NUREG/CR-2601
Addendum 1

Technology, Safety and Costs of Decommissioning Reference Light Water Reactors Following Postulated Accidents

Re-evaluation of the Cleanup Cost for the Boiling Water (BWR) Scenario 3 Accident from NUREG/CR-2601

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Operated by
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Prepared for
U.S. Nuclear Regulatory Commission

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ABSTRACT

The estimated costs for post-accident cleanup at the reference BWR (developed previously in NUREG/CR-2601, Technology, Safety and Costs of Decommissioning Reference Light Water Reactors Following Postulated Accidents) are updated to January 1989 dollars in this report. A simple formula for escalating post-accident cleanup costs is also presented. Accident cleanup following the most severe accident described in NUREG/CR-2601 (i.e., the Scenario 3 accident) is estimated to cost from $1.22 to $1.44 billion, in 1989 dollars, for assumed escalation rates of 4% or 8% in the years following 1989. The time to accomplish cleanup remained unchanged from the 8.3 years originally estimated. No reanalysis of current information on the technical aspects of TMI-2 cleanup has been performed. Only the cost of inflation has been evaluated since the original PNL analysis was completed.

FOREWORD
BY
NUCLEAR REGULATORY COMMISSION STAFF

The Nuclear Regulatory Commission (NRC) has issued regulations related to the decommissioning of nuclear facilities.(1) As part of this activity, the NRC initiated two series of studies through technical assistance contracts. These contracts were undertaken to develop information to support the preparation of new standards covering decommissioning.

The first series of studies covers the technology, safety, and costs of decommissioning reference nuclear facilities.(2-27) Light water reactors (LWRs) and fuel-cycle and non-fuel-cycle facilities were included. Facilities of current design on typical sites were selected for the studies. Separate reports were prepared as the studies of the various facilities were completed.

The second series of studies covers supporting information on the decommissioning of nuclear facilities.(28-32) This series includes an annotated bibliography on decommissioning and studies on facilitation and radiation survey methods appropriate for decommissioning, as well as an examination of regulations applicable to decommissioning.

This report contains information on post-accident cleanup and decommissioning of a reference boiling water reactor power station in support of the Rule on Property Insurance Requirements for reactor owners. Any comments will be included in the record for consideration by the Commission in establishing criteria and new standards for decommissioning. Comments on this report should be mailed to:

Chief
Radiation and Health Effects Branch
Division of Regulatory Applications
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

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CONTENTS

TABLES

1.0 INTRODUCTION

The results of a study to re-examine the analyses presented in NUREG/CR-2601 (Technology, Safety and Costs of Decommissioning Reference Light Water Reactors Following Postulated Accidents) on post-accident cleanup of a reference boiling water reactor (BWR) power station are given in this report. Included are an update of the estimated costs for cleanup (in January 1989 dollars) and the development of a simple cost escalation formula for cleanup costs similar to the formula for escalation of decommissioning costs given in the final Rule on Decommissioning. The purpose of these new analyses is to support the planned revisions to the Rule on Property Insurance Requirements for reactor owners.

Just as in the parent document, which was published in 1982, the reader is referred to the appropriate sections of the pressurized water reactor (PWR) analysis in NUREG/CR-2601, where the reference accident scenarios and the technical requirements, costs, and safety impacts of PWR accident cleanup are discussed, to trace the logic and justify the assumptions used in making the original BWR analysis (and this cost update).

A discussion on the development of the bases for cost escalations to January 1989 dollars is presented in Appendix A. The principal results of the application of these bases to the original estimates in NUREG/CR-2601 are provided in Section 3. The cost escalation formula for accident cleanup costs is described in Section 4.

2.0 SUMMARY

The results of a re-examination of the analyses presented in NUREG/CR-2601 (Technology, Safety and Costs of Decommissioning Reference Light Water Reactors Following Postulated Accidents) on post-accident cleanup of a reference boiling water reactor (BWR) power station are summarized in this section. Included are an update of the estimated costs for accident cleanup and the development of a simple formula for escalation of cleanup costs due only to inflation considerations similar to the formula for escalation of decommissioning costs given in the final Rule on Decommissioning. The purpose of these new analyses is to support the planned revisions to the Rule on Property Insurance Requirements for reactor owners.

2.1 COSTS

Accident cleanup costs (in January 1989 dollars) at the reference BWR are summarized here from Section 3, based on analyses originally presented in Section 11.5 of NUREG/CR-2601. Four basic cost elements are identified:

- basic accident cleanup (as estimated in the report)
- stabilization of the facility
- basic plant maintenance and operations
- incremental escalation of the above costs over the future years of the various activities.

While a detailed analysis was not performed for the BWR accident in the original NUREG report, an analysis has been performed for this report, by analogy to the analysis for the reference pressurized water reactor (PWR) scenario 3 accident, as discussed in Section 11.5 of NUREG/CR-2601.

A summary of total estimated costs for accident cleanup at the reference BWR is given in Table 2.1, including all four basic cost elements mentioned above. Accident cleanup following the most severe accident described in NUREG/CR-2601 (i.e., the scenario 3 accident) is estimated to cost from $1.22 billion to $1.44 billion, depending on the assumed escalation rates (4%, 8%) in the years following 1989. The time requirement of 8.3 years for completion of accident cleanup remains unchanged from the original analysis.

A summary of plant cleanup costs (Cost Item 1 in Table 2.1) at the reference BWR by cost category is presented in Table 2.2, to illustrate the relative importance of individual cost items. The major cost items are labor, waste management, and nuclear insurance and regulatory fees. Labor costs, including staff labor, engineering support, and specialty contractors, account for greater than 66% of plant cleanup costs at the reference BWR.

TABLE 2.1. Summary of Estimated Total Costs of Accident Cleanup Following the Reference BWR Scenario 3 Accident

Cost Item	Costs ($ Millions)[a] Accident Cleanup in Reference BWR Following Scenario 3 Accident
1. Estimated Cost of Plant Cleanup	530.3[b]
2. Facility Stabilization[c]	259.0[d]
3. Base Operations and Maintenance[c]	239.6[e]
4. Incremental Cost Escalation[c]	186.5 to 409.9[f]
Total Estimated Costs	1,215.4 to 1,438.8

(a) Costs are from this report in January 1989 dollars, and include a 25% contingency.
(b) For the reference BWR, this includes preparations for accident cleanup, accident cleanup in the radwaste building, and accident cleanup in the reactor building and the containment vessel.
(c) See Section 3.4.
(d) See Section 3.5.
(e) Over a postulated 3-year period for the reference BWR.
(f) Cost values shown are based on annual escalation rates of 4% and 8%, respectively.

The major waste management cost item in NUREG/CR-2601 was the cost of disposal of the damaged fuel from reactor defueling following an accident. However, as a result of the Nuclear Waste Policy Act of 1982 and its subsequent amendment in 1987, the U.S. Department of Energy (DOE) is obligated to receive and dispose of commercial nuclear fuel. The costs (i.e., cask rental, transportation, and disposal) are covered by the 1 mill/kWh fee for waste disposal delineated in the Act. Therefore, while these costs have been estimated and updated to January 1989 dollars for this report, these costs are <u>not</u> included in the total costs for accident cleanup given in this report.

Another principal change resulting from this re-examination is a significant increase in the costs associated with nuclear insurance and regulatory fees. The bases used to estimate the cost of nuclear insurance and regulatory fees during accident cleanup are described in Section A.7 of Appendix A.

TABLE 2.2. Summary of Estimated Cost of Plant Cleanup at the Reference BWR by Cost Category[a,b]

Cost Category	Accident Cleanup Following Scenario 3 Accident Estimated Costs ($ millions)	Percent of Total
Preparations for Accident Cleanup[c]		
Utility Staff Labor	58.215[d]	43.6
Waste Management	1.560	1.2
Energy	8.572	6.4
Special Equipment and Supplies	9.834	7.4
Miscellaneous Supplies	0.236	0.2
Specialty Contractors	30.386	22.8
Nuclear Insurance and License Fees	24.578	18.4
Subtotal for Preparations for Cleanup	133.381	100.0
Accident Cleanup in the Radwaste Building[e]		
Cleanup Worker Labor	10.694	58.9
Waste Management	2.136	11.8
Special Tools and Equipment	1.960	10.8
Miscellaneous Supplies	1.379	7.6
Specialty Contractors	1.979	10.9
Subtotal for Cleanup in the Radwaste Building	18.148	100.0
Accident Cleanup in the Reactor Building and Containment Vessel		
Operations and Support Staff Labor	87.961	23.2
Accident Cleanup Staff Labor	134.216	35.4
Waste Management[f]	30.255	8.0
Disposal of Fuel from Reactor Defueling[f]	(60.705)[g]	(g)
Energy	16.608	4.4
Special Tools and Equipment	21.499	5.7
Miscellaneous Supplies	16.243	4.3
Specialty Contractors	28.956	7.6
Nuclear Insurance and License Fees	43.056	11.4
Subtotal for Cleanup in the Reactor Building and Containment	378.794	100.0
Total Accident Cleanup Costs	530.3	

(a) Costs are in January 1989 dollars and include 25% contingency.
(b) Number of figures shown is for computational accuracy only and does not imply precision to the nearest one thousand dollars.
(c) Costs are based on assumed time period of 3 years for preparations for cleanup following the scenario 3 accident.
(d) Includes labor cost for loading spent fuel from the spent fuel pool into casks for shipment to a DOE storage facility.
(e) Accident cleanup in the radwaste building following the scenario 3 accident is assumed to be accomplished during preparations for cleanup in the reactor building. Management and support staff costs and other incidental costs are included in the costs of preparations for cleanup.
(f) Costs for disposal of fuel are shown separately from other waste management costs.
(g) As a result of the NWPA, the DOE is obligated to receive and dispose of commercial nuclear fuel. The costs (i.e., cask rental, transportation, and disposal) are covered by the 1 mill/kWh fee for waste disposal delineated in the Act. Therefore, while these costs have been estimated and updated to January 1989 dollars for this report, these costs are not included in the total costs for accident cleanup.

2.2 COST ESCALATION FORMULA

The escalated accident cleanup cost, described in detail in Section 4, is given by:

$$\text{Estimated Cost (Year X)} = [(\text{January 1989 Cost})(A\,L_X + B\,E_X + C\,B_X + D\,I_X)] + L_X \Delta T(1989\$)$$

where A, B, C, and D are fractions of the total cost in January 1989 dollars that are attributable to labor, energy, burial, and insurance, respectively, and sum to 1.0, and L_X, E_X, B_X and I_X are escalation factors from 1989 to year X for labor, energy, burial, and insurance. Addition of the last term, $L_X \Delta T(1989\$)$, provides the means for escalating the cost of plant cleanup, facility stabilization, and base operations and maintenance beyond year X, and completes the formula for estimating total cleanup cost:

$$\Delta T(1989\$) = \sum_{i=1}^{n} Qi\,(1 + y)^i - Qi$$

where Qi = annual expenditures in year (i) during cleanup period

$(1 + y)^i$ = projected escalation factor through year (i) of the cleanup period.

3.0 ESTIMATED SCENARIO 3 ACCIDENT CLEANUP COSTS

Estimated costs of plant cleanup (Cost Item 1 in Table 2.1) at the reference BWR following the postulated scenario 3 accident are presented in this section for the three operations that comprise plant cleanup costs: preparations for accident cleanup, accident cleanup in the radwaste building, and accident cleanup in the reactor building and the containment vessel.

3.1 ESTIMATED COSTS OF PREPARATIONS FOR ACCIDENT CLEANUP

The estimated costs of preparations for accident cleanup following the reference BWR scenario 3 accident are summarized in Table 3.1. Preparations for accident cleanup are estimated to require 3 years (no change from NUREG/CR-2601) and to cost approximately $133.4 million. About 44% of these costs are utility staff labor costs. Total labor costs, including the cost of contractor labor for engineering support as well as utility staff labor, are about 66% of the total cost of preparations for accident cleanup.

The accumulated spent nuclear fuel (SNF) present in the spent fuel storage pool at the time of an accident is assumed to be transported to a DOE-owned facility under the provisions of 10 CFR 961, Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Waste. This fuel will be accepted by the federal waste management system based on oldest-fuel-first priority unless: 1) acceptance priority may be provided to shutdown reactors, or 2) emergency deliveries of SNF and/or high-level waste may be accepted by DOE before the date provided in the delivery commitment schedule upon prior written approval by DOE. The licensee is responsible for storage costs associated with the fuel until acceptance by DOE. In this study, all subsequent costs are assumed to be covered under the contract and therefore were not examined further in this analysis nor included in Table 3.1.

The cost of waste management is expected to be small during preparations for accident cleanup. Wastes generated during this period consist mostly of compactible and combustible solids (e.g., disposable clothing, rags, plastic covers, laydown pads, and miscellaneous trash) as well as some filters and ion exchange materials. The generation rate for these wastes during preparations for accident cleanup is expected to be similar to the generation rate during normal reactor operations.

Once the spent fuel in the pool has been shipped to an independent spent fuel storage installation (ISFSI), the old fuel racks are removed during preparations for accident cleanup to provide space in the pool for the filter/demineralizer system used to process accident water and for new fuel racks to accommodate canistered fuel. All of the racks are postulated to be removed following the scenario 3 accident cleanup. The costs of packaging, transportation, and disposal of the old fuel racks at a shallow-land burial ground are given in Table 3.2. These costs are included as part of the waste management costs for preparations for accident cleanup.

TABLE 3.1. Estimated Costs of Preparations for Accident Cleanup Following the Reference BWR Scenario 3 Accident

Cost Category		Estimated Costs[a,b] ($ millions)	Percent of Total
Utility Staff Labor[c]		46.572[c]	43.6
Waste Management		1.248	1.2
Energy		6.858	6.4
Special Equipment and Facilities[d]			
Demineralizer System	1.235		
Fuel Racks for Canistered Fuel	0.811		
Processed Water Storage Tanks	0.706		
Facilities for Interim Storage of Wastes[e]	1.195		
Mockup of Reactor Vessel	3.920		
Total Equipment and Facilities Costs		7.867	7.4
Miscellaneous Supplies		0.189	0.2
Specialty Contractors			
Engineering	23.940		
Environmental Surveillance	0.169		
Laundry	0.200		
Total Specialty Contractors Costs		24.309	22.8
Nuclear Insurance and License Fees		19.662	18.4
Subtotal		106.705	100.0
Contingency (25%)		26.676	
Total Costs		133.381	

(a) Costs are in January 1989 dollars. Number of significant figures shown is for computational accuracy only.
(b) Total costs are based on an assumed time period of 3 years for preparations for accident cleanup following scenario 3 accident as described in NUREG/CR-2601.
(c Includes labor cost for loading spent fuel from the spent fuel pool into casks for shipment to a DOE storage facility.
(d) Costs include contractor labor, materials, and overhead costs for the design and construction of the indicated items.
(e) Facilities include a warehouse-type building for onsite storage of drummed and boxed wastes and a facility for shielded storage of liners containing high-activity wastes.

TABLE 3.2. Waste Management Cost Parameters and Estimated Cost for the Disposal of BWR Spent Fuel Racks[a,b]

Item	Value
Burial Volume (m^3)	350
Estimated Radioactivity Content (Ci)	3.5
Type of Disposable Container	Metal Box
Number of DisposableContainers[c]	15
Number of Waste Shipments	5
Disposable Container Costs ($)	55,000
Transportation Costs ($)	10,250
Shallow-Land Burial Costs ($)	
Disposal Charge	365,750
Handling Surcharge	7,170
Total Waste Management Costs ($)	438,670

(a) Number of significant figures shown is for computational accuracy only.
(b) Costs are in January 1989 dollars.
(c) Assumes racks are packaged without sectioning.
Note: Surcharge for non-Northwest Compact users at $706.28/m^3$ would add an incremental cost of $247,198.

3.2 SUMMARY OF COSTS OF ACCIDENT CLEANUP IN THE RADWASTE BUILDING

The estim-ted costs of accident cleanup in the radwaste building following the scenario 3 accident are summarized in Table 3.3. Accident cleanup in the radwaste building is postulated to take place during preparations for cleanup in the reactor building, and is estimated to require 1.5 years (no change from NUREG/CR-2601) and to cost approximately $18 million.

Costs shown in Table 3.3 include worker labor costs, waste management costs, costs of equipment and supplies, and specialty contractor costs specifically related to accident cleanup in the radwaste building. Management and support staff costs, costs of maintaining the reactor in a safe shutdown condition during this period, and the incidental costs such as energy costs, environmental surveillance costs, and insurance costs are included with the costs of preparations for cleanup following the scenario 3 accident shown in Table 3.1.

Based on the waste management disposal assumptions discussed in Section 10.4.1.5 of NUREG/CR-2601, costs of radioactive waste management for accident cleanup in the radwaste building are estimated to be about $1.7 million. These costs are shown in detail in Table 3.4. As discussed in Section 10.4.1.5, all wastes from accident cleanup except the high-activity

TABLE 3.3. Summary of Estimated Costs of Accident Cleanup in the Radwaste Building Following the Postulated BWR Scenario 3 Accident[a]

Cost Category		Estimated Costs[b] ($ millions)	Percent of Total
Cleanup Worker Labor		8.555	58.9
Waste Management		1.709	11.8
Special Tools and Equipment[c]		1.568	10.8
Miscellaneous Supplies		1.103	7.6
Specialty Contractors			
Engineering	1.330		
Laundry	0.253		
Total Specialty Contractor Costs		1.583	10.9
Subtotal		14.518	100.0
Contingency (25%)		3.630	
Total Costs		18.148	

(a) Accident cleanup in the radwaste building is assumed to be accomplished during preparations for accident cleanup in the reactor building. Management and support staff costs and incidental costs are included in the costs of preparations for accident cleanup.
(b) Costs are in January 1989 dollars. Number of significant figures is for computational accuracy only.
(c) Includes cost of design and installation of system to process contaminated radwaste system liquids.

TABLE 3.4. Estimated Costs of Radioactive Waste Management for Accident Cleanup in the Radwaste Building Following the Postulated BWR Scenario 3 Accident[a]

Waste Category	Burial Volume (m^3)	Estimated Radioactivity Content (Ci)	Disposable Containers: Type	Disposable Containers: Number	Number of Shipments	Packaging and Transport Costs: Disposable Container Cost[d] ($)	Packaging and Transport Costs: Cask Rental Charge[e] ($)	Packaging and Transport Costs: Transport Costs[f,b] ($)	Disposal Site Costs[b,c]: Shallow-Land Burial Ground Cost ($): Disposal Charge	State Surcharge[g]	Handling Surcharge	Liner Surcharge	Curie Surcharge	Federal Repository Costs ($)	Total Waste Management Costs ($)
Sludge	2	20	0.21-m^3 steel drum	10	1	300	2,700	3,318	2,278	[1,413]	1,789				10,385
Process Solids															
Filter Cartridges	0.3	20	(.3-m^3 steel liner	1	0.5		1,350	1,659						3,600	6,609
Zeolite Liners	0.9	20,000	0.3-m^3 steel liner	3	2		4,050	6,636						10,800	21,486
Organic Resin Liners	0.3	100	0.3-m^3 steel liner	1	0.5		1,350	1,659						3,600	6,609
Chemical Decontamination Solutions	200	50	0.21-m^3 steel drum	950	8	28,500		16,400	209,000	[141,256]	7,002				260,902
Trash															
Compactible, Combustible	52	88	0.21-m^3 steel drum	250	2	7,500		4,100	57,096	[36,727]	1,745				70,441
Compactible, Noncombustible	171	28	0.21-m^3 steel drum	815	7	24,450		14,350	178,695	[120,774]	6,130				223,625
Noncompactible	434	13	3.5-m^3 metal box	124	21	136,400		43,050	453,530	[306,526]	15,337				648,317
Contaminated Equipment															
LSA Materials	150	10	3.5-m^3 metal box	42	7	46,200		14,350	156,750	[105,942]	4,800				222,100
High-Activity Materials	50	100	2.85-m^3 steel liner	18	18	55,800	32,400	59,724	52,250	[35,314]	24,520	13,446	–		238,140
Subtotals															
Wastes Sent to Shallow-Land Burial	1,059	309		2,209	63	299,150	35,100	155,292	1,109,599	[747,952]	61,323	13,446	0		1,673,910
Wastes Sent to Federal Repository	2	20,120		5	3		6,750	9,954					–	18,000	34,704
Totals	1,061	20,429		2,214	66	299,150	41,850	165,246	1,109,599	[747,952]	61,323	13,446	0	18,000	1,708,614

(a) Number of significant figures shown is for computational accuracy only.
(b) Charges are computed on the assumption that all shipments for a given waste category are identical. Actually, charges for individual shipments would vary depending on the specific physical and radiological characteristics of individual shipments. The averaging technique used is believed to be appropriate for computing total charges.
(c) Based on information from Table A.9 of Appendix A.
(d) Based on information from Table A.2 of Appendix A.
(e) Based on information from Table A.3 of Appendix A. Assumes 6 days for a round-trip truck shipment.
(f) Based on information from Table A.8 of Appendix A. Includes overweight charges and second-driver costs where applicable.
(g) The costs shown in brackets would apply to those generators outside the NW Compact. For the purpose of this cost update, these costs are not included in the total.

wastes (filter cartridges and ion exchange materials) from processing contaminated water are transported by truck to a shallow-land burial ground for disposal. The high-activity wastes are placed in temporary shielded storage at the site and are ultimately transported in shielded containers to a federal repository. Both the shallow-land burial ground and the federal repository are assumed to be located 1600 km from the reactor site.

3.3 ESTIMATED COSTS OF ACCIDENT CLEANUP IN THE REACTOR BUILDING AND CONTAINMENT VESSEL

The estimated costs of accident cleanup in the reactor building and containment vessel following the postulated BWR scenario 3 accident are summarized in Table 3.5. Accident cleanup in the reactor building and containment vessel is estimated to require 5.3 years (no change from NUREG/CR-2601) and cost about $379 million.

It can be seen from Table 3.5 that labor costs are a major cost item for reactor building and containment vessel cleanup. Utility staff labor costs account for about 59% of the accident cleanup costs. Contractor costs for engineering support contribute an additional 7% to the total accident cleanup costs. An additional labor cost shown in the table is the living allowance paid to crew leaders and utility operators brought from other plants to assist in reactor defueling operations. As explained in NUREG/CR-2601, Section F.3.1 of Appendix F, personnel on temporary assignment are assumed to be paid a monthly living allowance in addition to their regular salaries.

Based on the waste management disposal assumptions discussed in Section 10.4.1.5 of NUREG/CR-2601, costs of radioactive waste management for accident cleanup in the reactor building and containment vessel are estimated to be about $24.2 million. These costs are shown in detail in Table 3.6. The costs shown in the table include container costs, transportation, and disposal costs. Labor costs for packaging the wastes prior to shipment are included in the utility staff labor costs shown in Table 3.5. Labor costs for transportation and disposal are included in the total charges for these activities shown in Table 3.6.

As discussed in Section 10.4.1.5 of NUREG/CR-2601, high-activity wastes (filter cartridges, ion exchange resin liners, and evaporator bottoms from processing radioactive liquids) and damaged fuel assemblies are assumed to be transported to a DOE-owned facility. Fuel assemblies that are not damaged are also transported to a DOE-owned facility. All other radioactive wastes are shipped to a shallow-land burial ground for disposal. The federal facility and the shallow-land burial ground are both assumed to be located 1600 km from the reactor site. Although the great majority of the waste (by volume) is shipped to a shallow-land burial ground, most of the costs of waste management in NUREG/CR-2601 was for the packaging, transportation, and disposal of wastes shipped to a federal facility. In fact, the cost of disposal of the fuel from defueling the reactor accounted for most of the cost of waste management in NUREG/CR-2601. As previously mentioned, however, as a result of the NWPA of 1982, the DOE is obligated to receive and dispose

TABLE 3.5. Summary of Estimated Costs of Accident Cleanup in the Reactor Building and the Containment Vessel Following the Postulated BWR Scenario 3 Accident

Cost Category	Estimated Costs[a] ($ millions)		Percent of Total
Utility Staff Labor			
Management and Support Staff	43.455		
Plant Operations Staff	26.914		
Accident Cleanup Staff	97.893		
Per Diem During Defueling[b]	9.480		
Total Staff Labor Costs		177.742	58.6
Waste Management Costs			
Disposal by Shallow-Land Burial	12.899		
Disposal at Federal Repository	5.407		
Fuel and Fuel Core Debris[c]	5.898		
Total Waste Management Costs		24.204	8.0
Energy		13.286	4.4
Special Tools and Equipment		17.199	5.7
Miscellaneous Supplies		12.994	4.3
Specialty Contractors			
Engineering	21.147		
Environmental Surveillance	0.298		
Waste Evaporator System	0.266		
Laundry	1.454		
Total Specialty Contractor Costs		23.165	7.6
Nuclear Insurance and License Fees		34.445	11.4
Subtotal		303.035	100.0
Contingency (25%)		75.759	
Total Costs		378.794	

(a) Costs are in January 1989 dollars. Number of significant figures shown is for computational accuracy only.
(b) Per diem paid to crew leaders and utility operators temporarily assigned from other plants during defueling operations. See explanation in Section E.4.2 of Appendix E of NUREG/CR-2601. The per diem costs have been adjusted to January 1989 dollars.
(c) Reflects only container costs. Transportation and disposal are covered by the 1 mill/kWh fee for waste disposal under the NWPA of 1982.

TABLE 3.6. Estimated Costs of Radioactive Waste Management for Accident Cleanup in the Reactor Building and the Containment Following the Postulated BWR Scenario 3 Accident[(a)]

Waste Category	Burial Volume (m^3)	Estimated Radioactivity Content (Ci)	Disposable Containers: Type	Disposable Containers: Number	Number of Shipments	Packaging and Transport Costs: Disposable Container Cost[(d)] ($)	Packaging and Transport Costs: Cask Rental Charge[(e)] ($)	Packaging and Transport Costs: Transport Costs[(f,b)] ($)	Disposal Site Costs[(b,c)]: Shallow-Land Burial Ground Cost ($): Disposal Charge	Shallow-Land Burial Ground Cost ($): State Surcharge[(g)]	Shallow-Land Burial Ground Cost ($): Handling Surcharge	Shallow-Land Burial Ground Cost ($): Liner Surcharge	Shallow-Land Burial Ground Cost ($): Curie Surcharge	Federal Repository Costs ($)	Total Waste Management Costs ($)
Sludge	9	1,000	0.21-m^3 steel drum	40	5	1,200	8,100	9,954	12,700	(6,357)	5,142		4,854		41,958
Process Solids															
Filter Cartridges	11	3,020	0.3-m^3 steel liner	35	18		47,250	59,724						126,000[(h)]	232,974
Zeolite Liners	19	3,000,000	0.3m^3 steel liner	66	33		89,100	109,494						237,600[(h)]	436,194
Organic Resin Liners	19	15,100	0.3-m^3 steel liner	62	31		83,700	102,858						223,200[(h)]	409,758
Process Solids															
Filter Cartridges	2	2,000	0.21-m^3 steel drum	8	1	240	1,350	3,318	7,790	(1,413)	1,711		1,987		16,395
Evaporator Bottoms	296	2,000,000	2.85-m^3 shielded steel liner	104	104	2,340,000	187,200	345,072						1,456,000[(h)]	4,328,272
Organic Resins	357	2,060	0.21-m^3 steel drum	1,700	122	51,000	328,050	404,796	391,986	(252,142)	208,967				1,386,799
Chemical Decontamination Solutions	1,050	500	0.21-m^3 steel drum	5,000	42	150,000		86,100	1,097,250	(741,594)	36,760				1,370,110
Trash															
Compactible, Combustible	309	516	0.21-m^3 steel drum	1,470	12	44,100		24,600	330,282	(218,261)	10,503				418,485
Compactible, Noncombustible	998	167	0.21-m^3 steel drum	4,750	40	142,500		82,000	1,042,910	(706,868)	35,009				1,302,419
Noncompactible	2,520	76	3.5-m^3 metal box	720	120	792,000		246,000	2,633,400	(1,779,826)	66,147				3,737,547
Contaminated Equipment															
LSA Materials	144	6	3.5-m^3 metal box	41	7	45,100		14,350	150,480	(101,705)	4,800				214,730
High-Activity Materials	312	2,000	2.85-m^3 steel liner	109	109	337,900	196,200	361,662	326,040	(220,560)	140,531	170,604			1,541,027
Irradiated Hardware															
LSA Materials	28	8	3.5-m^3 metal box	8	4	8,800	7,200	13,272	30,744	(19,776)	6,247				66,263
High-Activity Materials	91	[illegible]	2.85-m^3 shielded steel liner	32	32	720,000	57,600	106,176	95,095	(64,272)	43,591	418,647	1,364,328		2,805,437
Fuel Assemblies															
Intact Assemblies														(48,132,000)[(i)]	5,806,400
Damaged Assemblies	115		0.15-m^3 steel canister	764	77	5,806,400	(4,620,000)[(i)]	(4,697,000)[(i)]						(432,000)[(i)]	91,200
Fuel Core Debris	4	1,200	0.3-m^3 steel canister	12	3	91,200	(180,000)[(i)]	(183,000)[(i)]							
Subtotals															
Wastes Sent to Shallow-Land Burial	5,820	6,508,311		13,878	492	2,292,840	178,500	1,352,228	6,127,686	(4,110,554)	567,408	589,341	1,371,169		12,809,170
Wastes Sent to Federal Repository	346	5,018,120		267	186	2,340,000	407,250	617,148						2,042,800[(h)]	5,407,198
Reactor Fuel and Fuel Core Debris	119			776	80	5,897,600	(4,800,000)[(i)]	(4,880,000)[(i)]						(48,564,000)[(i)]	5,897,600
Totals	6,285			14,921	758	10,530,440	1,305,750	1,969,376	6,127,686	(4,110,554)	567,408	589,341	1,371,169	2,042,800[(h)]	24,203,968

(a) Number of significant figures shown is for computational accuracy only.
(b) Charges are computed on the assumption that all shipments for a given waste category are identical. Actually, charges for individual shipments would vary depending on the specific physical and radiological characteristics of individual shipments. The averaging technique used is believed to be appropriate for computing total charges.
(c) Based on information from Table A.9 of Appendix A.
(d) Based on information from Table A.2 of Appendix A.
(e) Based on information from Table A.3 of Appendix A. Assume 6 days for a round-trip truck shipment.
(f) Based on information from Table A.8 of Appendix A. Includes overweight charges and second-driver costs where applicable.
(g) The costs shown in brackets would apply to those generators outside the NW Compact. For the purpose of this cost update, these costs are not included in the total.
(h) For the purpose of this re-evaluation of costs, the wastes are considered to be greater than Class C. However, because no fee has yet been established for these materials, the estimated costs are simple escalations of the 1981 estimates (see Appendix A, Section A.4.1 for details).
(i) As a result of the NWPA of 1982, the DOE is obligated to receive and to dispose of commercial nuclear fuel. The costs (i.e., cask rental, transportation, and disposal) are covered by the 1 mill/kWh fee for waste disposal delineated in the Act. Therefore, while these estimated costs have been calculated and updated to January 1989 dollars for this report, these costs are not included in the totals.

of commercial nuclear fuel. The costs (i.e., cask rental, transportation, and disposal) are covered by the 1 mill/kWh fee for waste disposal delineated in the Act. Therefore, while these costs have been estimated and updated to January 1989 dollars for this report, these costs are not included in the total costs for accident cleanup given in Table 3.6.

3.4 OTHER POSSIBLE ADJUSTMENTS TO THE ACCIDENT CLEANUP COST

Rationale and analyses were presented in Section 11.5 of NUREG/CR-2601 regarding why the costs being estimated at that time for cleanup at TMI-2 were significantly larger than were estimated in the NUREG report for the reference PWR. Four basic cost elements were identified:

- basic accident cleanup (as estimated in the report)
- stabilization of the facility
- basic plant maintenance and operations
- incremental escalation of the above costs over the future years of the various activities.

While this analysis was not performed for the BWR accident in the original NUREG report, a similar analysis has been performed for this report, by analogy to the analysis for the reference PWR scenario 3 accident, as discussed in Section 11.5 of NUREG/CR-2601.

The four cost elements are presented in Table 3.7 for the original TMI-2 estimates, the original PWR estimates, and for the current BWR estimates. The methodology for performing these last three estimates is developed in subsequent paragraphs. The estimated total costs for cleanup at the reference BWR following a scenario 3 accident, including all four of the cost elements, is $1.22 to $1.44 billion in 1989 dollars, depending upon the assumed escalation rates (4%, 8%) in the years following 1989.

3.5 PLANT STABILIZATION COSTS

The costs at TMI-2 for facility stabilization (which encompasses stabilization of the plant, preparations for cleanup, and maintenance of the plant in a safe condition over a 2-1/2 year period following the accident) were $226 million, or about $90.4 million per year. The cost of preparations for cleanup at the reference PWR was estimated to be about $98 million in 1981 dollars over a 3-year period. When deflated to 1980 dollars (x 0.94), the annual cost of preparations for cleanup is about $30.8 million per year. Assuming that the preparations costs are equivalent for the reference PWR and for TMI-2, then the fractions of the total facility stabilization costs attributable to stabilization of the plant and to maintenance of the plant in a safe condition during delays can be derived as follows:

TABLE 3.7. Comparison of Estimated Cleanup Costs for TMI-2, the Reference PWR, and the Reference BWR

Cost Item	Costs ($ Millions)		
	TMI-2 Cleanup Costs[a]	Accident Cleanup in Reference PWR Following Scenario 3 Accident[b]	Accident Cleanup in Reference BWR Following Scenario 3 Accident[c]
1. Estimated Cost of Plant Cleanup	474.9[d]	404.5[e]	530.3[e,f]
2. Facility Stabilization	226.0[g]	(h)	259.0[i]
3. Base Operations and Maintenance			
a. Expended to Date[j]	49.1	(h)	86.6[i]
b. Estimated - Future Years	75.0	(h)	153.0[i]
4. Incremental Cost Escalation	209.3	(h)	186.5 to 409.9[k]
Total Estimated Costs	1,034.3	(h)	1,215.4 to 1,438.8

(a) Costs are from NUREG/CR-2601, Section 11.5, and are in 1980 dollars.
(b) Costs are from NUREG/CR-2601, Appendix F, are in early-1981 dollars, and include a 25% contingency.
(c) Costs are from this report in January 1989 dollars, and include a 25% contingency.
(d) For TMI-2, this includes maintaining plant in a safe condition, auxiliary building decontamination, and defuel reactor & decontamination of containment building.
(e) For the reference PWR, this includes preparations for accident cleanup, accident cleanup in the auxiliary building, and accident cleanup in the reactor containment building. For the reference BWR, this includes preparations for accident cleanup, accident cleanup in the radwaste building, and accident cleanup in the reactor building and the containment vessel.
(f) Cost is from Table 2.
(g) These costs were incurred at TMI-2 over a period of 2-1/2 years for activities such as stabilization of the plant, preparations for accident cleanup, and maintenance of the plant in a safe shutdown condition. The proportional cost allocations assigned to each activity were not defined in NUREG/CR-2601.
(h) Not estimated in NUREG/CR-2601.
(i) Study estimate; see text for details.
(j) Over a 2-1/2 year period for TMI-2; over a postulated 3-year period for the reference BWR.
(k) Cost values shown are based on annual escalation rates of 4% and 8%, respectively.

$$\% \text{ Preparations} = 30.8 / 90.4 = 34\% \quad (1)$$

$$\% \text{ Stabilization \& Maintenance} = (90.4 - 30.8) / 90.4 = 66\% \quad (2)$$

The costs for facility stabilization and maintenance of the reference BWR can be derived in an analogous manner. The preparations costs are estimated to be $133.4 million in constant 1989 dollars (see Table 2.2 for details). Given that similar percentage allocations within the facility stabilization costs are as determined above, then the total costs for facility stabilization at the reference BWR is given by equations (3) and (4):

$$\frac{(\text{Preps})_{BWR}}{(\text{Preps/Total})_{PWR}} = (\text{Total})_{BWR}; \quad 133.4 / 0.34 = \$392 \text{ million} \quad (3)$$

$$\text{Total}_{BWR} (0.66) = (\text{Stabilization \& Maintenance})_{BWR};$$

$$\$392 \text{ million } (0.66) = \$259 \text{ million} \quad (4)$$

3.6 PLANT MAINTENANCE AND OPERATION COSTS

Similarly, base operations and maintenance costs were not estimated in NUREG/CR-2601 for either the reference PWR or the reference BWR. Cumulative costs for these activities at TMI-2 by the time of the original NUREG/CR-2601 analyses are shown in Table 3.7 to be $49.1 million (in 1980 dollars) over a 2-1/2 year period, or an average of $19.64 million per year. If similar activities should be required at the reference BWR over the 3-year period following the postulated scenario 3 accident, they are estimated to cost about $86.6 million (in constant 1989 dollars) in this analyses. This cost estimate is based on the average annual TMI-2 cost, adjusted by a factor of 1.47 which represents the cost escalation for labor between 1980 and 1989. Using this same methodology, base operations and maintenance costs for 5.3 future years of accident cleanup at the reference BWR are estimated as follows:

$$(\$19.64 \text{ million} \times 1.47)\ 5.3 \text{ years} = \$53 \text{ million (in constant 1989 dollars)} \quad (5)$$

3.7 INCREMENTAL COST ESCALATION

For the purpose of this study, Cost Items 1, 2, and 3 presented in Table 3.7 (in 1989 dollars) were distributed uniformly over the appropriate portions of the cleanup period, resulting in a series of annual expenditures. The additional costs due to escalation of those annual expenditures during the cleanup period are summed and listed in Table 3.7 as Cost Item 4, in 1989 dollars, for two postulated escalation rates, 4% and 8% per year. The results of these calculations are presented in Table 3.8, with the methodology developed in subsequent paragraphs.

TABLE 3.8. Derivation of Incremental Cost Escalation Based on Annual Escalation Rates of 4% and 8%

Cost Item[(a)]	Escalation Period, Years	Expenditure in Year X, (Q_i), Millions '89 $	$(1 + y)^i$ 4%	$(1 + y)^i$ 8%	Δ_i (millions '89 $) 4%	Δ_i (millions '89 $) 8%
1	1	50.51	1.0400	1.0800	2.0204	4.0408
	2	50.51	1.0816	1.1664	4.1216	8.4049
	3	50.51	1.1249	1.2597	6.3069	13.1181
Subtotal		151.53			12.4489	25.5638
1	4	71.47	[illegible]	1.3605	12.1398	25.7641
	5	71.47	1.2167	1.4693	15.4842	33.5429
	6	71.47	1.2653	1.5869	18.9624	41.9439
	7	71.47	1.3159	1.7138	22.5796	51.0170
	8	71.47	1.3686	1.8509	26.3416	60.8160
	8.3	21.44	1.3848	1.8942	8.2494	19.1708
Subtotal		378.79			103.7570	232.2547
2	1	86.33	1.0400	1.0800	3.4532	6.9064
	2	86.33	1.0816	1.1664	7.0445	14.3653
	3	86.33	1.1249	1.2597	10.7795	22.4209
Subtotal		259.0			21.2772	43.6926
3	1	28.87	1.0400	1.0800	1.1547	2.3094
	2	28.87	1.0816	1.1664	2.3356	4.8036
	3	28.87	1.1249	1.2597	3.6045	7.4972
	4	28.87	1.1699	1.3605	4.9034	10.4064
	5	28.87	1.2167	1.4693	6.2542	13.5483
	6	28.87	1.2653	1.5869	7.6591	16.9416
	7	28.87	1.3159	1.7138	9.1202	20.6063
	8	28.87	1.3686	1.8509	10.6397	24.5642
	8.3	8.66	1.3848	1.8942	3.3321	7.7434
Subtotal		239.6			49.0234	108.4205
4 $\Sigma\Delta i = \Delta_T$					186.5	409.29

(a) From Table 3.7.

The estimated cost in Year X (beyond 1989) for Cost Item 4 can be calculated using Equation (6), assuming that these costs, Q_i, escalate as does labor. This assumption is based on the information in Table 4.2, which shows the accident cleanup costs to be dominated by labor costs.

$$\Delta T \text{ escalated} = \sum_{i}^{n} [Q_i L_x (1 + y)^i - Q_i L_x] \quad (6)$$

where:

ΔT escalated = total incremental escalations over the cleanup period

Q_i = annual expenditure in year (i) during the cleanup period

L_x = labor escalation factor from 1989 to Year X

$(1 + y)^i$ = projected escalation factor through year (i) of the cleanup period

Because the labor escalation factor, L_x, is common to all terms in the sum, it may be factored out of the sum as shown below.

$$\Delta T \text{ escalated} = (L_x) \sum_{i}^{n} Q_i (1 + y)^i - Q_i \quad (7)$$

or,

$$\Delta T \text{ escalated} = Lx \, \Delta T \quad (8)$$

where Δ_T is the summation from Equation (7).

The value of the summation shown in Equation (7) is presented in Table 3.8, for escalation rates of 4% and 8%. The sum, Δ_T, can be escalated from 1989 to year X by multiplying by the labor escalation factor, L_x, as shown by Equations (7) and (8).

Therefore, the projected incremental cost escalation, Δ_T, for Cost Items 1, 2, and 3, during the cleanup period can be escalated beyond Year X using Equation (8). This quantity can be added to Equation (9), which is developed in the following section, to estimate the total cost of the scenario 3 accident cleanup at the reference BWR in Year X.

4.0 DEVELOPMENT OF A COST ESCALATION FORMULA FOR ACCIDENT CLEANUP COSTS

The cost estimates for accident cleanup at the reference BWR were developed in 1981 dollars initially. Because a significant amount of escalation has occurred since that time, it has been necessary to update the estimated costs to reflect increases in the various components of those costs, with the results given in the previous section. As a result of performing these cost updates, it became apparent that the total costs could be divided into four principal components, as regards to cost escalation. These components are:

- labor and other components that escalate at the same rate as labor
- energy: electricity, fuel, and other components that escalate at the same rate as energy
- waste disposal: handling and burial charges at a low-level waste disposal site
- nuclear insurance.

Assuming that the escalation factors for each of these components can be derived for any point in the future, relative to the 1989 data provided in this report, then the escalated accident cleanup cost is given by Equation (9).

$$\text{Estimated Cost (Year X)} = [(\text{January 1989 Cost}) (A\ L_X + B\ E_X + C\ B_X + D\ I_X)] + L_X \Delta T(1989\$) \quad (9)$$

where A, B, C, and D are fractions of the total cost in January 1989 dollars that are attributable to labor, energy, burial, and insurance, respectively, and sum to 1.0. As discussed in the previous section, addition of the last term, $L_X \Delta T(1989\$)$, which provides the means for escalating Cost Items 1, 2, and 3 (see Table 4.1) beyond year X, completes the formula for estimating total cleanup cost. The factors L_X, E_X, B_X, and I_X are defined below.

L_X = [labor cost escalation from 1989 to Year X]

E_X = [energy cost escalation from 1989 to Year X]

B_X = [burial cost escalation from 1989 to Year X]; i.e.,

[burial cost in Year X / burial cost in 1989]

I_X = [nuclear insurance cost escalation from 1989 to year X]

Evaluation of B_X is to be provided to the licensees via NUREG-1307, a report issued periodically by the U.S. NRC, which contains the disposal rate schedules for each radioactive waste disposal site operating in the U.S. at the

TABLE 4.1. Distribution of Radioactive Waste Disposal Costs into Components that Escalate Proportional to Labor, Energy, and Burial Costs[a,b]

	Millions of Jan. '89 $				
Cleanup Operation	Reference Table	Container Costs (Labor)	Transportation Costs (Energy)	Disposal Costs (Burial)	Totals ($)
Preparations for Accident Cleanup	4	0.069	0.016	0.466	0.551
	(c)	0.085	0.070	0.854	1.009
Accident Cleanup in the Radwaste Building	6	0.374	0.259	1.503	2.136
Accident Cleanup in the Reactor Building and the Containment	8	13.163	3.719	13.373	30.255
Totals		13.691	4.064	16.196	33.951

(a) All costs include a 25% contingency.
(b) For Cost Item 1 from Table 3.7, based on the original estimates given in NUREG/CR-2601.
(c) Study estimate for all other wastes, except the spent fuel racks presented in Table 3.2.

time of report issuance, and values of B_x applicable to each operating site. Evaluation of L_x and E_x for years subsequent to 1989 is left to the licensees, based on the national consumer price indices and on local conditions at a given site, following the basic procedures given in NUREG-1307 Rev. 1.

Evaluation of I_x for years subsequent to 1989 is left to the licensees, based on insurance costs applicable to their facility. Evaluation of the coefficients A, B, C, and D is illustrated in the following tables and paragraphs.

The distribution of total disposal costs between container cost, transportation cost, and burial cost is illustrated in Table 4.1, with the costs given in January 1989 dollars for Cost Item 1 from Table 3.7, based on the original estimates given in NUREG/CR-2601.

Evaluation of the coefficients A, B, C, and D in the accident cleanup cost escalation formula is presented here for the reference BWR. This evaluation is based on information presented in Tables 2.2, 3.7, and 4.1 of this report and in Tables A.11 and A.12 in Appendix A. The cost components that escalate similarly are grouped together in Table 4.2. The sum of those grouped costs is divided by the total cost of accident cleanup (sans incremental cost escalation) to obtain the fraction of the total cost attributable to that group of components. The analyses presented in Table 4.2 show the values of A, B, C, and D to be 0.90, 0.03, 0.02, and 0.05, respectively, for the reference BWR scenario 3 accident.

TABLE 4.2. Derivation of Coefficients A, B, C, and D in the Postulated Accident Cleanup Cost Escalation Formula[a,b]

Cost Item Number/Component[c]	Millions of Jan. '89 $	Coefficient Derivation
1/Labor	429.9	
2/Labor[d]	259.0	
3/Labor[d]	239.6	
Subtotal	928.5	A = 928.5/1028.9 = 0.90
1/Energy and Transportation	29.2	B = 29.2/1028.9 = 0.03
1/Burial	16.2	C = 16.2/1028.9 = 0.02
1/Insurance	55.0	D = 55.0/1028.9 = 0.05
Total[e]	1028.9	

(a) All costs include a 25% contingency.
(b) The cost information shown in this table is dervived from Tables 2.2, 3.7, and 4.1 and Tables A.11 and A.12 in Appendix A.
(c) Cost Item Numbers are from Table 3.7.
(d) Study estimate; see text for details.
(e) Does not include Cost Item Number 4, Incremental Cost Escalation (see text for details).

APPENDIX A

COST ESTIMATING BASES

APPENDIX A

COST ESTIMATING BASES

This appendix presents the cost data that was used to develop an updated cost estimate for a boiling water reactor (BWR) accident cleanup, assuming the maximum severity accident (i.e., scenario 3 as described in NUREG/CR-2601 by Murphy and Holter 1982). Categories for which basic cost data are presented include: labor, waste packaging, transportation, waste disposal, equipment, and services and supplies. The data presented are all January 1989 costs, whereas the parent document used an early-1981 cost base. The updating of costs from the 1981 to the 1989 cost base is discussed in Section A.8.

A.1 LABOR COSTS

Cost adjustment factors for staff labor were determined by using the January 1989 Handy Whitman Index of Public Utility Construction Costs. Average values, determined by averaging cost escalation factors for building trades labor for the six regions of the United States defined by the Handy-Whitman index, were used in making the adjustments from 1981 to 1989 costs.

Salary data for the various accident cleanup and decommissioning staff members are listed in Table A.1. The base pay rates in Table A.1 are increased by 70% for nonunion employees and by 50% for union employees to account for such costs as fringe benefits, taxes, and insurance.

Labor costs shown in Table A.1 are representative of average labor costs across the U.S. rather than labor costs for a particular accident cleanup or decommissioning project at a given location. One decommissioning cost study (Manion and LaGuardia 1980) indicates that regional labor costs can deviate by as much as 17% from the national average. Costs at individual locations might deviate even more. In addition, the licensee costs will depend on the values used to estimate fringe benefits, taxes, insurance, and other overhead expenses.

A.2 WASTE PACKAGING COSTS

The costs of packaging radioactive waste materials prior to shipment to a shallow-land burial site or other authorized waste repository include the shipping container cost, the cost of additional shielding provided by overpacks and/or casks, and the cost of a solidifying or dewatering agent for radioactive liquids or wet wastes. These costs are discussed in the following subsections.

TABLE A.1. Labor Cost Data for Accident Cleanup and Decommissioning

Position	Base Pay ($/yr)	Assumed Overhead Rate (%)	Cost ($/yr)
Management and Support Staff			
Plant Superintendent	69,950	70	118,915
Assistant Plant Superintendent	59,700	70	101,490
Decommissioning Superintendent	69,950	70	118,915
Decommissioning Engineer	59,700	70	101,490
Assistant Decommissioning Engineer	41,230	70	70,090
Secretary/Word Processor/Clerk	21,550	50	32,325
Construction Engineering Supervisor	47,880	70	81,400
Construction Engineer	40,970	70	69,650
Estimator	36,710	70	62,410
Draftsman/Engineering Technician	26,600	50	39,900
Health and Safety Supervisor	47,215	70	80,265
Health Physicist	36,975	70	62,860
Industrial Safety Specialist	41,230	70	70,090
Radioactive Shipment Specialist	30,855	70	52,455
Contracts and Accounting Supervisor	36,840	70	62,630
Accountant	30,725	70	52,235
Contracts/Insurance/Procurement Specialist	30,725	70	52,235
Security Supervisor	43,760	70	74,395
Security Shift Supervisor	28,730	70	48,840
Security Patrolman	22,610	50	33,915
Quality Assurance Supervisor	41,230	70	70,090
Quality Assurance Engineer	36,975	70	62,860
Quality Assurance Technician	24,740	50	37,110
Plant Operations Supervisor	47,880	70	81,400
Plant Chemist	40,965	70	69,640
Chemist	36,710	70	62,410
Operations Engineer	40,965	70	69,640
Engineer	36,710	70	62,410
Operations Shift Supervisor	40,965	70	69,640
Senior Reactor Operator	36,710	70	62,410
Reactor Operator	30,855	50	46,285
Cleanup Superintendent	47,880	70	81,400
Warehouseman/Attendant (Tool Crib, Protective Equipment)	24,740	50	37,110
Consultant	--	--	133,000
Cleanup and Decommissioning Workers			
Shift Supervisor/Shift Engineer	41,230	70	70,090
Craft Supervisor	36,975	70	62,860
Craftsmen/Instrument Technician/Maintenance Mechanic	28,730	50	43,095
Crew Leader/Foreman	34,980	70	59,470
Utility Operator	28,730	50	43,095
Laborer/Power Plant Helper	27,665	50	41,500
Senior Health Physics Technician	30,855	70	52,455
Health Physics Technician/Safety Technician	26,865	50	40,300

(a) Adjusted to January 1989 (see text for details).

A.2.1 Shipping Container Costs

The shipping containers assumed to be used for packaging radioactive materials for disposal are listed in Table A.2. Because of increases in labor and material costs, some container costs have increased significantly since 1981. Insofar as possible, container costs were updated using actual 1989 costs determined by telephone contact with a supplier. For cases where this was not practicable, 1981 container costs were increased by the equipment escalation factor of 1.26.

TABLE A.2. Unit Costs of Shipping Containers for Radioactive Materials

Description	Burial Volume (m^3)	1989 Estimated Unit Cost ($)
Standard Steel Drum 0.21 m^3, 23 kg empty	0.21	30
Small Steel Drum 0.11 m^3 18 kg empty	0.11	23
Polyethylene Drum Liner	(a)	25
Metal Box 1.2 m x 1.2 m x 2.4 m, 275 kg empty	3.46	1,100
Metal Box Specially Fabricated	Variable	74/m^2 of surface
Steel Cask Liner 0.63 m OD x 1.02 m high, 150 kg empty	0.33	630
Steel Cask Liner 1.38 m OD x 1.9 m high, 680 kg empty	2.84	3,100
Shielded Cask Liner 1.38 m OD x 1.9 m high	2.84	22,500
Stainless Steel Canister for Spent Fuel 0.35 m OD x 4.2 m high	0.40	7,600
Steel Box Specially Fabricated	Variable	365/m^2 of Surface

(a) Included in outer steel drum, no added burial volume.

A.2.2 Overpack and Cask Charges

Some packaged wastes with high surface dose rates require transport to a burial site in reusable overpacks or shielded casks. In general, it is more economical to rent such containers than to purchase them, especially the larger ones or those used infrequently or for a short time period. The overpacks and casks assumed for transportation of high activity or high surface dose rate decommissioning wastes are listed in Table A.3, together with physical characteristics and estimated rental charges.

A.2.3 Additional Shielding Costs

In some cases, additional shielding must be added to shipping containers to reduce surface radiation dose rates. The addition of this shielding is estimated to cost an average of $1.97/kg, including labor and energy, based on the 1981 estimate used in NUREG/CR-2601, adjusted by a factor of 1.33.

TABLE A.3. Rental Charges for Reusable Shielded Casks

Description	Empty Weight (kg)	Daily Rental ($)
Truck Cask for Spent Fuel (1 PWR or 2 BWR Assemblies)	22,000	800
1.24 m OD x 1.56 m high 150-mm Pb thickness (B3 cask)	9,300	225
1.63 m OD x 2.34 m high 100-mm Pb thickness	16,300	300
1.95 m OD x 1.04 m high 50-mm Pb thickness (7D-3L cask)	7,000	225
1.4 m x 1.4 m x 6.1 m shielded autoloader for metal boxes	16,400	300
2.44 m x 2.44 m x 6.10 m double-walled steel with fire resistant insulation (Super Tiger)	6,800	300
IF-300 Spent Fuel Rail Cask (7 PWR or 18 BWR Assemblies)	120,000	4,000

A.2.4 Solidifying Agent Costs

The solidifying agents assumed to be used for packaging of wet solid and liquid wastes are listed in Table A.4 together with their respective costs.

TABLE A.4. Solidifying Agent Costs

Item	Estimated Unit Cost ($)
Cement (45-kg bag)	8/bag
Diatomaceaous Earth (23-kg bag)	15/bag
Vinyl Ester Styrene (0.21-m^3 drum)	158/drum

A.3 TRANSPORTATION COSTS

Most radioactive wastes from cleanup and decommissioning operations are assumed to be transported to a disposal site by exclusive-use truck. The exception is the transport of spent fuel, which is assumed to be by rail. The transportation costs for both truck and rail shipments are discussed in the following subsections.

A.3.1 Shipment by Exclusive-Use Truck

Shipments of radioactive wastes to a shallow-land burial site or to an authorized waste repository are assumed to be by truck. Transportation costs for these shipments are based on the published rates of a carrier licensed to transport radioactive materials (ICC TSMT 1988). To compute transportation costs, the following assumptions are made:

- One-way shipping distance is 1600 km.

- Shipments not requiring casks or overpacks are separate one-way shipments destined for west of the Mississippi River (the highest rate category). Cask or overpack shipments are continuous excursion round-trips.

- Where applicable, overweight charges are computed at the rate for the state of Washington, and regulations and conditions governing overweight and oversize shipments in the state of Washington are assumed.

The rate schedule for truck shipments of legal size and weight that forms the basis for transportation costs in this study is shown in Table A.5. Overweight charges by states vary widely (ICC TSMT 1988). For this study, the maximum allowed GVW and the overweight charges for the state of Washington are assumed to apply. These overweight charges are shown in Table A.6. An additional surcharge of $0.13 per km is imposed by the carrier for shipments with payloads greater than 21.77 Mg. Shipments with payloads in excess of 33.11 Mg require special equipment and special permission. Carrier charges for these shipments would have to be determined on a case-by-case basis.

The GVW of an unloaded exclusive-use van or tractor-trailer is assumed to be 14.52 Mg. Therefore the payload per shipment in an exclusive-use van is 21.77 Mg legal weight. Any vehicle exceeding 36.29 Mg GVW is considered to be overweight.

Oversize (as well as overweight) shipments may be required in certain instances. Table A.7 summarizes the applicable requirements for oversize shipments on two-lane highways. The oversize shipments assumed in this study are estimated to cost $1140/shipment more than legal-size shipments of the same weight. This additional cost covers the expense of special permits and escort cars.

Example shipping costs, calculated for several different payloads and for one-way and round-trip shipments, are shown in Table A.8. For a one-way 1600-km shipment, the base charge is that shown in Column 2 of Table A.5. To this must be added any applicable overweight charges shown in Table A.6, and any applicable oversize costs. Casks and overpacks are assumed to be picked up loaded at the site of accident cleanup operations, delivered to the disposal site to be unloaded, and then returned to the original site. Thus,

TABLE A.5. Transportation Rates for Legal-Size and -Weight Shipments (effective January 19, 1988)

TRI-STATE MOTOR TRANSIT CO.

ITEM NO. 3000 — SECTION II - MILEAGE COMMODITY RATES (Cont.)

MILEAGE COMMODITY RATES

COMMODITY: Radioactive Waste (low level) and empty containers therefor moving to or from points of loading, unloading or storage. (For rates on non-radioactive hazardous waste, see Tri-State Motor Transit Co. Tariff ICC TSMT 4033.)

BETWEEN: All points in the United States, except Alaska and Hawaii, as published in Scope of Operating Rights published herein.

▲RATES IN CENTS PER MILE

One Way Mileage (Not Over)	Column 1	Column 2	Column 3	One Way Mileage (Not Over)	Column 1	Column 2	Column 3
100	429	525	358	750	183	222	151
125	459	487	332	800	175	215	151
150	420	446	306	850	174	214	151
175	384	412	284	900	172	212	151
200	222	364	260	950	169	209	151
225	314	349	247	1000	165	205	151
250	301	334	230	1100	165	204	151
275	287	322	216	1200	165	201	151
300	275	308	206	1300	165	199	151
325	267	302	194	1400	165	198	151
350	259	295	188	1500	165	197	151
375	249	284	181	1600	165	195	151
400	237	273	175	1700	165	194	151
425	230	267	172	1800	165	193	151
450	219	257	167	1900	165	192	151
475	214	251	164	2000	165	191	151
500	206	244	161	2100	165	190	151
550	201	239	158	2200	165	188	151
600	196	235	151	2300	165	187	151
650	190	228	151	2400	165	186	151
700	187	224	151	2500 & Beyond	165	184	151

NOTES:

(1) Rates apply on legal size and weight shipments per vehicle used only. Overweight shipments not exceeding a gross vehicle weight of 85,000 pounds shall be subject to an additional charge of $0.21 per mile for each mile traveled in a state or states requiring overweight permits, in addition to all other applicable charges. For rates on shipments exceeding 85,000 pounds gross vehicle weight, see Section II, Item 2000 application.

(2) Column 1 rates applicable to one-way shipments having a destination East of the Mississippi River.

(3) Column 2 rates applicable to one-way shipments having a destination West of the Mississippi River.

(CONTINUED)

The provisions published herein will not, if effective, have an effect on the quality of the human environment.

For explanation of reference marks and abbreviations, see Item 110.

ISSUED: July 31, 1987 — EFFECTIVE: August 13, 1987

Issued by: George Cain, Vice-President, Traffic, P. O. Box 113, Joplin, MO 64802

TABLE A.5. (contd)

ITEM NO. 3000 (Cont.) SECTION II - MILEAGE COMMODITY RATES (Cont.)

NOTES: (Continued)

(4) Subject to restriction. Column 3 rates apply only to continuous excursion moves in which a subsequent shipment is made available to carrier within 24 hours after arrival at point of loading or unloading. Only one stop in transit allowed under Column 3 rates. RESTRICTION: Column 3 rates will not apply in connection with shipments moving under Item 520 deadhead of special equipment application.

(5) Minimum charge per trip to be computed on basis of 100 one-way miles.

(C)

(6) When temperature controlled van trailers or shielded van trailers are required, the rate shall be based on the round trip miles from point of origin to destination and return to point of origin. Column 3 rates shall apply unless trailer is not released to carrier within 24 hours after arrival at point of unloading in which case the inbound loaded movement and subsequent empty move shall be subject to the applicable Column 1 or Column 2 rates. When temperature control trailer is provided, a second driver is assigned and the charges in Item 530 will apply.

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The provisions published herein will not, if effective, have an effect on the quality of the human environment.

For explanation of reference marks and abbreviations, see Item 110.

ISSUED: July 9, 1985 EFFECTIVE: August 15, 1985

Issued by: C. H. Mayer, Vice-President, P. O. Box 113, Joplin, Mo. 64802

TABLE A.6. Additional Charges When the Payload Exceeds 21.77 Mg, Based on Rates for the State of Washington[a,b,c]

Weight (Mg)	Charge ($/km)
21.77 to 25.85	0.062
25.86 to 28.57	0.124
28.58 to 31.29	0.186
31.30 to 34.01[d]	0.280
34.02 to 36.73[d]	0.466
36.74 to 39.45[c]	0.621
39.46 to 42.18[d]	0.932
42.19 to 44.90[d]	1.087
Greater than 44.90[d]	1.243

(a) A flat charge of $25.00 is levied in addition to the charges shown in the table.
(b) From ICC TSMT 1988.
(c) The unloaded GVW for this study is assumed to be 14.52 Mg.
(d) Normally require special equipment/permission.

TABLE A.7. Requirements for Oversize Truck Shipments[a]

Characteristic Dimension of Vehicle/ Load Combination	Special Permit Required in Excess of:	Escort Car Required in Excess of:	Maximum Allowed Dimensions
Width	2.44 m (8 ft)	3.05 m (10 ft)	4.27 m (14 ft)
Height	4.11 m (13.5 ft)	--[b,c]	--[b,c]
Length	19.81 m (65 ft)	30.48 m (100 ft)	--[b]

(a) Based on regulations in the state of Washington for two-lane highways (Washington State Highways Commission 1974).
(b) No specific requirement, but escort car may be required at discretion of Highway Department.
(c) Heights exceeding 4.42 m (14.5 ft) are generally considered unacceptable because of the special routing and preparations required.

TABLE A.8. Example Shipping Costs of Truck Shipments

Status	Number of Drivers	Payload (Mg)	GVW (Mg)	Cost ($)
Legal weight, one-way[(a)]	1	19.95	34.47	2,050
Legalweight, round-trip[(b)]	2	19.95	34.47	3,318
Legal weight, one-way[(a)]	1	21.77	36.29	2,050
Overweight, one-way[(a)]	1	25.85	38.55	2,383
Oversize and overweight, one-way[(a)]	1	25.85	38.55	3,523
Overweight, round-trip[(c)]	2	25.85	38.55	3,958

(a) 1500-km distance.
(b) Shipments involving casks or overpacks, charges computed on the basis of two 1600-km trips.
(c) Shipments involving casks or overpacks, with overweight charges applicable both directions. Charges computed on the basis of two 1600-km trips.

each 3200-km round trip consists of two 1600-km one-way moves, with charges based on the continuous excursion rates shown in Column 3 of Table A.5. From the reference rate schedule, the basic charge for the round trip is $3,020. Applicable overweight charges must also be added. To ensure rapid turnaround on these shipments and to minimize cask rental charges, a second driver is assumed to be used, costing an additional $0.093/km.

A.3.2 Shipment by Rail

Formulas have been developed for use in estimating rail transportation costs for the federal waste management system. These formulas are presented in the Transportation System Data Base (DOE 1989) and are summarized here.

Rail Transport Algorithms

$$\text{Speed (mph) for general freight} = (0.11915)\, D^{(0.541)}$$

$$\text{Speed (mph) for dedicated train} = (0.17873)\, D^{(0.541)}$$

$$\text{Transport Cost (\$/Shipment)} = [(9/40)(0.1616)\, D^{(0.586)}\, (W_L + W_E)\, n] + F\, D$$

$$\text{Security Cost (\$/Shipment)} = 0.76\, D + [500\, D\, \{[1/(24\, RS_L)] + [1/(24\, RS_E)]\}] + 500\, T$$

where D = one-way distance in miles

W_L = loaded cask weight (hundredweight)

W_E = empty cask weight (hundredweight)

RS_L = loaded shipment speed

RS_E = empty shipment speed

n = number of casks per shipment

F = 0 for roundtrip, 48 for dedicated shipments from-reactors and general freight shipment back to reactors, 96 for dedicated roundtrip from-MRS or from-defense site shipments

T = turnaround time at origin (days).

It is not clear that a shipment containing only greater-than-Class C (GTCC) wastes would require any security escorts, as those requirements are intended for safeguarding the special nuclear materials contained in spent fuel.

Shipment by rail is assumed for the spent fuel removed from the reactor core during accident cleanup. Assuming a round-trip distance of 3200 km, the shipping cost (based on the rail transport algorithms) is estimated to be about $61,000, including security costs of about $7,300 for a rail car carrying a GE IF-300 cask.

A.4 WASTE DISPOSAL COSTS

A basic assumption of this study is that nearly all of the radioactive material resulting from cleanup (and decommissioning) of the reference reactor can be disposed of by burial at a commercial shallow-land burial facility. The only exceptions are the undamaged spent fuel, which is assumed to be placed in extended storage at an independent spent fuel storage installation (ISFSI), and the high-activity waste from accident-water processing and the damaged fuel assemblies and fuel core debris, which are assumed to be placed in interim storage at a federal facility. The unit costs of waste disposal are given in the following subsections.

A.4.1 Shallow-Land Burial

The shallow-land burial costs used in this study are based on an August 17, 1987 price list from U.S. Ecology, Inc., which operates burial sites at Richland, Washington, and Beatty, Nevada. These rates were still in effect for January 1989 and are shown in Table A.9.

TABLE A.9. Commercial Shallow-Land Burial Charges[a,b]

I. DISPOSAL CHARGES, NON-TRU WASTE

A. Packages 12.0 ft^3 each or less

Container Surface Dose Rate (R/hr)[c]	Price/Unit Volume ($/m3)
0.00 to 0.20	1045
0.201 to 1.00	1098
1.01 to 2.00	1139
2.01 to 5.00	1163
5.01 to 10.00	1298
10.01 to 20.00	1412
20.01 to 40.00	1589
40.01 to 60.00	By Request
60.01 to 80.00	By Request
80.01 to 100.00	By Request
>100	By Request

B. Disposable Liners Removed from Shield (greater than 12.0 ft^3 each)

Container Surface Dose Rate (R/hr)[c]	Surcharge/Liner ($)	Price/Unit Volume ($/m3)
0.00 to 0.20	None	1045
0.201 to 1.00	193.50	1045
1.01 to 2.00	441.00	1045
2.01 to 5.00	747.00	1045
5.01 to 10.00	1,192.50	1045
10.01 to 20.00	1,566.00	1045
20.01 to 40.00	1,791.00	1045
40.01 to 60.00	By Request	By Request
60.01 to 80.00	By Request	By Request
80.01 to 100.00	By Request	By Request
>100	By Request	By Request

II. SURCHARGES

A. State of Washington Surcharge:	$706.28/$m^3$ for those generators outside the NW Compact
B. Curie Surcharge (per load):	
Less than 100 curies	No charge
101 to 300 curies	$1,500, plus $0.21/Ci above 100 Ci by request
301 to License Limits (i.e., 50,000 Ci)	By request
C. Handling Surcharge:	
0 - 4.54 Mg	No charge
>4.54 Mg	$215.52 plus $0.10/lb above 10,000 lb/package
Special Equipment	By special quotation
D. Cask Handling Fee:	$550 minimum/cask

(a) Reproduced from the published rates of a licensed burial ground operator (U.S. Ecology 1987).
(b) Prices effective August 17, 1987 through January 1989.
(c) Maximum reading at container surface, irrespective of physical size or configuration.

A.4.2 Disposal of Wastes at a Federal Repository

At the present time, only shallow-land burial grounds are available for the disposal of commercial radioactive wastes. As explained in Sections 5.3.3 and D.5.2 of Murphy and Holter (1982), some wastes from the post-accident cleanup and decommissioning of a light water reactor (LWR) may not meet the acceptance criteria set forth in 10 CFR Part 61 for disposal by shallow-land burial. No regulatory framework has yet been developed to specifically address the disposal of wastes that are not acceptable for near-surface disposal. Accordingly, the disposition of these wastes may have to be determined on a case-by-case basis. Under the terms of a Memorandum of Understanding (1982) between the NRC and the DOE, DOE has agreed to assume responsibility for the storage and disposal of the damaged fuel core and other highly radioactive wastes from decontamination activities at TMI-2. The costs of disposition will ultimately be determined under an agreement to be negotiated between DOE and the owner.

Since a high-level waste repository does not presently exist, in this study, the high-activity wastes resulting from processing of the accident water and the damaged fuel assemblies and fuel core debris removed from the reactor during post-accident cleanup are assumed to be sent to a federal facility for interim storage. Storage and disposal costs at a federal facility have not been established at the time this report is being written. A recent draft study (Clark and Engel 1989) of DOE's spent fuel program gives $332/kg U as the estimated unit cost of disposal of spent fuel at a federal repository. This unit cost is the basis for the estimated spent fuel disposal costs given in this study. The disposal cost of a BWR assembly (189 kg U) is estimated to be about $63,000.

Estimated storage costs of other wastes postulated to be sent to a federal repository are chosen to be consistent with the spent fuel costs given above. Wastes from accident-water processing are assumed to be packaged in 0.3-m^3 cask liners for which estimated interim storage costs are $3600/liner. Evaporator bottoms and irradiated hardware are assumed to be packaged in 2.85-m^3 steel liners for which estimated interim storage costs are $14,000/liner. The fuel core debris is assumed to be packaged in stainless steel canisters costing about $36,000/canister to store.

<u>NOTE</u>: As a result of the Nuclear Waste Policy Act of 1982 and subsequent amendment, the U.S. Department of Energy is obligated to receive and dispose of commercial nuclear fuel. The cost (i.e., cask rental, transportation, and disposal) are covered by the 1 mil/kWh waste disposal fee delineated in the Act. Therefore, while these costs have been estimated and updated to January 1989 dollars for this report, these costs are <u>not</u> included in the total costs for accident cleanup given in the letter report.

A.5 EQUIPMENT COSTS

Equipment costs from the 1981 data base have been reviewed and updated as appropriate to reflect 1989 costs. Costs of selected construction-type items (hoists, cranes, lifts, etc.) are based on costs shown in the 1989 catalog of building construction costs published by the R. S. Means Company (1989). Other equipment costs were escalated based on national average cost escalation values for capital equipment obtained from the U.S. Department of Labor publication, "Producer Prices and Price Indexes." Equipment costs are shown in Table A.10.

TABLE A.10. Special Tools and Equipment

Item	Estimated Unit Cost (January 1989 $)
Underwater Manipulator	1,260,000
Underwater Plasma-Arc Torch	25,000
Underwater Oxyacetylene Torch	6,300
Arc Saw	151,000
Portable Plasma-Arc Torch	25,000
Portable Oxyacetylene Torch	1,300
Guillotine Pipe Saw	5,000
Power-Operated Reciprocating Hacksaw	1,300
Nibbler	1,300
Closed Circuit TV System	13,000-126,000[a]
Submersible Pump with Disposable Filter	2,500
High-Pressure Water Jet	25,200
Mobile Chemical Decontamination Unit	25,200
Mobile Chemical Mixing and Heating Unit	6,300
Powered Floor Scrubber	400
Wet-Dry Vacuum Cleaner (HEPA Filtered)	1,300-6,300[a]
Supplied-Air Plastic Suit	65
Respirator Facepiece	125
Shielded Vehicle with Manipulator Arms and Interchangeable Tools	151,000
Power-Operated Mobile Manlift	50,400
9100-kg Mobile Hydraulic Crane	35,300
9100-kg Forklift	35,300
Concrete Drill with HEPA Filtered Dust Collection System	2,500
Concrete Surface Spaller	6,300
Front-End Loader (Light Duty)	25,200
Portable Filtered Ventilation Enclosure	2,500-12,600[a]
Filtered-Exhaust Fan Unit	6,300
Blasting Mat	630
Polyurethane Foam Generator	6,300
Paint Sprayer	630-1,300[b]
Disposable Ion Exchange Liners	6,300
HEPA Filter	250
Roughing Filter	125
Waste Compactor	15,100
Incinerator	126,000-378,000[b]

(a) Depends on size and complexity.
(b) Depends on capacity of system.

A.6 SERVICES AND SUPPLIES

Various types of services and supplies are required for accident cleanup and decommissioning. The estimated unit costs of the major items are discussed here.

A.6.1 Electricity

A principal services cost item is electric power. Costs of electric power vary widely with location and usage rate. In this study, a unit wholesale cost of \$0.033/kWh, or \$33/MWh, is assumed for electricity.

A.6.2 Fuel Oil

Another energy service cost item is fuel oil. A unit cost of \$161/m^3 (\$0.61/gal) is assumed for fuel oil.

A.6.3 Decontamination Chemicals

The unit costs of the chemicals used for the EDTA/oxalic/citric acid solution for the decontamination of internal surfaces of the reactor coolant system are estimated to be:

- EDTA - \$1.56/kg
- Oxalic Acid - \$2.09/kg
- Citric Acid - \$2.20/kg.For a mixture of these three chemicals, one-third each by weight, the cost is \$1.95/kg.

The unit costs of the chemicals used to make up the oxalic-peroxide-gluconic (OPG) solution are estimated to be:

- Oxalic Acid - \$2.09/kg
- Hydrogen Peroxide - \$2.57/kg
- Gluconic Acid - \$2.92/kg
- Sodium Gluconate - \$1.21/kg.

For the OPG solution of specified concentration [see Section E.4.1 of Murphy and Holter (1982) for the chemical composition of OPG solution], the total unit cost for chemicals is \$67.68/m^3 of solution.

A.6.4. Ion Exchange Resins

The disposable ion exchange liners used in the submerged demineralizer system are estimated to cost \$6300 each, including the zeolite resins, the canister, and the necessary hardware to seal the unit for disposal. For the other ion exchange resins required, an average unit cost of $\$6300/m^3$ is also assumed.

A.7 COSTS OF NUCLEAR INSURANCE AND REGULATORY FEES

The estimated cost of nuclear liability insurance and of regulatory fees required during preparations for accident cleanup are shown in Table A.11. These costs are estimated to total about $19.7 million following the scenario 3 accident.

The estimated NRC fees shown in the table are a study estimate adapted from information contained in Code of Federal Regulations, 10 CFR Part 170.21. They include the cost of application fee ($150) and cost for review and approval of proposed license amendment, preparation of preliminary significance and hazards analyses, and preparation and publication of *Federal Register* notice (total estimated cost: about $164,600). Virtually all of these one-time administrative costs will ultimately be passed on to the licensee under the NRC's fee recovery program. The amount shown in the table represents a minimum estimate. Should the submittals be incomplete, or should difficulties be encountered during the accident cleanup operations, this estimated cost could increase significantly.

TABLE A.11. Estimated Costs of Property Damage Insurance, Nuclear Liability Insurance, and Regulatory Fees During Preparations for Accident Cleanup

Category	Unit Cost, $	Total Cost[a] Preparations for Cleanup Following Scenario 3 Accident
Property Damage Insurance	4,690,000/yr	14,070,000
Nuclear Liability Insurance	609,000/yr	1,827,000
License Fees[b]	164,800	164,800
Routine Health, Safety, and Environmental Inspections; Routine Safeguards Inspections	1,200,000/yr	3,600,000
Total Costs		19,661,800

(a) Costs are in 1989 dollars.
(b) Adapted from 10 CFR 170.21.

The property damage insurance and nuclear liability insurance costs presented in Table A.11 are based on conversations with a representative of the Washington Public Power Supply System for the reference BWR power station for 1989.

In addition, the cost of inspections shown in Table A.11 is based upon the current annual licensing fee for WNP-2. The fee bears a reasonable relationship to regulatory services performed by the NRC (Tri-City Herald 1989). Similar fees during accident cleanup are assumed for this cost update.

The bases used to estimate the costs of nuclear liability insurance and of regulatory fees required during accident cleanup are the same as those previously described for preparations for accident cleanup. For accident cleanup of the reference BWR, these costs are estimated to be about $34.4 million following the Scenario 3 accident (see Table A.12).

A.8 COST UPDATING FROM 1981 to 1989 COST BASE

As noted previously, the cost data used in this cost update are all January 1989 costs, while the parent decommissioning study used a 1981 cost base. To facilitate comparisons between the costs reported in this study and presented in the previous study, appropriate factors for adjusting costs from the 1981 data base to the 1989 base are presented by cost category in Table A.13. These cost updating factors are based on an analysis of cost indices and other measures of actual cost escalations over the period in question. The cost updating factors are rounded to three significant figures.

TABLE A.12. Estimated Costs of Property Damage Insurance, Nuclear Liability Insurance, and Regulatory Fees During Accident Cleanup

Category	Unit Cost, $	Total Cost[(a)] Cleanup Following Scenario 3 Accident
Property Damage Insurance	4,690,000/yr	24,857,000
Nuclear Liability Insurance	609,000/yr	3,227,700
Routine Health, Safety, and Environmental Inspections; Routine Safeguards Inspections	1,200,000/yr	6,360,000
Total Costs		34,444,700

(a) Costs are in 1989 dollars.

TABLE A.13. Decommissioning Cost Updating Factors: 1981 to 1989

Cost Category	Cost Adjustment Factor Applied to 1981 Costs
Staff Labor	1.33
Waste Management	
Container Costs	See rationale (Section A.2.1)
Transportation Costs	
Truck	See rationale (Section A.3.1)
Rail	See rationale (Section A.3.2)
Burial Site Costs	See rationale (Section A.4)
Energy	
Electricity	1.32[a]
Fuel Oil	0.61[a]
Special Tools and Equipment	1.26[a]
Miscellaneous Supplies	1.26[a]
Specialty Contractors	1.33
Nuclear Insurance	See rationale (Section A.7)
Regulatory Fees	See rationale (Section A.7)

(a) Based on cost data from U.S. Department of Labor publication, "Producer Prices and Price Indexes."

Most of the unit cost information in this study is developed from essentially the same sources as the unit cost information in the parent decommissioning study and, thus, the cost updating factors presented in Table A.13 are based on cost escalations shown by these sources. Actual cost escalations during the period are likely to vary from area to area. In addition, different sources of information may report somewhat different values for cost escalations over the same period. Therefore, care should be taken to ensure the use of appropriate data in escalating costs for any specific project.

A.9 REFERENCES

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The estimated costs for post-accident cleanup at the reference BWR (developed previously in NUREG/CR-2601, Technology, Safety and Costs of Decommissioning Reference Light Water Reactors Following Postulated Accidents) are updated to January 1989 dollars in this report. A simple formula for escalating post-accident cleanup costs is also presented. Accident cleanup following the most severe accident described in NUREG/CR-2601 (i.e., the Scenario 3 accident) is estimated to cost from $1.22 to $1.44 billion, in 1989 dollars, for assumed escalation rates of 4% or 8% in the years following 1989. The time to accomplish cleanup remained unchanged from the 8.3 years originally estimated. No reanalysis of current information on the technical aspects of TMI-2 cleanup has been performed. Only the cost of inflation has been evaluated since the original PNL analysis was completed.

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