVITY Ci	TYPE
POWDERED RESIN	2.0	<10	COMBUSTIBLE βγ
POWDERED RESIN	4.8	1100	COMBUSTIBLE βγ
POWEDERED RESIN	94	70	COMBUSTIBLE βγ
CARTRIDGES	2.3	1.0	COMBUSTIBLE βγ
PURIFIED LIQUID			
BEAD RESINS	.28	1.0	COMBUSTIBLE βγ
SLURRY ~25% DISSOLVED SOLIDS, MOSTLY Na_2SO_4	.14	<10	NON-COMBUSTIBLE LIQUID βγ
PRECOAT SLUDGE, DIATOMACEOUS EARTH OR CELLULOSIC FIBERS OR POWDERED RESIN	14	<5.0	COMBUSTIBLE βγ
PURIFIED LIQUID			
BEAD RESINS	5.7	<10	COMBUSTIBLE βγ
RESIN SLUDGE	42	<10	COMBUSTIBLE βγ
HEPA FILTERS, CHARCOAL ABSORBERS CLOTHING, PLASTIC, PAPER, WOOD, METAL, RUBBER	280	<5.0	COMBUSTIBLE βγ and NON-COMBUSTIBLE SOLID βγ

FIGURE: 2-2* Non-Gaseous Wastes from a PWR with Powdered Resin Condensate Cleanup

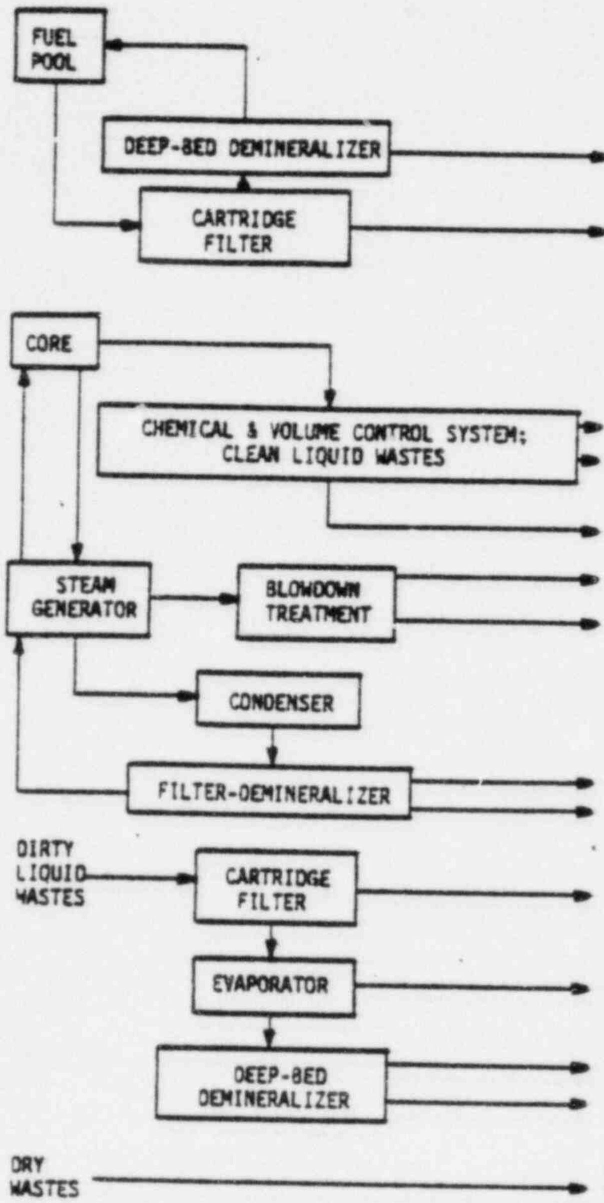
* (This figure was drawn from ERDA-76-43 (9), Vol. 1, Fig. 2.8, p. 2.13. The total waste for this case amounts to 445 m containing 1223 Ci.)



PRIMARY WASTE PER GWe-year			
FORM	UNCOMPACTED VOLUME M^3	RADIO-ACTIVITY Ci	TYPE
BEAD RESINS	1.4	5.0	COMBUSTIBLE $\beta\gamma$
FILTER CARTRIDGES	.14	5.0	COMBUSTIBLE $\beta\gamma$
BEAD RESINS	8.5	5500	COMBUSTIBLE $\beta\gamma$
FILTER CARTRIDGES	.28	500	COMBUSTIBLE $\beta\gamma$
EVAPORATOR SLURRY	5.7	5.0	NON-COMBUSTIBLE LIQUID $\beta\gamma$
BEAD RESINS	8.5	<20	COMBUSTIBLE $\beta\gamma$
FILTER CARTRIDGES	2.8	10	COMBUSTIBLE $\beta\gamma$
BEAD RESINS	9.9	<1.0	COMBUSTIBLE $\beta\gamma$
CARTRIDGES	2.8	1.0	COMBUSTIBLE $\beta\gamma$
CARTRIDGES	.28	2.0	COMBUSTIBLE $\beta\gamma$
SLURRY ~10% DISSOLVED SOLIDS, MOSTLY H_3BO_3	310	<10	NON-COMBUSTIBLE LIQUID $\beta\gamma$
PURIFIED LIQUID			
BEAD RESINS	5.7	<1.0	COMBUSTIBLE $\beta\gamma$
HEPA FILTERS, CHARCOAL, CLOTHING PLASTIC, PAPER, WOOD METAL, RUBBER	230	<5.0	COMBUSTIBLE $\beta\gamma$ and NON-COMBUSTIBLE SOLID $\beta\gamma$

FIGURE: 2-3* Non-Gaseous Wastes from a PWR with Deep-Bed Condensate Cleanup

* (This figure was drawn from ERDA-76-43, Vol. 1, Fig. 2.10, p. 2.25. The total waste for this case amounts to 586 m^3 containing 6065 Ci.)



PRIMARY WASTE PER GWe-year

FORM	UNCOMPACTED VOLUME M^3	RADIO-ACTIVITY Ci	TYPE
BEAD RESINS	1.4	5.0	COMBUSTIBLE By
FILTER CARTRIDGES	.14	5.0	COMBUSTIBLE By
BEAD RESINS	8.5	5500	COMBUSTIBLE By
FILTER CARTRIDGES	.28	500	COMBUSTIBLE By
EVAPORATOR SLURRY	5.7	5.0	NON-COMBUSTIBLE LIQUID By
BEAD RESINS	8.5	<20	COMBUSTIBLE By
FILTER CARTRIDGES	2.8	<10	COMBUSTIBLE By
POWDERED RESINS	93	5.0	COMBUSTIBLE By
CARTRIDGES	2.3	<.10	COMBUSTIBLE By
CARTRIDGES	.28	2.0	COMBUSTIBLE By
SLURRY~10% DISSOLVED SOLIDS, MOSTLY H_3BO_3	17	2.0	NON-COMBUSTIBLE LIQUID By
PURIFIED LIQUID			
BEAD RESINS	1.4	<1.0	COMBUSTIBLE By
HEPA FILTERS, CHARCOAL, CLOTHING, PLASTIC, PAPER, WOOD, METAL, RUBBER	230	<5.0	COMBUSTIBLE By and NON-COMBUSTIBLE SOLID By

FIGURE: 2-4* <u>Non-Gaseous Wastes from a PWR with Powdered Resin Condensate Cleanup</u>

* (This figure was drawn from ERDA -76-43, Vol. 1, Fig. 2.9, p. 2.24. The total waste for this case amounts to 371 m^3 containing 6060 Ci.)

Figure 2-5 Sheet 1

General Equipment Arrangement

This figure contains proprietary information

Figure 2-5 Sheet 2

General Equipment Arrangement

This Figure contains Proprietary Information

3.0 SYSTEM DESCRIPTION

3.1 General

The RWR-1^{TM} System is based on advanced fluidized bed technology using an inert bed media to incinerate and calcine within a single-chamber process vessel. The bed media has been demonstrated to be functional at temperatures required for incineration and calcination. The RWR-1^{TM} reduces the need to monitor particle size which is usually necessary in fluidized bed calcination processes. Supplemental energy required for wet solids incineration and calcination is provided by fuel oil burners.

Process off-gas leaving the incinerator/calciner vessel is cleaned in a mechanical dry cyclone and a wet scrubbing system. The wet scrubbing system is comprised of a spray quench tank, a high energy venturi scrubber followed by a wet cyclone, a condenser and a mist eliminator (demister). Gaseous fission products are adsorbed by the scrub liquid and a solid adsorbent bed. Particulate material is removed by the dry cyclone, wet scrub system and HEPA filters. Cleaned off-gas is vented to the atmosphere while the product, a dry granular residue from the dry cyclone, is removed for storage and shipment as reduced-volume radioactive waste. Scrub liquid is recycled through the liquid waste system.

The RWR-1^{TM} System permits the processing of liquid and combustible wastes such as evaporator concentrates, shoe covers, wood, paper, plastics, mops, etc., as well as spent ion exchange resins and filter sludges. Lubricating and transformer oils and other low level plant wastes can also be processed. The operating temperature and residence time in the bed assures complete destruction of all organic wastes fed to the unit.

Three different operating modes are utilized to process a range of waste types: liquid waste calcination, combustible waste incineration, and ion exchange resin and filter sludge incineration. The incineration modes are separated due to differences in the control system action. Mode selection instrumentation is provided so that only one operating mode can occur at any one time. Each mode of operation has a separate feed system. When operating in a given mode, the other feed systems are rendered inoperable by interlocking controls.

3.2 RWR-1™ System Process Description

This section of the Licensing Topical Report describes the processes which take place in the incinerator/calciner during the volume reduction of radioactive wastes and the processes which take place in the off-gas cleanup system during the removal of residue and during the cleaning of the off-gas stream before release to the atmosphere. The flow paths are shown in Figure 3-1.

3.2.1 Incineration and Calcination

The processes upon which the RWR-1™ System is based are incineration and calcination. Advances in fluidized-bed technology allow the incineration and calcination to take place in the same process vessel. The bed is composed of an inert heat-transfer medium which is identical for both the incineration and calcination modes of operation. The high heat capacity or thermal inertia of the bed gives the RWR-1™ System high temperature stability.

In the incineration mode, the basic process is one of combustion. Almost all of the feed is non-radioactive organic material which is intimately mixed with trace quantities of radioactive molecules. Radioactive carbon and radioactive hydrogen are almost entirely absent in the feed, so if the organic molecules are broken down into non-radioactive carbon dioxide and water and allowed to pass off as harmless gases, then the bulk of the waste will have been removed leaving the radioactive material behind. The bulk of the activity in many types of waste are in nuclides of the elements such as strontium, managanese, iron, and cobalt which will form oxides in the hot oxidizing atmosphere of the incinerator. These oxides are solids at the incineration temperature, so an efficient volume reduction process depends upon complete combustion and effective separation of gases and solids in the effluent. The separation takes place in the off-gas system and is discussed in the next subsection.

The fluidized-bed combustion process is a very efficient one. The constant agitation of the bed particles with the small pieces or droplets of the feed material results in a rapid rise of the waste material temperature. The air which maintains the bed in its fluid state provides an ample supply of oxygen, and complete combustion is enhanced by supplying over-fire air above the top of the bed. The rubbing action of the bed wears off the brittle oxidized surface which forms on the larger waste particles and virtually ensures that the center of particles do not remain unoxidized. This bed rubbing action also wears off any liquid coatings which may form on the bed particles. These coatings form because wastes such as plastic melt before oxidizing. Some wastes such as sludges and slurries do not have sufficient caloric content to maintain the bed at the desired temperature. In this case additional heat is provided by the injection of fuel oil. The thermal inertia of the bed material itself means that the system is relatively insensitive to variations in the exact caloric content of the feed.

In the calcination mode, the basic process is one of evaporation or drying: heat is used to drive off water as a vapor, leaving behind an incombustible residue. Spraying the liquid waste into the process vessel creates droplets which are heated rapidly by their contact with the hot bed particles. As the temperature rises the water evaporates leaving dried waste material on the individual bed particles. This dried waste material is ground off the bed particles by the agitation of the bed and is elutriated from the process vessel to the dry cyclone.

The calcination process is endothermic, and heat is supplied by the combustion of fuel oil in the fluidized bed. The supply of heat by direct combustion has two advantages over the supply of heat by electric heater or heat exchangers: it eliminates the hot, metallic, heat transfer surfaces which are prone to fouling, and it easily accomodates any organic material which may be contained in the liquid waste.

The use of an inert bed means that the bed material does not have to be changed when switching from incineration to calcination. The size of the bed particles is not greatly affected by contacts in the bed due to the hardness of the material from which the bed particles are made and the soft friable nature of the dry calcine. This means that the size distribution of the bed medium does not have to be monitored continuously. The RWR-1™ System is also largely independent of the chemical composition of the waste because of the inertness of the bed. This is important in an application such as a radwaste volume reduction system for a utility because the chemical composition of the waste is rarely known with any great accuracy.

3.2.2 Off-gas Cleanup

The processes which take place in the off-gas cleanup system depend upon which part of the system is being considered. All the processes are designed to remove material from the effluent of the incinerator/ calciner. All the off-gas cleanup system components except the adsorber are designed to remove particulate matter. The scrub liquid and the adsorber are designed to remove halogens because of the presence of radioactive iodine nuclides.

The first item in this system is the dry cyclone, which removes particles from the hot gas exhausted from the incinerator/calciner. These particles fall by gravity into the product container. The swirling motion of the air in a cyclone causes a centrifugal force to act upon the particles so that they migrate to the wall. The air velocity is lower close to the wall due to the boundary effect, so the particles slide downward along the wall to the particulate exit. The gas stream exits upward from the top center of the cyclone.

Following the dry cyclone is the quench tank. The processes here are cooling and wetting. The off-gas passes upward through the tank while scrub liquid is sprayed in from nozzles near the top of the tank. The turbulent gas motion in the tank causes intimate contact between the gas and liquid streams. One effect of this contact is the cooling of the gas; another is the wetting of most of the remaining particles in the off-gas stream. The larger droplets fall to the bottom of the tank and return to the scrub liquid tank, taking the wetted particles with them. Smaller droplets are swept out of the quench tank with the off-gas stream.

Following the quench tank is a venturi scrubber, which wets those few particles which were not wetted in the quench tank. The process is one of condensation. The off-gas leaving the incinerator/calciner contains a great deal of water vapor. Passage through the quench tank added more water vapor and cooled the gas so that the off-gas is saturated or nearly saturated when it reaches the venturi scrubber. More scrub liquid is sprayed into the gas as it passes through the throat of venturi to ensure saturation. As the off-gas passes through the venturi throat, the pressure drops, which causes an increase in the amount of moisture which the gas can hold in vapor form, so evaporation occurs. As the gas enters the divergent section of the venturi, the velocity decreases and the pressure increases, resulting in condensation of water vapor. This condensation causes the existing droplets to get larger, but it also causes new droplets to form on the unwetted particles which serve as condensation nuclei.

The purpose of the quench tank and the venturi scrubber is to wet as many of the particles as possible because it is easier to remove a liquid droplet than it is to remove a much smaller solid particle. The following pieces of equipment are designed to remove the droplets and the particles they contain. It is irrelevant whether the particle was composed of soluble material and has gone into solution in the droplet or the particle was composed of insoluble material and is retained as a wetted solid within the droplet - in either case the particle moves with the droplet. In the process of creating these droplets, an immense liquid surface area was created in the off-gas stream. The chemical additives to the scrub liquid have been designed to enhance gas liquid reactions which will draw gaseous halogens, especially iodine, from the gas into the liquid. The large surface area due to the process of droplet formation creates the ideal conditions for these reactions to proceed rapidly. Once the iodines are captured they are retained in the solution long enough to decay to stable xenon.

The first item which removes liquid droplets from the off-gas steam after the venturi scrubber is the wet cyclone. It operates on the same principles as the dry cyclone. The second droplet removal mechanism is a condenser, which is a shell and tube heat exchanger that cools the off-gas. The cooling here is substantial, and the droplets grow in size to the point where a significant amount of the water in the off-gas is removed by gravitational or momentum effects. In the gravitational removal mechanism, the drops are so large thay they fall to the bottom of the vessel as rain, in the momentum removal mechanism, the droplets are not large enough to fall out of the off-gas stream, but they are large enough so that when the gas changes direction suddenly, the droplets impinge upon the wall or other solid material which has caused the direction change.

Following the condenser is a demister, which removes drops solely by the momentum removal effect. The gas is passed through a filter of woven fibers and in doing so the air molecules make many rapid turns. The liquid drops are too large to turn as sharply and collide with the filter fibers. The droplets then run down the fibers to the wall of the demister and from there to the drain which returns the liquid to the scrub liquid system.

Following the demister is a heater which heats the gas stream. The purpose of this is to evaporate any remaining droplets and so protect the HEPA filter from plugging due to moisture overloading. The HEPA filter removes particles which have escaped unwetted or which were formed when the few droplets which were not removed in the demister were evaporated. The filter is composed of a medium with very small pores, and the particles are removed by impingement. Following the first HEPA is an iodine adsorber which removes halogens by adsorption. The halogen atoms are held on the surface of the material by a chemical bond with the adsorbing agent and decay to stable xenon. A second HEPA filter, following the adsorber, is purely a redundant safety item which will capture particles if a failure occurs in the first filter.

3.3 RWR-1™ Components Descriptions

The RWR-1™ System can be divided into three major subsidiary systems as shown on Figure 3-1. These are the (1) feed, (2) incineration/ calcination and (3) off-gas cleanup systems. Table 3-1 lists the components which make up the complete RWR-1™ System. Noted are those items which are always furnished and those which are optional. The standard system components are shown in Figure 3-2.

The feed system delivers radwaste to the incinerator/calciner where the volume reduction takes place at elevated temperatures. Off-gas from the incinerator/calciner is scrubbed and filtered to remove pollutants before leaving the system via the stack. Radioactive residues leave the system as dry granular solids which are packaged for further processing or storage.

3.3.1 Feed System

The feed system consists of three distinct subsystems, which supply the incinerator/calciner with three types of waste: low-level combustible waste, spent resins and sludges, and liquid waste.

3.3.1.1 Combustible Feed Subsystem

The combustible feed sub-system consists of a shredder, a storage hopper, a mechanical feed device and an isolation valve. The initial step in handling combustible waste is to reduce the size of the individual pieces of waste so that it can be transported into the incinerator efficiently. This is accomplished with a shredder located directly above the storage hopper so that the shredding and hopper loading operations occur simultaneously with minimum effort and exposure. The storage hopper is large enough to contain a month's supply of shredded waste. It will be sealed after filling. The possibility of combustion products filtering back through the feed system is remote because the waste is injected into a region of the incinerator where the pressure is lower than ambient pressure.

A mechanical feed device will automatically meter waste from the hopper into the incinerator through an isolation valve, which is used to provide a positive air tight seal when the low level combustible feed system is not in use.

3.3.1.2 Resin Sludge Feed Subsystem

The resins and sludges are fed to a mixing/dewatering tank, then through a metering device into the incinerator. The mixing/dewatering tank provides a continuous supply of waste material to the metering device. Mechanical agitation of the waste helps prevent bridging, compaction, or adhesion to the tank walls. The water that results from dewatering can be returned to the slurry pumping system as makeup water or pumped to the liquid waste storage tank. A positive displacement mechanical feed device meters the waste as it is injected into the incinerator. Compaction in this device causes a second dewatering cycle which further reduces the liquid content of the waste. This system can be continuously operated since dewatering, metering, and injection are simultaneous operations. The rate of feed is automatically regulated.

3.3.1.3 Liquid Feed Subsystem

The liquid waste feed subsystem consists of a pumping/metering/injection system. Contaminated liquid wastes will be pumped directly from plant storage facilities to the incinerator to allow a continuous calcining operation. The pumping/metering/injection system consists of a pump, strainer, meter and atomizing nozzles. The metering device automatically regulates the liquid waste flow. The self-cleaning strainer minimizes the chances that injection lines and the nozzles will become plugged. The atomizing nozzles, which can be remotely cleaned, atomize the liquid waste as it is injected into the incinerator. In addition, this feed system will be maintained at a high temperature to retard the precipitation of dissolved solids from the waste stream.

3.3.2 Incinerator/Calciner

The major components of this subsidiary system are the fluidized bed vessel, the fluidizing air blowers and air inlet nozzles, and the fuel oil pumps and nozzles. The fluidized bed vessel contains the inert bed medium and is the place in which the incineration and calcination processes take place. The three feed subsystems inject the feed into this vessel for processing. Air from the fluidizing blowers enters the bottom of the vessel to keep the bed at its proper height and to supply oxygen for combustion. Additional air is injected above the bed to enhance complete combustion. The fluidized bed vessel is tall enough to provide adequate residence time above the bed for combustion to take place before the entrained particulate matter is exhausted into the dry cyclone. Heat for endothermic reactions and for pre-heating the bed is provided by the combustion of liquid hydrocarbon fuel in an auxiliary burner in the bed.

3.3.3 Off-gas Cleanup System

The initial component of the off-gas cleanup system is the dry cyclone as shown in Figure 3-1. The dry cyclone removes the bulk of the solid material in the off-gas and transfers it by gravity to the product container. The off-gas entrance is at the side near the top so that a circular swirling motion is imparted to the gas. The off-gas exits through the top center of the cyclone and product exits out the bottom. The quench tank is a large vessel with provisions for gas entry at the bottom and exit at the top. Scrub liquid is sprayed in through nozzles at the top of the tank and exits by gravity through a drain in the bottom.

The venturi scrubber is essentially a piece of pipe with a nozzle which causes faster flow and lower pressure in the throat. It contains ports for spraying scrub solution into the off-gas at the throat. The wet cyclone is similar to the dry cyclone, but removes liquid droplets instead of solid particles. The liquid runs down the side of the cyclone to a drain in the bottom. The condenser is a shell and tube heat exchanger. Cool water is run through the heat exchanger in order to reduce the off-gas temperature. The demister is a tank containing a fiber air straining device in which the gas passes through many layers of a material which has small pores. The HEPA filters are constructed of a material with very small openings where particles are removed by impingement. Each filter has a roughing and a finish section. The adsorber is a solid adsorption bed containing a medium onto which an adsorbing chemical has been deposited.

The wet scrubbing system forms a major part of the off-gas system. It is composed of the scrub liquid system and the quench tank, venturi scrubber, wet cyclone, condenser and demister. The scrub liquid system is composed of a scrub liquid holding tank, pumps, a heat exchanger, and the pipes and nozzles though which the scrub liquid is injected into the quench tank and the venturi scrubber. Drain lines return the scrub liquid from the wet cyclone, condenser, and demister. Since much of the heat from the combustion process in the incinerator/calciner is given up to the scrub liquid, scrub liquid is circulated through a heat exchanger to keep the temperature of the scrub solution from getting too high. Condensate from the demister can be returned to the scrub liquid tank to keep the volume of the scrub liquid up if necessary, or it may be sent to the plant's condensate holdup tank. A side stream of scrub solution is recycled back to the liquid waste holding tank or the station evaporators to be processed during the liquid waste calcination mode. This recycle prevents an infinite buildup of solids containing fission and waste products in the scrub liquid since solids are continually entering the scrub liquid as the wet scrubbing system removes particulate material from the off-gas.

The high-temperature process vessels, the incinerator/calciner vessel, the dry cyclone, and connecting pipes will be insulated to limit building air conditioning requirements. The incinerator and much of the off-gas cleanup system will be made of corrosion-resistent material as discussed in Section 3.6.

3.3.4 Component Design

The RWR-1™ System is classed as a radioactive waste system and as such will be designed within the guidelines of the USNRC Effluent Treatment System Branch Technical Position ETSB No. 11-1. (Rev. 1) as discussed in Section 2.5 of this report. The recommendations from Table 1 of ETSB No. 11-1 are presented in Table 3-2.

The major system components as shown in Figure 3-1 are listed in Table 3-3. The operating conditions and volume are listed for each item.

3.4 Off-gas Cleanup System

A large part of the RWR-1™ System is devoted to cleaning the off-gas stream after it leaves the incinerator/calciner. The components of this system have been described in Section 3.3, and the processes which take place in these components are discussed in Section 3.2. The components have been selected and designed to clean the off-gas in a highly efficient manner so that the emissions to the atmosphere are "as low as is reasonably achievable". Decontamination factors (DFs) are determined in Section 4.2. Two values of each DF are given, a value which is expected when the RWR-1™ System is in actual operation at a utility plant, and a lower, more conservative, value used in computing releases to the atmosphere. The overall DFs used in calculating emissions are $4x10^4$ for particulate material and $1x10^4$ for iodine.

3.5 RWR-1^{TM} System Instrumentation and Controls

3.5.1 Reliability Effects

The RWR-1^{TM} System reliability is enhanced by an extensive instrumentation and control system. This instrumentation and control system provides the operator information for process control and also for monitoring the performance characteristics of the components. Monitoring the performance of the components allows the operator to anticipate many problems before a system shutdown becomes necessary. For example, the scrub liquid strainer pressure differential is recorded in the control room. The operator is able to observe the effects of plugging and then remotely change to the redundant strainer before a condition such as loss of scrub liquid flow develops.

Another feature which is included in the instrumentation and control system is a two-level alarm and protective action. When a process parameter drifts outside of the normal operating band, the first indication is an alarm which notifies the operator of the problem. If corrective action is not made, a second alarm, set slightly further outside the control band is actuated. This second alarm is accompanied by automatic protective action. By using this two-level action, many process problems can be corrected by the operator before protective action is initiated and possible process shutdown results.

Another feature of the RWR-1^{TM} instrumentation and control system which leads to improved reliability is the remote control capability of the system. Process flows are automatically controlled so that operator's attention can be directed to the anticipation of process excursions rather than maintenance of steady flow conditions. All redundant equipment can be remotely valved in or out and remotely started. This feature minimizes the operator actions away from the control room.

3.5.2 Instrumentation Types

The sensors used to monitor process temperatures and pressures are thermocouples and pressure transmitters which have well established reliability. The transmitters, controllers, and temperature recorders are all solid-state electrical devices of high reliability. Two types of automatic control valves are used - motor driven and pneumatic. Pneumatic valves are widely used for flow controlling operations. The electrical signal from the automatic controllers is transmitted to the valve where an I/P transducer converts the electrical signal to the required pneumatic pressure range. This combination of electrical controllers and pneumatic flow control valves takes advantage of the strengths of each component. Motor driven valves are used for automatic isolation valves where modulation is not required. The use of these electrically driven valves minimizes the problem of transmission of pneumatic air signals.

3.5.3 Control System Description

The RWR-1™ System's instrumentation and controls maintain process parameters within the limits which assure safe and efficient system operation. The safe operation of the RWR-1™ System is provided by control sequencing and interlocks which prevent improper operation and effect automatic system shutdown if system parameters are not maintained within prescribed limits. Alarms are provided to alert the operator of abnormal conditions. The efficient operation of the RWR-1™ System is accomplished by control devices which maintain the system temperatures, flow rates, and pressures within prescribed limits.

Figure 3-2 is a piping and instrumentation diagram (P&ID) for the system. The following sections describe the protection features of the control system.

3.5.3.1 Incinerator/Calciner Instrumentation and Control

3.5.3.1.1 Vessel Instrumentation and Control

The incinerator/calciner vessel is instrumented for the measurement of temperature and pressure. Thermocouples or equivalent are located in the fluidized bed to measure and allow control of the bed temperature and to activate the interlock system, if necessary. Should the bed temperature drop below the operating range, an alarm is activated. Should the bed temperature continue to drop and approach a condition in which operation is detrimental to the process, a second alarm is sounded and automatic corrective action is initiated. The same two level (alarm/protective) feature applies to high temperature operation. Thermocouples in the vapor space above the fluidized bed are also equipped with two-level high temperature alarm/protection. A temperature logic system is incorporated to prevent spurious initiation of protective action.

Pressure taps are located in the incinerator/calciner vessel which connect to both absolute and differential indicators. These taps are used to measure absolute pressure in the vessel, the fluidized bed density, and the fluidized bed pressure differential. The fluidized bed height can be derived from these measurements.

3.5.3.1.2 Control During Dry Combustible Waste Incineration

During the incineration of combustible wastes the fluidizing air and overfire air flows are set at predetermined levels to maintain optimum fluidization and combustion conditions required for normal expected combustible waste composition. Waste is fed at a controlled rate for these optimum conditions.

Startup of the RWR-1™ System requires a definite sequence of events. The off-gas subsystem is placed in operation first. Only after the bed has been preheated to a pre-set incineration temperature can the combustible waste feeder be started.

Failure of the fluidizing blower scrub liquid pump or off-gas blower will result in an automatic shutdown of the system.

3.5.3.1.3 Control During Resin and Sludge Incineration Mode Controls

Resin and sludge incineration is controlled in the same manner as combustible waste incineration. The operational difference is that bed temperature will be controlled by the fuel burner firing rate.

3.5.3.1.4 Control During Liquid Waste Calcination

The energy for liquid waste calcination is supplied by hydrocarbon fuel. Waste flow is automatically controlled at a predetermined rate and fuel flow is automatically regulated to maintain the appropriate bed temperature. The high and low temperature protective features of the controls terminate the flow of liquid waste and fuel.

System startup procedures require that the off-gas system be in operation and the bed preheated to the pre-set calcination temperature before liquid waste feed can be initiated. A shutdown sequence initiates purging of the liquid waste feed lines with water before the fuel flow is stopped. This water purge insures against line plugging during or after the shutdown sequence.

3.5.3.2 Off-Gas System Instrumentation

3.5.3.2.1 Quench Tank

Scrub liquid flow to the quench tank nozzles is automatically controlled at a rate which is optimum for efficient gas scrubbing and cooling. The temperatures of the scrub solution and the gas leaving the quench tank are recorded. A liquid level indicator and alarm at the bottom of the tank aid in control of liquid level. A high temperature sensor in the gas exit line is provided to indicate quench system malfunctions and initiate protective action.

3.5.3.2.2 Venturi Scrubber

Scrub liquid flow to the venturi scrubber is automatically controlled to ensure optimum particle removal.

3.5.3.2.3 Condenser-Demister

The temperature of gas leaving the condenser is controlled by regulating the cooling water flow rate through the condenser.

3.5.3.2.4 Heater

The heater power input will be regulated to maintain a constant differential temperature. A temperature limit switch insures that the heater does not heat the exit gas above the temperature which could damage the HEPA filter.

3.5.3.2.5 Filters

The roughing and HEPA filter system are equipped with pressure differential indicators to indicate the degree of filter loading.

3.5.3.2.6 Off-Gas Blower

Flow rate, temperature, pressure, humidity, and radiation monitors determine the condition of the gas stream released to the stack. A sample station is provided for analytical determination of the composition of emitted gases. An alarm and automatic shutdown devices will be activated if the radiation detection equipment, located at the blower exit, detects excessive radiation levels.

3.6 Material Selection

The most corrosive conditions occur in the incinerator/calciner, the dry cyclone, and the gas duct leaving the cyclone. Temperatures in the range of 1000°C together with acidic residues result in highly corrosive conditions requiring that these components be fabricated with corrosion resistant alloys such as Inconnel 601. Other metals are also being considered for these components. Samples of these metals will be evaluated in corrosion tests. Final selection will be made following these tests.

The quench tank, associated nozzles, and venturi scrubber will be exposed to corrosive chlorides; however, the presence of the scrub solution will result in the formation of a protective liquid film on these items. They will be fabricated with 304 stainless steel.

The commercial components of the scrub solution and off-gas systems will be fabricated from 304 or 316 stainless steel, whichever is the manufacturer's standard.

The solid waste feed system components, fluidizing air system, off-gas blower, fuel systems, motors, control panels, and other minor components not subject to corrosive conditions will be fabricated with carbon steel.

Table 3-4 summarizes the component materials and alternate candidate materials which have been tentatively selected.

It is recognized from past experience in the field of incineration that material problems have occured in systems similar to RWR-1™. A review of existing radwaste incineration equipment, LA-6252,[5] indicates the magnitude of the corrosion problem. It is known that suitable alloys exist for the construction of the components exposed to these severe corrosive and thermal conditions. However, tradeoffs between availability, ease of fabrication, servicability, process chemistry control and cost must be considered.

The high operating temperature of the incinerator and hot gas duct may require external cooling or the selection of high temperature refractory linings. Also, the possible formation of HCl from the combustion of plastic may pose a threat to prolonged life of austenitic stainless steels. It is believed that scrub liquid chemistry can be adjusted to correct this problem but further material studies are planned. The results of these studies will be included as an addendum to this report when available.

3.7 System/Plant Interfaces

The RWR-1™ System boundary is defined by a series of interfaces with the plant radwaste system and other non-radioactive service piping. These interfaces are listed in Table 3-5 and illustrated in Figure 3-2.

The radioactive waste streams entering the RWR-1™ from the station are:

(1) Concentrated aqueous solutions (bottoms) from the liquid radwaste evaporator - the interfaces are the inlet isolation valves on the pumps between the plant liquid radwaste storage tank and the incinerator/calciner.

(2) Spent resins from the demineralizers - the interface is an isolation valve just upstream of the dewatering tank.

(3) Combustible radwaste from handling, cleaning or maintenance - the interface is a door over the dry waste shredder.

(4) Filter sludges from precoat filters - the interface is an isolation valve just upstream of the dewatering tank.

Radioactive waste streams leaving the RWR-1™ are:

(1) Off-gas scrub solution tank purge - the interface is an isolation valve just downstream of the purge flow control valve.

(2) Floor drain and equipment drain wastes - the interface is the entrance to the drains, which are connected to the station liquid radwaste system.

(3) Ventilation exhaust from the building housing the RWR-1™ System - the interfaces are grates which lead to the station HVAC exhaust system.

(4) Water from dewatering the spent resins and filter sludges - the interface is an isolation valve between the dewatering tank and the plant liquid radwaste system.

(5) Off-gas to the stack - the interface is an isolation valve downstream of the off-gas blower.

(6) Condensate from the demister - the interface is an isolation valve between the demister and the plant condensate water system.

(7) Solid product - the interface is an isolation valve between the dry cyclone and the product container.

The non-radioactive connections with the station are:

(1) Electric power - the interfaces are the output connections of the motor control center(s).

(2) Cooling or service water - the interfaces are isolation valves located between the plant supply and return and the RWR-1™ System.

(3) Instrument and service air - the interfaces are isolation valves between the plant supply systems and the RWR-1™ System.

(4) Fuel oil - the interfaces are isolation valves upstream of the fuel pumps.

(5) Plant or ambient air - the interfaces will be the inlet to the fluidizing blowers.

(6) HVAC makeup air into the building housing the RWR-1™ System - the interfaces will be the grates from the building HVAC inlet system.

(7) Chemical addition - the interface will be an isolation valve upstream of the scrub solution tank.

3.8 RWR-1™ System Operation

3.8.1 Introduction

The RWR-1™ System is a highly instrumented remotely operated system utilizing components with demonstrated reliablity. This section describes automatic control system actions and required operator actions during normal operation. The RWR-1™ System has three operational modes for the three waste feed systems: combustible waste, resins and sludges, and liquid wastes. Startup in all three modes requires preheating the bed to the operating temperature using the fuel burner. Control set points and protective system actions are specific to the mode of operation.

3.8.2 Combustible Waste Incineration Mode

Complete combustion of combustible wastes require adequate air (oxygen) and high temperatures. These requirements are met in the RWR-1™ System by automatically controlling the waste feed, fluidizing air and overfire air rates at pre-set flows. The dry product (ash) elutriated out of the fluidized bed and captured by the dry cyclone accumulates in the product container.

3.8.3 Resin/Sludge Incineration Mode

Adequate air for incineration of ion exchange resins and filter sludges is achieved by automatic control of flows for the resin/sludge feed, the fluidizing air, and the atomizing air. The temperature of the fluidized bed is automatically controlled by a fuel burner to assure complete combustion.

3.8.4 Liquid Waste Calcination Mode

In this mode the fluidized bed temperature is controlled by the fuel burner. The liquid waste and fluidizing air flows are automatically controlled at prescribed values. Since there is no waste combustion in the overfire area in this mode, no overfire air is required.

3.8.5 Off-gas System

The scrub liquid temperature and scrub liquid flows to the quench tank and venturi scrubber are automatically maintained at optimum values. The scrub liquid composition is controlled by the scrub liquid recycle rate to the station liquid waste system. This flow is automatically controlled at a pre-set value which is selected to give the optimum scrub liquid composition.

The amount of water vapor condensed from the off-gas is controlled by the condenser exit temperature. The operator has the option of either contolling this temperature at the value which gives a constant scrub liquid system inventory or running the condenser exit at its lowest achievable temperature. By running at the lowest achievable temperature there is excess condensate which is available for return to the station for cleanup and reuse.

3.9 RWR-1™ System Reliability

The investment in a nuclear reactor system is very large; therefore, ensuring a high capacity factor with high reliability in support equipment, such as a radwaste system, is imperative. In the RWR-1™ System, high reliability comes from minimizing the amount of equipment with moving parts and using redundant equipment where moving parts cannot be avoided. The fluidized bed provides high processing efficiency without the mechanical complexity of a moving grate incinerator or a scraped wall evaporator. The off-gas system is composed of low maintenance equipment such as cyclones and quench tanks instead of high maintenance items such as bag filters or packed columns.

Components such as blowers and pumps require periodic maintenance as well as occasional replacement of parts. The actual vendor equipment selected for inclusion in the RWR-1™ System will be items with proven high reliability. Further assurance of high system reliability comes from the use of redundant pumps and blowers.

In summary, equipment selection for the RWR-1™ System is based upon high reliability. In areas where equipment selection alone cannot ensure good reliability, redundant equipment is installed.

3.10 RWR-1™ System Internal Decontamination

The RWR-1™ System is designed to minimize possible crud traps. However, because of the nature of the materials handled, the potential exists for a buildup of radioactive contamination in the form of scale and solid material. To facilitate maintenance in the RWR-1™ System, nozzles for remote decontamination by solution spray are built into the major process vessels.

During a decontamination cycle, the excess decontamination solution will be routed to the plant liquid waste system prior to calcination in the RWR-1™ System during the next operating campaign.

3.11 RWR-1™ System Maintenance

The RWR-1™ System components are designed for high reliability and low maintenance. However, equipment with moving parts such as pumps and control valves will require periodic maintenance. The ease of maintenance of this equipment is greatly influenced by the location of the components in relation to one another.

The RWR-1™ System is based upon the philosophy of placing the basic function components as modules in different cells. For example, the main process cell holds the incinerator/calciner and dry cyclone. The wet scrubbing cell contains the quench tank, venturi scrubber, condenser and demister. The scrub liquid pumps and most of the valves are located in cubicals outside the major processing cells. Thus, they are accessible for maintenance without decontaminating the complete system. The final off-gas treatment equipment (HEPA filters and iodine adsorbers) are located in individual cells to permit ease of maintenance and replacement. Figure 2-5 shows the plan location of the major components.

Major maintenance would occur only after a decontamination cycle using the internal decontamination headers located in all major process vessels. Depending upon the residual radiation fields, either direct maintenance or a combination of direct plus remote maintenance will be used. All weldments are of the butt type and flanges are minimized to reduce possible locations where crud buildup might occur. Socket welds are not used. Provisions have been made for retracting the screw feeders used in the feed systems.

TABLE 3-1

RWR-1™ SYSTEM COMPONENTS

Component	No. Required	Normally Furnished With RWR-1™
1. Solid Waste Shredder	1	*
2. Solid Waste Feed Bin & Screw	1	
3. Solid Waste Block Valve	1	
4. Liquid Waste Storage Tank	1	Optional
5. Liquid Waste Feed Pump	2	
6. Liquid Waste Strainer	2	
7. Liquid Waste Control Valve	2	
8. Liquid Waste Feed Nozzle	2	
9. Resin/Sludge Mixing Tank	1	
10. Resin/Sludge Metering Pump & Valve	1	
11. Dewater Liquid Return Pump	1	
12. Fuel Oil Burner, All Valves, Pumps & Ducting	2	
13. Incinerator/Calciner Vessel	1	
14. Fluidizing Air Blower	2	
15. Fluidizing & Overfire Air Control Valves	5	
16. Dry Cyclone	2	
17. Dry Cyclone Product Shutoff Valves	2	
18. Dry Product Storage Hopper	1	Optional
19. Dry Cyclone Product Duct Between Valves	1	
20. Fluidizing Air Ducting - From Valves to Incinerator/Calciner Vessel	1	
21. Fluidizing Air Ducting - From Blower to Valves	1	
22. Hot Gas Duct	1	
23. Quench Tank	1	
24. Quench Tank Spray Nozzles	6	

TABLE 3-1 (Contd)

Component	No. Required	Normally Furnished With RWR-1™
25. Venturi Scrubber	1	*
26. Wet Cyclone	1	
27. Off-Gas Condensor	1	
28. Demister	1	
29. Scrub Solution Tank	1	
30. Off-Gas Duct Connecting Quench Tank, Venturi, Wet Cyclone, Condenser, Demister, Pre-heater, HEPA Filters, Adsorber and Off-Gas Blower	-	
31. Scrub Solution Piping	-	
32. Scrub Solution Pump	2	
33. Scrub Solution Valves	~51	
34. Off-Gas Valves	~34	
35. Air Preheater	1	
36. Raw Water Valves	~12	
37. HEPA & Roughing Filters & Housing	4	
38. Iodine Absorber	2	
39. Off-Gas Blower	2	
40. Off-Gas to Stack, Recirculation & Makeup Air Ducts	-	
41. Fuel Oil System Including Filter, Storage Tank and Piping	2	Optional
42. Control Panel, Controls & Instrumentation, Including Transmitters & Detectors	1	
43. Motor Control Center	1	Optional
44. Fan and Pump Drive Motors - Electric	-	
45. Solenoid and Motor Valve Operators	-	
46. Scrub Solution Cooler	1	
47. Sample Valves	-	Optional

* Blank indicates this item is furnished as a part of RWR-1™.

TABLE 3-2

EQUIPMENT CODES

Equipment	Codes			
	Design and Fabrication	Materials[2]	Welder Qualifications and Procedure	Inspection and Testing
Pressure Vessels	ASME Code Section VIII, Div. 1	ASME Code Section II	ASME Code Section IX	ASME Code Section VIII, Div. 1
Atmospheric or 0-15 psig tanks	ASME Code[3] Section III, Class 3, or API 620 & 650, AWWA D-100	ASME Code[4] Section II	ASME Code Section IX	ASME Code[3] Section III, Class 3 or API 620; 650 AWWA D-100
Heat Exchanger	ASME Code Section VIII, Div. 1 and TEMA	ASME Code Section III	ASME Code Section IX	ASME Code Section VIII, Div. 1
Piping and Valves	ANSI 31.1	ASTM or ASME Code Section II	ASME Code Section IX	ANSI B 31.1
Pumps	Manufacturer's[1] Standards	ASME Code Section II or Manufacturer's Standard	ASME Code Section IX (as required)	ASME[3] Section III Class 3; or Hydraulic Institute

Notes:

[1] Manufacturer's standard for the intended service. Hydrotesting should be 1.5 times the design pressure.

[2] Material Manufacturer's certified test reports should be obtained whenever possible.

[3] ASME Code Stamp and material traceability not required.

[4] Fiberglass reinforced plastic tanks may be used in accordance with Part M, Section 10, ASME Boiler and Pressure Vessel Code, for applications at ambient temperature.

Table 3-3

Component Design Data

This Table contains proprietary information

Table 3-3

Component Design Data
(continued)

This Table contains proprietary information

Table 3-4

RWR-1™ Major Component Materials List

This Table contains proprietary information

TABLE 3-5

INTERFACES OF RWR-1™ SYSTEM WITH PLANT

SYSTEM	INTERFACE
Radioactive Wastes In:	
1. Concentrated Liquid	Inlet isolation valves between plant concentrated waste storage tank and liquid waste pumps.
2. Spent Resin	Inlet isolation valve between plant resin slurry tanks & dewatering tank.
3. Combustible Solids	Door into waste shredder from plant.
4. Filter Sludge	Inlet isolation valve between plant resin slurry tank and dewatering tank.
Radioactive Wastes Out:	
1. Off-gas Scrub Liquid	Outlet isolation valve between flow control valve & concentrated waste storage tank in plant.
2. Floor & Equipment Drain	Entrance to drains connecting with plant liquid waste system.
3. Ventilation Air	Grates leading to plant HVAC system.
4. Resin Dewatering Liquid	Outlet isolation valve between dewatering tank and plant liquid waste system.
5. Off-gas	Outlet isolation valve between off-gas blower and plant stack.
6. Demister Condensate	Outlet isolation valve between demister and plant condensate system.
7. Solid Product	Outlet isolation valve between dry cyclone and plant furnished product container.
Non-Radioactive Connections:	
1. Electric Power	Outlet connections from motor control center to loads.
2. Service Water	Inlet and outlet isolation valves between plant and RWR-1™.
3. Instrument & Service Air	Inlet isolation valves between plant supply and RWR-1™.
4. Fuel Oil	Isolation valves between the plant tanks and the fuel pumps.
5. Ambient Air	Inlet to fluidizing blowers.
6. HVAC Makeup Air	Inlet grates from plant HVAC System.
7. Chemical Addition	Inlet isolation valve between plant and scrub solution tank.

Figure 3-2 Sheet 1

Piping and Instrumentation Diagram

This Figure contains proprietary information

Figure 3-2 Sheet 2

Piping and Instrumentation Design

This Figure contains proprietary information

4.0 ENVIRONMENTAL IMPACT ANALYSIS

This section describes the impact of the operation of the RWR-1™ System on the general environment. An adverse impact may result from the release of gaseous, liquid or solid radioactive material in large, uncontrolled amounts. The RWR-1™ System has been designed on the basis of safety and containment so that no credible accident results in the release of more than a few hundred Curies of airborne activity, this amount of activity being based on several worst case assumptions. The normal operating atmospheric releases are so low that even with very conservative assumptions the resulting doses are orders of magnitude less than typical background doses. Liquid releases to the environment are not envisaged from the RWR-1™ System, either under normal operating conditions or as the result of accidents. Liquid spilled from the RWR-1™ System due to accidents will be contained by the building housing the system.

The solid material from the dry cyclone is placed in a product container and removed in a controlled manner for immobilization or storage. The final destination of the product is burial at a regulated site.

Two types of releases to the atmosphere are considered, normal and abnormal. To determine the normal operating releases, the off-gas cleanup system decontamination factors are determined and applied to the maximum activity feed rates developed earlier (see case E of Table 2-4). Abnormal releases may result from either anticipated transients or postulated accidents. Anticipated transients are considered to be non-catastrophic failures, some of which may be expected to occur at some time during the life of the RWR-1™ System. Postulated accidents are catastrophic events whose occurrence is considered credible though unlikely.

4.1 General Background

Most systems designed to incinerate or calcine radioactive wastes have employed some system to reduce the releases to the atmosphere, although some small, early installations had no off-gas cleaning whatsoever. A review here of the dozens of previous incinerators is not needed because of the recent summaries contained in LA-6252[5] and ERDA-76-43.[6] The older reviews, WASH-1168[7] and IAEA Safety Series No. 28[13] may also be consulted. Four incinerator or calciner systems have off-gas cleanup systems which closely resemble the RWR-1™ System. They are the second incinerator built at Harwell (U.K.)[5,14,15,16], the Waste Calcining Facility (WCF)[2, 17-20] at INEL, the New Waste Calcining Facility at INEL,[21,22] and the Aeropep System.[23,24] Data of sufficient detail from Harwell was not located and NWCF is not built yet, so data from WCF and Aeropep was used. When available, data from WCF is preferred because it comes from long-duration production runs, whereas the Aeropep data is from test operations of relatively short duration.

4.2 Decontamination Factors

The off-gas clean-up system is described in Sections 2 and 3.3 and Figure 3.1. The quench tank, venturi scrubber, wet cyclone, condenser and demister make up the wet scrubbing system. While there are some differences in the efficiency with which the clean-up system removes various elements, the bulk of the activity will be contained in elements which will form stable oxides in the incinerator/calciner, i.e. Cr, Mn, Fe, Co, Sr, Zr, and Cs. Cesium may be in the oxide or hydroxide form depending upon whether hydrolysis takes place. The overall effect of the off-gas cleanup system will be equivalent regardless of whether cesium leaves the calciner/incinerator as an oxide or as a hydroxide. These oxides are all in solid phase at the highest temperatures expected in the RWR-1™ process, and therefore will remain as solid particles throughout the off-gas system. Iodine is present in volatile forms, and its removal from the off-gas is considered separately.

4.2.1 Decontamination Factors for Particles

The RWR-1™ off-gas clean-up system is similar to that used on the Waste Calcining Facility (WCF) at Idaho National Engineering Laboratory (formerly National Reactor Testing Station).[2, 17-20] The two systems are similar in that the incinerator/calciner is followed by a dry cyclone, a quench tank, a venturi scrubber and a wet cyclone. After this first wet cyclone, the WCF System has a second cyclone whereas the RWR-1™ System has a condenser and a demister. Following the second cyclone, the WCF System has a heater, an adsorber, a third cyclone, a second heater, and a filter. Following the demister, the RWR-1™ off-gas clean-up system has a heater, a filter, an adsorber and a second filter. The difference in the arrangement of the heater(s), filter(s) and adsorber are not significant. The major difference is that the wet cyclone following the venturi scrubber was followed by a second wet cyclone in the WCF System while the wet cyclone following the venturi scrubber is followed by a condenser and a demister in the RWR-1™ System.

The Decontamination Factors (DFs) reported by WCF are summarized in Table 4-1 for the five processing campaigns. A DF for the dry cyclone is specifically identified only in the report for the fifth campaign.[20] The DFs for the RWR-1™ System are given in Table 4-2. Two values are listed for particles and for iodine; an expected value and a lower, more conservative value which is used in computing emissions and site boundary concentrations.

The efficiency of the dry cyclone was established using data from sodium sulfate calcination feasibility studies.[25] Analysis of solids collected from the cyclone bottom outlet indicate that approximately 82% of the mass of the total solids entering the dry cyclone are collected, with the remainder leaving as fines with the gas stream. Therefore, assuming that the non-gaseous radionuclides exit the dry cyclone in direct proportion to the total solids mass, the DF shown in Table 4-2 can be expected for particulate matter. Similar DFs have been measured in other dry cyclones.[26] For use in computing emissions, however, a more conservative value has been selected.

The size distribution of solids entering and leaving the dry cyclone in the feasibility studies was used to determine the particle size distribution entering the quench tank. The potential of the quench tank for removing solid insoluble particles from the gas stream is dependent upon the particles striking liquid droplets. Knowing the particle size distribution and the expected droplet size distribution in the quench tank, the fraction of the particles which strike a droplet may be computed by standard procedures.[26] Some of the droplets, however, are carried out of the quench tank with the gas stream. Assuming that the mass of the particles collected by the scrub solution leaves the quench tank in proportion with the liquids leaving the quench tank, the DF shown in Table 4-2 for the nuclides in solid form has been computed. Once the solid particle strikes the droplet, its fate is that of the entire droplet and is independent of the solubility of the particle in the liquid comprising the droplet.

A particle wetting efficiency has been calculated for the venturi scrubber, using the particle size distribution leaving the quench tank and standard methods.[26] The unwetted particles reaching the wet cyclone continue with the gas stream and the wetted particles, soluble or insoluble, leave the wet cyclone in proportion to the liquids leaving the cyclone. So few particles will remain unwetted at the wet cyclone that the relative liquid flow rates from the cyclone become the dominant factors in determining the DF across the venturi and wet cyclone. Almost all of the liquid remaining in the off-gas downstream of the wet cyclone is removed by the condenser and the demister.[27] Since the wetted particles will leave the exhaust stream in the same proportion as the liquid, the DF across the condenser and demister is quite high.

The DF across the entire wet scrubbing system is listed in Table 4-2. It is the product of the DF across the quench tank, the DF across the venturi scrubber and wet cyclone, and the DF across the condenser and demister. A much lower value has been used in computing the emissions, so that there may be no question about the fact that the emissions are conservatively overestimated.

For the particle sizes measured in preliminary tests,[25] measured effiencies greater than 99.95% have been reported for HEPA filters.[28,29,30] The DF expected is shown in Table 4-2 and a much lower value has been entered for use in calculating emissions. The second HEPA filter in the system is purely a back-up filter and no credit for its existance is taken.

Table 4-2 lists the overall DF of 4×10^4 which will be used in computing particulate material emissions from RWR-1™. This overall DF is many orders of magnitude below the expected overall DF. In addition, it is lower than the lowest DF measured at WCF. Therefore, 4×10^4 is thought to be a conservative figure.

4.2.2 Decontamination Factors for Iodine

The radionuclides I-131 and I-133 are not mentioned by WASH-1258 because of its 180 day decay basis and their short half-lives. For the same reason, they are not often found in analyses of radwaste shipments. I-131 and I-133 have been included in Tables 2-2 and 2-3 however, because they are expected to be present when the radwaste is fed into the RWR-1™ System. I-131 has also been included in Table 2-9 for the same reason. At the temperature of the incinerator, iodine will be present primarily as I_2 or as HI, both volatile species. Therefore, the iodine will react differently than the particles, and a separate consideration of DFs for iodine is required.

Table 4-2 lists two values for each iodine decontamination factor, a value which should be seen in actual operation, and a lower, conservative value used for computing emissions from the RWR-1™ System. On the basis of tests made with the Aeropep system, a DF of 2 is expected across the dry cyclone, but for the purpose of computing emissions it is assumed that no iodine at all is in particulate form and therefore there is no iodine removal by the dry cyclone.

In the feed to the RWR-1™ System, iodine may be present as elemental iodine (I_2), hydrogen iodide (HI), hypoiodus acid (HOI), or it may be in particulate or organic form. After passage through the highly oxidizing atmosphere of the incinerator/calciner no organic forms remain. It was shown in tests with the Aeropep system[24] that the removal efficiency of a wet scrubbing system was lower for HOI than it was for either elemental or particulate iodine. Therefore it is conservative to assume that all the iodine is present in the form of hypoiodus acid. The Aeropep tests indicated that a DF of 4 was obtained across one wet contacting stage, a venturi scrubber. The RWR-1™ System contains two wet contacting stages in series, a quench tank followed by a venturi scrubber. Therefore a DF of 16 is a very conservative estimate of the DF across the wet scrubbing system in the RWR-1™ System, and this value is used for computing emissions.

More efficient iodine removal than this is expected in actual operation since a proprietary iodine removal additive is being developed for the RWR-1™ System. Tests have been conducted[31] in which a DF greater than 30 was repeatedly obtained in an experimental apparatus which contained one wet contacting stage. The feed gas stream was rich in CO_2 and poor in O_2, as is the case with the off-gas from the incinerator/calciner, and contained iodine gas at about 100 ppm. Since the RWR-1™ System contains two wet contacting stages in series, the DF might be expected to be on the order of 10^3. However, a more conservative value has been entered in Table 4-2 for the expected performance DF of the wet scrubber.

The radioiodine which goes into solution in the scrub liquid will decay with a half-life of about 8 days. Therefore most of the radioiodine will decay to stable xenon isotopes while in the scrub liquid system. The xenon atoms will be vented through the off-gas exhaust. Almost all the iodine which succeeds in passing through the wet scrubbing system will be caught in the silver-loaded adsorber: Table 4-2 lists the DF expected across the adsorber. A DF of this magnitude is well within the capabilities of current technology[32,33]. A value lower than the expected DF has been used in computing iodine emissions. The overall DF for iodine to be used in computing emissions is 1×10^4. It is expected that the actual DF of the operating system will significantly exceed this value.

4.2.3 Release Rates from Maximum Expected Operations

In Table 4-3, the rate of feed from Table 2-9 is divided by the DFs to obtain the rate of release from the RWR-1™ System. Since the rate of feed is conservatively high and the DFs are conservatively low, the calculated release rates are conservatively high. Actual operating releases are expected to be considerably lower than those listed in Table 4-3 due to these conservatisms. Even with these assumptions that overestimate the activity released, the total activity released is computed to be less than 0.5 Ci per year. This may be compared to the thousands of Curies of noble gases estimated to be emitted each year by a 3500 MWt plant.(8)

4.2.4 Dose Rates and Concentrations Resulting from Maximum Expected Operations

The site boundary has been assumed to be 1,000 meters from the point of release. The dilution factor (χ/Q) used, 1.2×10^{-5} sec/m^3, is the 4 to 30 day value for a ground-level release from Regulatory Guide 1.3.(34) Using this value for an annual average dilution factor is very conservative because the average χ/Q varies inversely with the length of time over which the average is taken. Site boundary concentrations calculated from the release rates, with this χ/Q, are listed in Table 4-3. For most nuclides the concentrations are four or five orders of magnitude below the limiting concentrations specified by 10CFR20. The nuclide with the highest concentration has a concentration more than three orders of magnitude less than the limiting concentration.

The last three columns of Table 4-3 list the whole body, thyroid and lung dose rates for the concentrations at the site boundary. It has been assumed for the purposes of this report that the recipient is located at the 1000 meter site boundary and is breathing at a rate of 20 m^3/day. The dose factors used have been taken from Regulatory Guide 1.109.(35) The dose rates are very low even with respect to background radiation. The highest dose rate is that to the thyroid with the feed assumed from a 3500 MWt BWR. This dose rate is less than one millirem per year. Due to the many conservatisms in the computation of the dose rates, the expected dose rates will, in all probability, be much lower than those listed in Table 4-3.

4.3 Exposures from Anticipated Transients and Postulated Accidents

In this section the dose received from radiation due to abnormal occurances in the RWR-1™ System is considered for a hypothetical person standing at the site boundary. Anticipated transients are those events which can reasonably be expected to occur during the operating life of the RWR-1™ System. This class of events includes such occurances as leaks in pipes and tanks, pump failure, and plugs in nozzles. Accidents, on the other hand, are considered to be more catastrophic events which are not expected to occur, but which must be considered possible. An example of an accident is the complete, sudden rupture of a tank. As might be expected, the consequences of the postulated accidents are generally more serious than the consequences of the anticipated transients. Even so, with very conservative assumptions, the maximum dose from the maximum credible accident is shown to be only slightly greater than the maximum annual occupational dose limit.

4.3.1 Anticipated Transients

Transients resulting from the non-catastrophic failure of some component of RWR-1™ may be expected during the lifetime of the system. Because the complete instrumentation system is coupled to alarms and interlocks, most of these transients will cause the RWR-1™ system to shut down quickly with little or no radiation consequences. Table 4-4 lists all the transients which appeared to be reasonably credible.

The first two cases in Table 4-4 concern leaks in liquid lines or tanks. There, leaks will cause contaminated liquid to accumulate on the floor of the radwaste building. The leaks in themselves will not affect the performance of the RWR-1™ System, and the operator will shut down the system. Because the radioactivity will be in the liquid or in particles contained in the liquid, no significant gaseous releases from the building containing the RWR-1™ System are expected. Since the foundation of the building is of seismic design and is capable of containing the entire liquid inventory within the building, no liquid release is expected. There are no adverse radiological consequences associated with leaks in the incinerator/calciner or with leaks in the off-gas system (Item 3 in Table 4-4) because the pressure in the entire system is slightly below atmospheric pressure.

Items 4, 5 and 6 in Table 4-4 concern plugs in the scrub liquid lines. If one of these lines should plug, either a low reading from the flow sensor in the line or a high reading from the liquid level indicator in the quench tank or in the wet cyclone will cause the system to shut down. If the iodine adsorber or one of the HEPA filters plugs (due to excessive moisture loading or particle loading), the increased pressure drop across the adsorber or filter will be sensed. If the adsorber or filter should blow out, the final radiation monitor will register an increase in radiation levels and shut down the incinerator/calciner while recirculating the exhaust gas back through the off-gas clean-up system.

The last ten items listed in Table 4-4 have little potential, if any, for distributing radioactive material to the general environment. These transients either tend to keep radioactive material within the RWR-1™ System or they tend to shut the system down. Out-of-range sensor readings will either shut down the system automatically or initiate both auditory and visual warnings to the operator.

4.3.2 Postulated Accidents

A number of potential accidents have been considered, such as rupture of the resin-sludge dewatering tank, fracture of the dry waste hopper, rupture of the calciner/incinerator, leaks in the off-gas system, rupture of the scrub liquid tank, and failure of any component in the off-gas system. None of these accidents was as potentially serious as the violent rupture of the product container. This is due to the fact that no other portion of the system can accumulate as much activity in dry form. The only other component of RWR-1™ which can accumulate much activity is the scrub liquid tank. If this tank were to rupture, the activity would be released into the radwaste building in wet form. In this form it would be much less likely to pass into the air and escape from the building than it would be in the dry, granular form of the material in the product container. The tanks which accumulate resin, sludge or liquid waste prior to processing in the RWR-1™ System might contain a significant amount of activity, but they are outside the RWR-1™ System and their contents are wet. Therefore, the postulated maximum credible accident is the violent rupture of the product container.

For the purpose of this analysis it is assumed that the product container is a 55-gallon drum. The 55-gallon (0.208 m^3) drum has been chosen because the specific activities in the product are high enough to make larger containers infeasible. Further, the volume reductions occurring in the RWR-1™ process eliminate the necessity for containers larger than 55-gallon drums to contain the product.

By the following analysis it has been determined that 1670 Ci is the upper limit to the activity that will be contained in one drum. Table 4-5 shows all those reactor sites which list resins or resins and sludges separately as well as those which differentiate between wet and dry wastes and which shipped more than 200 Ci/yr of wet waste. A review of this material indicates that it would be extremely unlikely that the RWR-1™ System would process more than 2000 Ci or less than 5 m^3 in one month. Therefore, the maximum specific activity, before processing, would be 400 Ci/m^3. While individual shipments of resin or sludge have had higher specific activities than 400 Ci/m^3 (see Table 2-11), they did not amount to a great deal of volume, as discussed in Section 2.2.3. Other shipments during the month were greater in volume and much lower in specific activity so that the average specific activity of resins and sludges for the month was much less than 400 Ci/m^3. Further, it is assumed in this analysis that the volume reduction is the maximum envisaged for wastes for other than the dry combustible waste, 20:1. A volume reduction of 20:1 is greater than the 18:1 volume reduction expected for spent resin, and has been used here to conservatively increase the specific activity in the drum. Use of a 20:1 volume reduction factor gives a specific activity in the product container of 8000 Ci/m^3, or 1670 Ci per 55-gallon drum. This implies that more than one sixth of the maximum amount of activity for the entire year accumulates in one drum (1670/9500 = 0.166), which is unlikely to occur. It would seem conservative to assume that ten percent of the granular ash in the product container escapes from the building containing the RWR-1™ System and remains airborne long enough to reach the site boundary.

4.3.3 Exposure at the Site Boundary from Anticipated Transients and Postulated Accidents

The potential for the release of radioactive material to the general environment from the postulated maximum credible accident is greater than that from any of the anticipated transients. This is due to the fact that the worst anticipated transient results in the release of the radioactive waste in wet form. In this form it is less mobile and less likely to migrate to the general environment than it is in dry form. The possibility of the release of dry radioactive material by an anticipated transient is essentially zero because the entire off-gas system is operated at a pressure slightly below ambient pressure.

The maximum abnormal release from the RWR-1™ System, then, is that from the postulated maximum credible accident, which is the violent rupture of the product container at a time when the container, assumed to be a

55-gallon drum, is filled with product material which has a specific activity greater than that likely to occur under any reasonable circumstances.

Doses computed assuming that ten percent of the maximum credible contents of the drum (167 Ci) escape from the building in two hours are given in Table 4-6. The dilution factor, χ/Q, used is the 0-2 hour value from Regulatory Guide 1.3[34] for 1000 m and a ground level release. The dose factors were taken from Regulatory Guide 1.109,[35] and the breathing rate was 20 m^3/day. The nuclide distribution has been assumed to be that shown in Table 2-9.

The maximum accidental doses are seen to be quite small, all of them are under 6 rem. This may be compared to the annual occupational permitted dose of 5 rem. Even if 167 Curies were to escape, it is unlikely that the thyroid doses would be as high as shown in Table 4-6. It was assumed in computing these doses that I-131 is present in the product container in the same proportion that it is present in the feed. Actually, due to the volatility of iodine, a much smaller fraction of iodine than of the other nuclides will be removed in the dry cyclone. As shown earlier in this section, the I-131 is captured in the scrub solution and adsorber where it decays to stable Xe-131. Therefore the radioiodine will comprise a smaller fraction of the activity in the product container than it did in the feed. In any event, it is very conservative to assume that one product container will accumulate 1670 Ci, so the likelihood of accident doses as high as those of Table 4-6 is very low, given the rupture of the product container.

TABLE 4-1

SOLID PARTICLE (OXIDE) DECONTAMINATION FACTORS FOR THE OFF-GAS CLEAN-UP SYSTEM OF THE WASTE CALCINING FACILITY

Basis	Reference	Dry Cyclone	Wet Scrubbing System	Adsorber	Filter	Overall
Average of Sr-90 and Cs-137 Measurements During the First Processing Campaign	2	NR	645	10	220	1.4×10^{6}
Sr-90 Measurements During the Second Processing Campaign	19	NR	2750	10	3000	1.6×10^{8}
Sr-90 Measurements During the Third Processing Campaign	20	NR	1000	10	1500	1.5×10^{7}
Sr-90 Measurements During the Fourth Processing Campaign	21	NR	2760	8	630	1.4×10^{7}
Cs-137 Measurements During the Fifth Processing Campaign	22	3	25	3	1300	3.0×10^{5}

NR = Not Reported. In the first processing campaign, a DF of 6.25 is reported for the calciner and dry cyclone together. For the second, third and fourth campaigns, no DF is reported for the dry cyclone, alone or in combination.

Table 4-2

Decontamination Factors For the Off-Gas
Cleanup System of the RWR-1™ System

This Table contains proprietary information

TABLE 4-3

EMISSION RATES, BOUNDARY CONCENTRATIONS, AND DOSE RATES RESULTING FROM THE OPERATION OF THE RWR-1™ SYSTEM*

FOR A 3500 MWt BWR

Nuclide	Rate of Feed	Decontamination Factor	Rate of Release	Concentration Limit	Boundary Concentration	Whole Body Dose Rate	Thyroid Dose Rate	Lung Dose Rate
	Ci/yr		mCi/yr	pCi/m^3	pCi/m^3	mrem/yr	mrem/yr	mrem/yr
CR-51	2000	$4x10^4$	50	80000	.019			
MN-54	800	$4x10^4$	20	1000	.007			.010
FE-55	100	$4x10^4$	2.5	30000	.001	.0001		.001
FE-59	300	$4x10^4$	7.5	2000	.003			.003
CO-58	1800	$4x10^4$	45	2000	.017			.015
CO-60	1300	$4x10^4$	32.5	300	.012	.0002		.067
ZN-65	400	$4x10^4$	10	2000	.004	.0002		.003
SR-89	80	$4x10^4$	2.0	300	.0006			.001
SR-90	20	$4x10^4$	0.5	30	.0002	.0011		.002
I-131	300	$1x10^4$	30	100	.014	.0002	.124	
CS-134	700	$4x10^4$	17.5	400	.007	.0044		.001
CS-137	1400	$4x10^4$	35	500	.013	.0052		.001
CE-141	300	$4x10^4$	7.5	5000	.003			.001
Total	9500		260.0			.0114	.124	.103

TABLE 4-3 (Contd.)

FOR A 3500 MWt PWR

Nuclide	Rate of Feed	Decontamination Factor	Rate of Release	Concentration Limit	Boundary Concentration	Whole Body Dose Rate	Thyroid Dose Rate	Lung Dose Rate
	Ci/yr		mCi/yr	pCi/m^3	pCi/m^3	mrem/yr	mrem/yr	mrem/yr
CR-51	100	$4x10^4$	2.5	80000	.001			
MN-54	400	$4x10^4$	10	1000	.004			.005
FE-55	100	$4x10^4$	2.5	30000	.001	.0001		.001
FE-59	100	$4x10^4$	2.5	2000	.001			.001
CO-58	2700	$4x10^4$	67.5	2000	.026			.022
CO-60	1800	$4x10^4$	45	300	.017	.0002		.093
ZN-65	100	$4x10^4$	2.5	2000	.001			.001
SR-89	20	$4x10^4$	0.5	300	.0002			
SR-90	80	$4x10^4$	2	30	.0008	.0042		.007
I-131	2000	$1x10^4$	200	100	.076	.0014	.828	
CS-134	700	$4x10^4$	17.5	400	.007	.0044		.001
CS-137	1300	$4x10^4$	32.5	500	.012	.0048		.001
CE-141	100	$4x10^4$	2.5	5000	.001			
Total	9500		387.5			.0153	.828	.131

*The rate of feed is taken from Table 2-9. The Decontamination Factors are from Table 4-2. The Concentration Limit is that for unrestricted areas and is taken from 10CFR20, Appendix B, Table II; when the soluble and insoluble limits vary, the lower limit has been used. The boundary concentration has been computed using the 4-30 day χ/Q value for 1000m from Regulatory Guide 1.3, Figure 3 (ground level release). The dose rates have been computed assuming that the recipient stands at the boundary breathing at a rate of 20 m^3/day. The dose factors have been taken from Regulatory Guide 1.109, Table C-1.

TABLE 4-4

ANTICIPATED TRANSIENTS FOR THE RWR-1™ SYSTEM AND THEIR CONSEQUENCES

CASE	COMPONENT(S)	TYPE OF FAILURE	IMMEDIATE CONSEQUENCE	PROCESS INDICATION OF FAILURE	PROCESS IS SHUT DOWN BY	RADIATIONAL CONSEQUENCE
1	Resin-Sludge Tank or Line Dewatering-Tank or Line Liquid Waste Tank or Line	Leak	Contaminated Water on Floor	Room Air Monitor Alarm	Operator	Minor, confined to Radwaste Building
2	Scrub Liquid Tank	Leak	Contaminated Water on Floor	Room Air Monitor Alarm	Operator	Minor, confined to Radwaste Building
3	Incinerator/Calciner Off-Gas Piping	Leak	Building Air Flows into Off-Gas System	System Pressure and Component Differential Pressure Indicators	Operator	None
4	Scrub Liquid Feed Lines	Plug	Loss of Cooling in Quench Tank, or Decrease of Decontamination Factors in Off-gas Cleanup System	High Temperature in the Quench Tank Exhaust, Venturi Exhaust and Wet Cyclone Exhaust. Low Flow Alarms for Quench Tank and Venturi Scrub Liquid. High Radiation Alarm in the Exhaust	Quench Tank Exhaust Temperature Interlock or the Venturi Scrub Liquid Flow Interlock or the Quench Tank Scrub Liquid Flow Interlock or Exhaust Radiation Interlock	Minor
5	Scrub Liquid Return Lines	Plug	Scrub Liquid Accumulates in Quench Tank or Wet Cyclone	High Level Alarm in Quench Tank or Wet Cyclone or Low Level Alarm in Scrub Liquid Tank	Operator	None
6	Coolant Line to or from Scrub Liquid Cooler	Plug	Scrub Liquid Temperature Rises	High Scrub Liquid Temperature and High Quench Tank and Venturi Exhaust Temperature Indicators	Operator or Quench Tank Exhaust Temperature Interlock	None
7	HEPA or Iodine Adsorber	Plug	Increased Pressure Drop	High Pressure Differential Indication or Alarm. Low Pressure Indication at Off-Gas Blower Inlet.	Operator	None

TABLE 4-4 (Contd.)

CASE	COMPONENT(S)	TYPE OF FAILURE	IMMEDIATE CONSEQUENCE	PROCESS INDICATION OF FAILURE	PROCESS IS SHUT DOWN BY	RADIATIONAL CONSEQUENCE
8	HEPA or Iodine Adsorber	Blowout	Increased Activity Downstream	High Radiation Alarm or High Pressure Differential Indication and Alarm prior to Blowout	Operator	None
9	Off-Gas Heater	Electrical	Moisture Plugs HEPA Filter	Low Heater Temperature Differential and High HEPA Pressure Differential Indication or Alarm	Operator	Minor
10	Dry Cyclone	Plug	Particles in Dry Cyclone	High Pressure in Dry Product Exit Pipe	Operator	None
11	Coolant Line to Condenser	Plug	Moisture Plugs HEPA Filter	High Temperature in the Condenser Exhaust, High Temperature Alarm in the Heater Exhaust or High HEPA Differential Pressure Indication or Alarm	Operator	None
12	Fluidizing Blower	Insufficient Flow	Bed Settles	Fluidizing Air Low Flow Alarm	Fluidizing Air Interlock or Fluidizing Blower Interlock	None
13	Off-Gas Blower	Insufficient Flow	Bed Settles	High Off-Gas System Pressure and Low Fluidizing Air Flow	Fluidizing Air Interlock or Off-Gas Blower Interlock	None
14	Scrub Liquid Pump	Insufficient Flow	Loss of Cooling in Quench Tank Decrease of Decontamination Factors	Low Flow Alarms for Quench Tank and Venturi High Temperature in the Quench Tank Exhaust, High Radiation Alarm in the Stack Line	Quench Tank or Venturi Scrub Liquid Low Flow Interlocks or Quench Tank Exhaust Temperature Interlock, Exhaust Radiation Interlock, or Scrub Liquid Pump Interlock	None

TABLE 4-4 (Contd.)

CASE	COMPONENT(S)	TYPE OF FAILURE	IMMEDIATE CONSEQUENCE	PROCESS INDICATION OF FAILURE	PROCESS IS SHUT DOWN BY	RADIATIONAL CONSEQUENCE
15	Fuel Pump	Insufficient Flow	Bed Temperature Drops	Low Fluidized Bed Temperature	Fluidized Bed Temperature Interlocks	None
16	Resin-Sludge Feed Pump Liquid Feed Pump	Insufficient Flow	No Waste Feed	Low Waste Feed Alarms	Operator	None
17	Dry Waste Screw Feeder	Stops	No Waste Feed	Waste Feed Hopper Low Level Alarm Fluidized Bed Low Temperature Alarm	Operator or Fluidized Bed Low Temperature Interlock	None
18	Plant Compressed Air	Low Pressure	Loss of Air to Atomize Fuel and Operate Valves	Low Atomizing Air Flow or Low Pressure Alarms, Multiple Alarms as Control Valves Move in Fail-Safe Direction	Operator	None

TABLE 4-5

RESINS AND TOTAL WET SOLIDS SHIPMENT RATES*

Site	Type of Waste	Shipment Rate Ci/yr	m^3/yr	Ci/mo	m^3/mo
Browns Ferry 1 & 2	Low-level Resin	280	185	23	15
	High-level Resin	387	7	32	0.6
	Total Resin	667	192	53	16
Brunswick 2	Total Wet Solids	267	879	22	73
Conn Yankee	Total Wet Solids	1970	160	164	13
Cooper	Total Wet Solids	549	344	46	29
Dresden 1, 2 & 3	Total Wet Solids	570	1668	47	139
Fitzpatrick	Total Wet Solids	241	718	20	60
Indian Point	Total Wet Solids	2071	442	173	37
Maine Yankee	Total Wet Solids	1878	195	156	16
Millstone 1	Total Wet Solids	3635	1034	303	86
Nine Mile Point	Resin	1493	38	124	3
	Evaporator Bottoms	891	467	74	39
	Filter Sludge	2454	123	204	52
	Total Wet Solids	4838	628	403	52
Oyster Creek	Resin	1857	18	155	1.5
Pilgrim	Total Wet Solids	12244	970	1020	81
Point Beach	Resin	4804	14	400	1.2
Robinson		1389	291	116	24
ERDA-76-43	Total Wet Solids -BWR	1331	182	111	15
	PWR	6055	141	505	12

*These radwaste shipment rates are for reactor sites which distinguished resin or total wet solids (resins, sludge, and evaporator bottoms) and which shipped over 200 Ci/year. The rates are normalized to 3500 MWt. Values from ERDA-76-43 (powdered resin system) have been included for comparison.[9]

TABLE 4-6

DOSES AT THE SITE BOUNDARY RESULTING FROM THE POSTULATED MAXIMUM CREDIBLE ACCIDENT*

ORGAN	BWR Dose (rem)	BWR Nuclides** Making Major Contribution	PWR Dose (rem)	PWR Nuclides** Making Major Contribution
Bone	0.69	SR-90,CS-137	2.04	SR-90
Liver	2.03	FE-59	1.07	FE-59
Whole Body	0.31	CS-137,CS-134	0.39	CS-137,CS-134
Thyroid	0.87	I-131	5.74	I-131
Lung	2.86	CO-60 CO-58,MN-54	3.62	CO-60,CO-58

*The doses are based upon the assumption that 167 Curies (10% of the activity in the product container) escapes from the radwaste building. The χ/Q used is the 0-2 hour value for 1000 m from Regulatory Guide 1.3, Figure 3 (ground level release). The dose factors have been taken from Regulatory Guide 1.109, Table C-1. The breathing rate was 20 m^3/day.

**The nuclide distribution in the escaping material is assumed to be that shown in Table 2-9.

5.0 RWR-1™ SYSTEM BENEFITS

5.1 On-Site Benefits

The environmental and economic benefits of any volume reduction system are very much a function of site specific considerations. However, certain qualitative assessments can be made with some validity on a generic basis.

The RWR-1™ volume reduction system reduces the number of containers that must be handled by the plant operating personnel and, therefore, some reduction in occupational radiation exposure can be expected. This volume reduction will also result in a reduction in the amount of on-site radwaste storage space required.

The volume reduction achieved with this system suggests that, in general, substantial reductions in the cost of radwaste disposal can be expected. In some cases, these cost savings can amount to over 50% of the total present annual radwaste disposal costs.

5.2 Off-Site Benefits

The reduced volumes of radwaste indicate a reduction in the number of shipments of radwaste to licensed disposal sites. This should therefore decrease the probability of radioactive releases to the environment due to transportation accidents.

Volume reduction at the origin results in reducing the rate at which available space will be exhausted at existing disposal sites. Volume reduction by an overall factor of approximately ten suggests that presently available disposal sites could continue to accept wastes for a longer period of time; perhaps doubling present predictions.

Thus it would appear that the RWR-1™ volume reduction system has the potential for substantial, beneficial impacts upon the environmental and economic aspects of radwaste disposal.

6.0 REFERENCES

1. Richard C. Corey, ed. Principles and Practices of Incineration. Wiley-Interscience, New York, 1969. p. 239.

2. R. E. Commander, et al. Operation of the Waste Calcining Facility with Highly Radioactive Aqueous Waste: Report of the First Processing Campaign. IDO-14662, Phillips Petroleum Co., Idaho Falls, ID, June 1966.

3. W. A. Freeby. Interim Report: Fluidized-Bed Calcination of Simulated High-Level Commercial Wastes. ICP-1075, Allied Chemical Corp., Idaho Falls, ID, June 1975.

4. U.S. Energy Research and Development Administration. Alternatives for Managing Wastes from Reactors and Post-Fission Operations in LWR Fuel Cycle. ERDA-76-43, USERDA, Washington, DC, May 1976. V. 2, p. 6.13-6.34.

5. B. L. Perkins. Incineration Facilities for Treatment of Radioactive Wastes: A Review. LA-6252, Los Alamos Scientific Laboratory, Los Alamos, NM, February 1976.

6. U.S. Energy Research and Development Administration, op. cit., V. 2, Ch. 9.

7. U.S. Atomic Energy Commission. Incineration of Radioactive Solid Wastes. WASH-1168, USAEC, Washington, DC, August 1970.

8. U.S. Atomic Energy Commission, Directorate of Regulatory Standards. Final Environmental Statement Concerning Proposed Rule Making Action: Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low As Practicable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents. WASH-1258, USAEC, Washington, DC, July 1973. V. 1, Ch. 2.

9. U.S. Energy Research and Development Administration, op. cit., V. 1, Sec. 2.2.

10. A. H. Kibbey and H. W. Godbee. Critical Review of Solid Radioactive Waste Practices at Nuclear Power Plants. ORNL-4924, Oak Ridge National Laboratory, Oak Ridge, TN, March 1974.

11. U.S. Nuclear Regulatory Commission, Effluent Treatment Systems Branch. Branch Technical Position 11-1: Design Guidance for Radioactive Waste Management Systems Installed in Light-Water Cooled Nuclear Reactor Power Plants, Revision 1, November 24, 1975.

12. American Society of Mechanical Engineers. Boiler and Pressure Vessel Code, Section VIII, Division 1: Rules for Construction of Pressure Vessels. ASME, New York, 1974.

13. Internation Atomic Energy Agency. Management of Radioactive Wastes at Nuclear Power Plants. (IAEA Safety Series 28). IAEA, Vienna, 1968.

14. R. H. Burns, G. W. Clare, and J. H. Clarke. Radioactive Waste Control at the United Kingdom Atomic Research Establishment, Harwell. AERE-R-5900, Atomic Energy Research Establishment, Harwell, England, 1968.

15. International Atomic Energy Agency. The Volume Reduction of Low-Activity Solid Wastes. (IAEA Technical Reports Series 106). IAEA, Vienna, 1970.

16. R. H. Burns and J. H. Clarke. "Harwell Experiences in Waste Management", in Management of Low- and Intermediate-Level Radioactive Wastes, Proceedings of the Symposium held at Aix-en-Provence, September 7-11, 1970. IAEA, Vienna, 1970. p. 419.

17. G. E. Lohse and M. P. Hales. Second Processing Campaign in the Waste Calcining Facility. IN-1344, Idaho Nuclear Corp., Idaho Falls, ID, March 1970.

18. C. L. Bendixsen, G. E. Lohse, and M. P. Hales. The Third Processing Campaign in the Waste Calcining Facility. IN-1474, Idaho Nuclear Corp., Idaho Falls, ID, May 1971. p. 23.

19. J. A. Wielang, G. E. Lohse, and M. P. Hales. The Fourth Processing Campaign in the Waste Calcining Facility. ICP-1004, Allied Chemical Corp., Idaho Falls, ID, March 1972, p. 25.

20. J. A. Wielang and W. A. Freeby. The Fifth Processing Campaign in the Waste Calcining Facility. ICP-1021, Allied Chemical Corp., Idaho Falls, ID, June 1973, p. 19.

21. U.S. Atomic Energy Commission. Draft Environmental Statement: New Waste Calcining Facility, National Reactor Testing Station, Idaho. WASH-1531, USAEC, Washington, DC, January 1974.

22. R. R. Smith and J. A. Carter. Final Design Criteria for New Waste Calcining Facility (NWCF), (Allied Chemical Corp. Internal Report ACI-176, January 1976.)

23. Topical Report: Fluid Bed Dryer and Aeropep Solidification System. AECC-1, Aerojet Energy Conversion Co., Sacramento, CA, February 21, 1975.

24. Amendment 2 to Topical Report: Fluid Bed Dryer and Aeropep Solidification System. AECC-1, Amend. 2, Aerojet Energy Conversion Co., Sacramento, CA, September 30, 1975.

25. L. G. Gale et al. Final Report - Liquid Waste Calcination Feasibility Tests - Task I-C. Energy Inc., Idaho Falls, ID, February 1976.

26. J. M. Marchello and J. J. Kelly. Gas Cleaning for Air Quality Control. Marcell Dekker, New York, 1975, p. 258-283, 314-319.

27. C. A. Burchsted, J. E. Kahn, and A. B. Fuller. Nuclear Air Cleaning Handbook: Design, Construction, and Testing of High-Efficiency Air Cleaning Systems for Nuclear Application. ERDA-76-21, Oak Ridge National Laboratory, Oak Ridge, TN, March 1976, p. 64-72.

28. Flanders Air Filtration Systems. Flanders Filters, Inc., Washington, NC, 1975.

29. C. A. Burchsted, op. cit., p. 42-43.

30. J. D. DeField and H. J. Ettinger. "Efficiency Testing of the Air Cleaning System for a High Temperature Reactor", in Treatment of Airborne Radioactive Wastes, Proceedings of the Symposium held in New York, August 26-30, 1968. IAEA, Vienna, 1968. p. 265.

31. R. Vance. Liquid Scrub Solution Study For Radiodine Retention (Proprietary). EI-77-8, Energy Inc., Idaho Falls, ID, June 1977.

32. U.S. Energy Research and Development Adminstration, op. cit., V.2, Sec. 13.2.

33. J. G. Wilhelm, J. Furrer, and E. Schultes. "Head-End Iodine Removal from a Reprocessing Plant with a Solid Sorbent", Proceedings of the 14th ERDA Air Cleaning Conference, Sun Valley, Idaho, August 2-4, 1976, (CONF-760822, V. 1), p. 447-477.

34. U.S. Nuclear Regulatory Commission. Regulatory Guide 1.3: Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors. Revision 2, June 1974.

35. U.S. 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 10CFR50, Appendix I. March 1976.

APPENDIX A

This appendix presents the derivations of the iodine activities found in Tables 2-2 and 2-3. The bases for these calculations are flow rates, concentrations, and decontamination factors taken from NUREG-0016[(A1)] and NUREG-0017.[(A2)] These values are for nominal 3400 MWt reactors, whereas the other values in Tables 2-2 and 2-3 are for nominal 3500 MWt reactors. In light of the many assumptions made, and other factors which are not known with great accuracy, this difference is not felt to be significant.

The concentration of radioiodine in the demineralizer resin may be computed once the following values are known: radioiodine concentration in the reactor coolant, flow rate of coolant through the demineralizer, iodine collection efficiency of the demineralizer resin, and the iodine decay rate. Separate determinations are given for BWRs and PWRs.

Boiling Water Reactors

Reactor water concentration at the nozzle where it leaves the reactor vessel:

2×10^{-2} µCi I-133/gm

2×10^{-3} µCi I-131/gm (A1, p. 2-3)

Cleanup demineralizer flow rate:

1.3×10^{5} lb/hr (A1, p. 2-5)

Reactor coolent demineralizer decontamination factor:

10 (A1, p. 2-36)

The rate, G, at which radioiodine is removed by the resins may now be computed. For iodine-131:

$$G = (.9)(1.3 \times 10^5 \text{ lb/hr})(5 \times 10^{-3} \text{ } \mu\text{Ci/gm}) \times (453.6 \text{ gm/lb})(24 \text{ hr/day})(\text{Ci}/10^6 \text{ } \mu\text{Ci}) = 6.4 \text{ Ci/day}$$

and for iodine-133:

$$G = (.9)(1.3 \times 10^5)(2 \times 10^{-2} \text{ } \mu\text{Ci/gm}) \times (453.6 \text{ gm/lb})(24 \text{ hr/day})(\text{Ci}/10^6 \text{ } \mu\text{Ci}) = 25.5 \text{ Ci/day}$$

Assume that the bulk of the radioiodine appearing in the feed to the RWR-1™ System has been collected from the primary coolant by the demineralizer resin.

Let:

A = activity on the demineralizer resins

and

λ = decay constant

Then

$$\frac{dA}{dt} = G - \lambda A$$

describes the change of activity on the resins. At equilibrium, $\frac{dA}{dt} = 0$, therefore, $G = \lambda A$.

The resin beds are typically changed out several times a year, so the period between bed changeouts is measured in months, while the half-lives of I-131 and I-133 are on the order of days. Therefore, most of the iodine nuclides removed by the resins will have decayed away before the resins are removed. The activity upon removal will be the equilibrium activity,

$$A = G/\lambda$$

for I-131:

$$A = \frac{(6.37\ \text{Ci/day})(8.065\ \text{days})}{\ln(2)} = 74.1\ \text{Ci}$$

and for I-133:

$$A = \frac{(25.5\ \text{Ci/day})(20.8\ \text{hours})}{\ln(2)(24\ \text{hours/day})} = 31.9\ \text{Ci}$$

Assuming that the resin bed is changed out once every two months, the activity removed each year on the resins is six times the activity just computed. The rate is, therefore:

445 Ci/yr for I-131

191 Ci/yr for I-133

Note that these are the rates for the resins as removed from the demineralizer beds and no allowance has been made for decay before processing in the RWR-1™ System.

Pressurized Water Reactors

The logic for the iodine found on the resins in a PWR is the same as that for the BWR, above. The following data was applied for the PWR case, however.

Concentration in primary coolant with U-tube steam generators:

2.7×10^{-1} μCi I-131/gm (A2, p. 2-3)

3.8×10^{-1} μCi I-133/gm

Concentration in primary coolant with once-through steam generators

2.7×10^{-1} μCi I-131/gm (A2, p. 2-5)

3.8×10^{-1} μCi I-133/gm

Notice that the radioiodine concentrations are the same regardless of whether the reactor uses a U-tube or a once-through steam generator.

Reactor coolant letdown flow:

3.7×10^{4} lb/hr (A2, p. 2-7)

Resin Decontamination Factor:

10 (A2, p. 2-41)

Using the same calculational procedures and assumptions as for the BWR, the generation rates from a PWR are:

6803 Ci/yr for I-131

1037 Ci/yr for I-133

These are the generation rates for the resins as removed from the demineralizers. The half-lives of these two nuclides are so low that even a few days' storage before processing will reduce the activity considerably. The greater generation rates for PWRs with respect to BWRs are primarily due to the higher concentrations in the PWR primary coolant as opposed to the BWR coolant. This is largely a function of assumptions made about leak rates through the fuel cladding.

APPENDIX A REFERENCES

A1. U.S. Nuclear Regulatory Commission. Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors (BWR-GALE Code), NUREG-0016, April 1976.

A2. U.S. Nuclear Regulatory Commission. Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors, (PWR-GALE Code), NUREG-0017, April 1976.

Natural Resources Defense Council, Inc.

917 15TH STREET, N.W.
WASHINGTON, D.C. 20005
202 737-5000

Western Office
2345 YALE STREET
PALO ALTO, CALIF. 94306
415 327-1080

New York Office
122 EAST 42ND STREET
NEW YORK, N.Y. 10017
212 949-0049

October 25, 1978

U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Secretary of the Commission

Dear Sir,

Please provide me with any technical information you have describing the health ahd safety consequences of operating the low level waste incinerator planned for installation at Nine Mile Point Unit No. 1 in New York.

Have you, or do you intend to prepare an environmental assessment of this technology? If not, why not? If so, please send me a copy when it becomes available.

Given the public concern over the installation of this incinerator, an environmental impact statement, or at least an environmental assessment would appear appropriate.

Sincerely,

Tom B Cochran

Thomas B. Cochran

TBC/ps

DUPE

7811130391