A SYSTEMS ENGINEERING APPROACH FOR ASSESSING RADWASTE CAPABILITIES AT SURRY & NORTH ANNA POWER STATIONS

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ABSTRACT

Virginia Power Company has determined that the existing liquid and solid radwaste capabilities are not fully adequate to handle the volumes of wastes being generated at their North Anna and Surry Nuclear Power Stations. This paper describes the systems engineering approach used to identify potential enhancement areas, to develop treatment configurations to improve waste management practices and to develop a conceptual design report. A summary of the results is included.

INTRODUCTION

The present systems for handling and processing radioactive wastes at Virginia Power's North Anna and Surry Nuclear Power Stations are not fully adequate to handle the volume of wastes being generated. This condition exists in the areas of liquid, solid, and dry active waste (DAW) streams. The nuclear industry has gained valuable experience in minimizing the generation of wastes and in optimizing the design of waste treatment equipment. This paper describes the results of a systems engineering approach undertaken by Virginia Power and Bechtel to identify potential enhancement areas and to develop treatment options to improve the waste management systems.

Virginia Power Company recognized the benefits of taking a systems engineering approach towards the development of what could turn out to be a major new facility. Bechtel Associates Professional Corporation (Virginia) was awarded a contract to develop a conceptual design report based on a systems approach methodology.

Systems engineering is a formal and orderly approach used to optimize design engineering and to achieve maximum satisfaction of stated objectives. This approach is commonly used by the U.S. Army Corps of Engineers, the Department of Defense and the Department of Energy for major projects on the forward edge of technology and its application to power facilities is increasing.

The purpose of systems engineering is to help ensure success through an orderly approach that defines as completely as possible all requirements for the systems and then establishes configurations which can be proven capable of meeting these requirements. The initial work focuses on clearly defining the system's functional criteria, performance goals and objectives and on performing trade-off studies to optimize the configuration and size of the systems. The accuracy and completeness of this early effort is essential to establishing and maintaining project technical direction as well as cost and schedule control.

A Systems Approach Document was therefore developed at the outset of the project by Bechtel and Virginia Power. The general steps to implement a systems engineering approach for the early stages of this project were delineated in this document and can be summarized as:

1) Evaluate existing radwaste management practices at both the Surry and North Anna sites to obtain site specific waste stream characteristics, identify potential enhancement areas, and identify additional information/data needs.

2) Develop the system and subsystem performance goals and objectives and functional criteria.

3) Survey available technologies that have successful operating histories.

4) Develop alternate treatment systems.

5) Conduct trade-off studies to compare the alternate treatment options both technically and economically and to select the preferred option.

A more detailed description of this approach and a summary of the results are provided below.

SITE INVESTIGATION

To perform the initial step, a Bechtel team of personnel experienced in radwaste operations, radwaste systems design and health physics worked closely with Virginia Power home office and station personnel. The team spent several weeks at each site reviewing existing radwaste systems and operational practices with the site operations and engineering personnel. The waste streams and functions that were evaluated included liquid radwaste, spent resin waste, oily radwaste, dry active waste, tool decontamination, laundry waste, gaseous waste, hot machine shop, and the primary coolant system filters and filter handling. For each of these radwaste management areas, the review involved:

1) analyzing existing system capabilities;
2) collecting site specific waste characteristic data;
3) defining existing problem areas;
4) defining any constraints (i.e., space).

Evaluation criteria employed by the Bechtel team included reliability, availability and maintainability considerations, practices to minimize waste generation and reduce the volume of existing wastes, success at minimizing radwaste discharges to the environment, and provisions for maintaining in plant personnel radiation exposures as low as reasonably achievable.

Sources of data included a review of operating reports, piping and instrument diagrams, as-built drawings, system walkthroughs, discussion with operators, and existing waste characterization data and records.

Once problems related to each waste stream were identified, Bechtel recommended possible changes to operating and maintenance practices as well as specific interim changes to existing equipment that could be implemented to reduce waste management problems. The recommendations took into account constraints identified during the site visits.

General findings included:

1) The need for additional waste characterization data. As a follow-up to this effort, an extensive waste sampling program has been initiated to establish a better data base and to verify parameters used in the development of the conceptual designs.

2) Waste volumes were higher than average for PWRs. Subsequent programs have significantly reduced waste generation.

3) Existing radwaste treatment equipment is undersized and/or outdated.

DEVELOPMENT OF PERFORMANCE GOALS AND OBJECTIVES

Both Virginia Power and Bechtel recognized the importance of establishing performance goals and objectives for the radwaste management systems. Key objectives defined by Virginia Power included limiting liquid effluent discharges to 0.1 Ci/year and limiting low specific activity wastes shipped off-site to less than 8,000 ft^3/year/reactor. (Subsequent to the establishment of this volume limit, the Amendment to the Low Level Waste Policy Act established a limit slightly higher than this.) Other key objectives identified were reliability, availability, operational requirements, and a comprehensive training program for a dedicated operating staff for new equipment.

In addition to performance objectives, functional criteria were also necessary in order to evaluate alternate new treatment equipment. Twenty functional evaluation criteria were developed and divided into three groups: Operating History; System Design Features; and Reliability and Maintenance Features. The first group included criteria such as successful operating history in a radioactive environment, product acceptability, and licensability. The second group addressed issues such as design maturity, need for technical development, simplicity of design and space requirements. The third group addressed maintainability, reliability, simplicity of operation, and decontamination features.

SURVEY OF AVAILABLE TECHNOLOGIES

As part of the development of possible solutions, an assessment of the radwaste treatment and volume reduction equipment available in the worldwide market was conducted.

The survey was initially conducted by a review of supplier information available in Bechtel files. To supplement and update these reference materials, vendors were contacted and asked to provide data on actual operating experience with radioactive waste. If vendor systems had actual operating experience, additional data was requested such as process descriptions, general arrangements and other related information about their equipment. The information supplied from these vendors, in addition to that already on file, provided information for the entire spectrum of radwaste technologies presently available and was used to focus on those technologies which were suitable for the PWRs under study.

Since the intent of this vendor survey was to identify the successful use of radwaste equipment types at nuclear stations, the comprehensive listing of all possible suppliers was secondary to determining if these equipment types were desirable candidates for the new radwaste facilities. Once this survey determined that a particular vendor system has been used successfully, that generic radwaste processing method was considered viable in the development of the overall radwaste management scenarios.

As a follow-up to vendor identification of successful operation experience, utilities were also contacted to obtain further operating information and feedback.

One interesting finding was that once worldwide radwaste equipment and experiences were included, there were very few types of radwaste management equipment that did not have several years of successful operations somewhere. This was important since it appeared evaporators and/or crystallizers would be required to meet the stringent liquid discharge goal of 0.1 Ci/year.

Another finding was the importance of operations personnel and training to the degree of success, especially for the more complicated equipment. A very brief overview of the types of equipment with successful nuclear operating experience and the countries where the operating experience was gained is given in Table I.

DEVELOPMENT OF ALTERNATE TREATMENT SCENARIOS

Based upon a review of the problems identified during the site visits, and identification of proven technologies available to address these problems, several treatment options were developed for each waste stream. The primary criterion employed in the development of treatment options was operating history, since Virginia Power intends to utilize technologies with good performance records in nuclear radwaste applications. The treatment options considered also satisfy the performance goals established by Virginia Power. The equipment types that were used in the development of treatment options for the major waste streams are presented in Table II.

Because of numerous viable technologies, as many as 11 options for each waste stream were available. Initial evaluations were performed to eliminate options that would not meet performance requirements. The Group I functional criteria (operating and performance history, product acceptability and licensability) were utilized in this initial screening.

TABLE I

Radwaste Equipment Operating Experience

Technology	Equipment Type	Operational Experience
Evaporation	Forced Circulation	U.S., Japan
	Crystallizers	U.S., Taiwan
	Thin Film	Sweden, Japan France
	Extruder	U.S.
	Drum Mixer	Japan
Demineralization	Bead Resin	U.S., Japan Europe
Filtration	Cartridge	U.S.
	Pre-coat	U.S., Japan
	Etched Disc	U.S., Taiwan
	Hyper/Ultra	Japan
	Bag	U.S.
	Hollow Fiber	U.S., Japan
Solidification	Cement	U.S., Japan
	Mobile Cement	U.S.
	Plastic	U.S., Japan
Resin Dewatering	Mobile	U.S.
DAW Incineration	Fluidized Bed	U.S.
	Controlled Air	U.S., Japan, Sweden, Canada
	Pyrolysis	U.S., Germany
Super Compactors	In-plant	Netherlands, Germany
	Mobile	U.S.

TABLE II

Equipment Types Considered

Radwaste Management Area	Options Considered
Process Liquid Radwaste	Evaporation Demineralization Filtration Drying Pelletizing Solidification
Process Spent Resins	Dewatering Drying Incineration (In-plant) Solidification
Process Oily Wastes	Absorption Incineration (In-plant, mobile, regional) Solidification
Dry Active Wastes	Compaction Incineration (In-plant, mobile, regional) Supercompaction Shredding Segregating de minimis wastes

DETAILED EVALUATIONS OF ALTERNATE TREATMENT OPTIONS

Trade-off studies were then performed on each of the remaining treatment options using the twenty detailed functional evaluation criteria delineated in the Systems Approach Document. Preliminary flow diagrams were developed for the nearly thirty options still being considered to support the detailed technical assessment. A figure of merit system was used to perform a subjective technical evaluation of specific treatment options. To perform these trade-off studies of the treatment options, a quantitative expression for the comparative worth of the option was generated. The following is a description of the scoring process used.

a. The functional evaluation criteria were assigned a weighting factor for each criteria. These are summarized in Table III.

b. Each treatment option was given a score from 1 to 4, with 1 being the lowest and 4 being the highest score. The preliminary flow diagrams developed for each treatment option were utilized to define these options.

c. The criterion score for each option was then multiplied by the weighting factor to determine its weighted score.

d. The weighted scores were then totaled to give a composite score for each option.

The results of the technical assessment are given in Table IV. Comparison of the various composite scores did not finalize the selection process. The objective of this rating system was to provide a semi-quantitative method to compare the relative technical merits of each treatment option. The composite scores provided a basis for determining how well each treatment option met the project functional criteria and Virginia Power goals and objectives.

The detailed cost evaluation included a life cycle assessment to determine the most cost effective method of treatment and disposal for waste. Consideration was given to both the relative capital investment and operating costs over the expected life of the power plants. Equipment costs were obtained through estimates furnished by radwaste vendors. Relative facility costs were developed by preparing preliminary layouts for each treatment option and estimating the building volume needed for each option. Annual and present worth operating costs were developed using the Bechtel Computer Code RWCOST which evaluates waste generation volumes, labor, equipment operation, transportation and disposal costs.

Table V summarizes the results of the economic assessment. It should be noted that the costs given in this table are not absolute costs but are relative and were developed to enable a comparison of each treatment option. They do not reflect the expected costs for an optimized radwaste treatment facility.

STUDY RESULTS

As a result of these trade-off studies, the following treatment options were chosen:

Liquid Wastes: Filtration followed by either evaporation or demineralization. Evaporators were needed to satisfy the stringent discharge goal established. Both evaporators and a demineralizer train were selected to provide operating flexibility for varying waste stream activities and chemical composi-

TABLE III

Functional Criteria and Weighting Factors

		Weighting Factor	Group
(1)	Operating history	10	I
(2)	Product acceptability	10	I
(3)	Performance (volume reduc.)	10	I
(4)	Licensing acceptance	10	I
(5)	Space requirements	5	II
(6)	Design maturity of the radwaste system	5	II
(7)	Soundness of the underlying technical design	5	II
(8)	Need for additional technical development	5	II
(9)	Simplicity of design controls and monitoring	5	II
(10)	Maintainability	5	II
(11)	Availability (reliability)	5	II
(12)	ALARA design	3	III
(13)	Compatibility with existing facilities	3	III
(14)	Simplicity of operation	3	III
(15)	Decontamination features	3	III
(16)	Material handling requirements	3	III
(17)	Layout requirements	3	III
(18)	Generation of secondary wastes	3	III
(19)	Use of common materials	2	III
(20)	Pre-assembly	2	III

tions. Dewatering would be used for the resins with the provisions to add solidification equipment in the future should licensability/disposal of dewatered resins become a problem.

Dry Active Wastes: Incineration and solidification of the ash. The high volume reduction factors for incineration were needed due to the apparently high volume of wastes being generated during the previous three years at the stations. A supercompactor ranked higher technically and had lower equipment, facility and operating costs but could not satisfy the 8,000 $ft.^3$/year performance goal. This selection was to be reassessed as in-plant management programs were implemented to reduce the quantity of wastes being generated.

Laundry Wastes: Cartridge filtration.

Spent Resins: Treatment of high activity resins in the existing radwaste building by dewatering with space reserved for the possible addition of solidification equipment should dewatering become unacceptable sometime in the future.

Primary Filters: Retain cartridge filtration with improved handling equipment.

Decon Solution: Neutralization followed by evaporation and/or solidification.

Oily Wastes: Separation followed by incineration.

Laundry and Respirators: Wet wash and dryers.

Based on these preliminary selections, a conceptual design for a new radwaste facility was developed for each site in order to develop budgetary cost estimates and preliminary project schedules. To promote cost effectiveness, the facility design for the two stations was standardized as much as possible.

The treatment selections were qualified in that they are based on waste stream characteristics and volumes available during the study. As mentioned previously, additional sampling and testing programs have been initiated as well as extensive waste volume minimization programs. This additional input data will be monitored closely and will be used to validate or modify as necessary the results of this study before proceeding with detailed design and construction.

REFERENCES

1. VIRGINIA POWER COMPANY, "Type II Radwaste Facility Study, Conceptual Design Report," March 1986

TABLE IV

Virginia Power
Radwaste Facility Study
Technical Assessment

Criterion	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	COMPOSITE
Weighting Factor	10	10	10	10	5	5	5	5	5	5	5	3	3	3	3	3	3	3	2	2	SCORE-RANK
Treatment Option																					
LIQUID WASTE:																					
Filter/Demineralizer/Solid	40	40	40	40	20	20	20	20	20	20	20	12	12	12	12	6	12	6	8	8	388-1
Filter/Evap /Solid	30	40	30	40	15	20	20	15	15	10	10	9	9	6	9	3	9	9	4	4	307-3
Filter/Dryer/Solid	20	30	30	40	10	15	15	15	10	5	10	9	9	3	6	3	6	12	4	4	256-4
Filter/Demin /Evap /Solid	40	40	40	40	10	20	20	15	15	10	20	9	12	9	9	6	9	9	8	6	347-2
LAUNDRY DRAINS:																					
Filter	40	40	30	40	20	20	20	20	20	20	20	12	12	12	12	12	6	12	8	6	388-1
R.O.	30	40	20	40	15	15	10	10	15	10	15	12	9	9	9	12	9	9	6	6	291-2
DECON SOLNS:																					
Neutralize/Solid	40	30	30	40	20	20	20	20	20	20	20	12	12	12	12	9	12	6	8	8	371-1
Neutralize/Evap/Solid	30	30	20	40	10	15	10	10	15	10	10	12	6	6	9	6	9	9	4	4	265-2
SPENT RESINS:																					
HIC/Solid (New Building)	30	40	40	40	5	15	20	20	15	15	15	9	12	6	9	9	9	6	8	8	331-2
HIC/Incin/Solid (New Building)	20	40	20	30	5	5	10	5	5	5	5	6	6	3	6	6	6	12	2	6	203-4
(New) HIC/Solid-(Old) HIC/Solid	40	40	40	40	15	20	20	20	20	20	15	12	12	9	9	9	9	6	8	8	372-1
(New) HIC/Incin/Solid-(Old) HIC/Solid	20	40	20	30	10	10	10	5	5	10	5	9	6	3	6	6	6	12	2	6	221-3
DAW:																					
Incinerator w/																					
A - Compactor	40	40	30	40	10	20	20	10	10	10	15	9	6	6	6	6	6	9	6	6	305-3
B - Comp/Super Compactor	30	40	30	20	5	15	20	10	10	5	15	9	6	6	6	6	3	9	6	4	255-6
C - Comp/Mobile Super Compactor	20	40	20	30	10	15	20	10	10	5	15	9	6	6	6	6	6	9	6	6	255-6
Mobile Incinerator w/																					
A - Compactor	20	40	30	40	15	15	20	10	15	10	15	9	6	6	6	6	9	9	6	8	295-4
B - Comp/Super Compactor	10	40	20	20	10	15	20	10	15	5	15	9	6	6	6	6	3	9	6	6	237-6
C - Comp/Mobile Super Compactor	10	40	20	20	15	15	20	10	15	5	15	9	6	6	6	6	6	9	6	8	247-8
Regional Incinerator w/																					
A - Compactor	10	40	10	20	20	5	10	5	20	20	5	12	12	12	12	9	12	12	8	8	262-5
B - Comp/Super Compactor	10	40	10	20	15	5	10	5	20	15	5	12	12	9	9	9	6	12	8	6	238-9
C - Comp/Mobile Super Compactor	10	40	10	20	20	5	10	5	20	15	5	12	12	9	9	9	9	12	8	8	248-7
Compactor/Super Comp	30	40	30	30	15	15	20	15	20	15	15	12	12	9	9	9	6	12	8	6	328-1
Super Compactor, Mobile	10	40	20	30	20	15	20	15	20	15	15	12	12	9	9	9	9	12	8	8	308-2
PRIMARY FILTERS:																					
Cartridge w/ Remote Changeout	40	40	30	40	15	20	20	20	20	15	15	6	9	9	12	3	9	9	6	6	344-1
Backflushable (Letdown & RC only)	20	40	20	40	10	15	20	15	10	10	15	12	9	9	9	6	6	6	4	6	282-2
LAUNDRY AND RESPIRATOR:																					
Wet Wash and Dry	40	40	40	40	20	20	20	20	20	20	15	12	9	12	12	12	9	6	6	6	379-1
Dry Clean and Wet Wash	40	40	40	40	20	20	15	20	20	15	15	12	9	12	9	12	9	9	6	6	369-2
OILY WASTE:																					
Inline Collection (Coalescer)	30	40	40	40	10	20	15	20	10	10	15	12	9	6	9	12	9	9	6	6	328-2
Sump Collection	40	40	40	40	20	20	15	20	20	15	15	9	6	6	9	9	12	9	6	6	357-1

TABLE V

Virginia Power
Radwaste Facility Study
Economic Assessment of Treatment Options

(Costs are $\$10^6$)

Surry

Treatment Option	Equipment Costs	Building Costs	Annual Oper. Costs	Oper. Costs (A) Present Worth	Total (A) Costs
LIQUID WASTE:					
Filter/Demineralizer/Solid	3.1	4.0	0.2	9/175	16/182
Filter/Evap /Solid	6.0	4.4	0.2	5/83	15/93
Filter/Dryer/Solid	6.6	6.6	0.2	3/42	16/55
Filter/Demin /Evap/Solid	6.5	6.0	0.2	7/30	20/145
LAUNDRY DRAINS:					
Filter	0.1	1.5	0.1	2/26	3/28
Reverse Osmosis	0.4	2.9	0.7	18/300	21/303
DECON SOLNS:					
Neutralize/Solid	3.1	2.6	0.2	5/83	11/89
Neutralize/Evap/Solid	6.0	4.4	0.1	0.1/2	11/12
SPENT RESINS:					
HIC/Solid (New Building)	3.1	4.7(B)	0.7	27/510	35/518
HIC/Incin/Solid (New Building)	8.0	9.7(B)	0.4	14/270	32/290
(New) HIC/Solid-(Old) HIC/Solid	4.1	2.6(B)	0.7	27/510	34/517
(New) HIC/Incin/Solid-(Old) HIC/Solid	8.6	7.6(B)	0.4	14/270	30/286
DAW:					
Incinerator w/					
A - Compactor	4.7	3.6	1.0	21/174	29/182
B - Comp/Super Compactor	6.5	3.8	1.0	18/120	28/130
C - Comp/Mobile Super Compactor	5.8	3.3	1.0	18/120	27/129
Mobile Incinerator w/					
A - Compactor	3.7	2.0	1.0	21/174	27/180
B - Comp/Super Compactor	5.5	2.2	1.0	18/120	26/128
C - Comp/Mobile Super Compactor	4.8	1.5	1.0	18/120	24/126
Regional Incinerator w/					
A - Compactor	0.2	1.3	1.1	215(C)	217(C)
B - Comp/Super Compactor	2.1	2.9	1.1	194(C)	199(C)
C - Comp/Mobile Super Compactor	1.5	2.2	1.1	194(C)	198(C)
Compactor/Super Compactor	2.1	2.9	0.7	22/417	27/422
Super Compactor, Mobile	1.5	2.2	0.7	22/417	26/421
OILY WASTES:					
Inline Collection (Coalescer)	0.2	1.5	0.1	2/39	4/38
Sump Collection	0.1	0.1	0.1	2/45	3/45
PRIMARY FILTERS:					
Cartridge w/Remote Changeout	1.0	-	0.1	1	2
Backflushable (Letdown & RC Only)	2.5	-	0.1	2	5

NOTES:

(A) 15% Escalation/40% Escalation for Burial Rates Cost Component
(B) Includes Cost of Transfer Tunnel
(C) Regional Incinerator Fees Escalated at 20%