DECOMMISSIONING BY IMMEDIATE DISMANTLEMENT PRELIMINARY COST ESTIMATE FOR PICKERING NGS A

Nuclear Materials Management Department

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1.0 PURPOSE AND SCOPE

PURPOSE

This report presents the estimated costs for decommissioning Pickering NGS A after a normal service life by the method of immediate dismantlement.

SCOPE

The report considers the activities required to remove all nuclear structures and materials from the Pickering NGS A site so that it is left suitable for unrestricted use. Dollar and radiation dose costs are estimated. The station is considered to be dismantled as rapidly as reasonably possible at the end of a normal service life.

A cost estimate for dismantling Bruce NGS A by immediate dismantlement was included in the study. Bruce NGS A decommissioning costs are estimated by a simple extrapolation of the Pickering NGS A estimated costs.

This report is based on Design and Development Division Report No. 81156 (Ref. 1) "Preliminary Nuclear Decommissioning Cost Study". Report No. 81156 summarized the estimated costs of decommissioning Pickering NGS A by the method of deferred dismantlement. A thirty year deferral period was selected as the study basis of Report No. 81156.

2.0 THE NEED TO EVALUATE IMMEDIATE DISMANTLEMENT

Immediate dismantlement is one of several possible methods of decommissioning a nuclear generating station at the end of its normal service life.

Any decommissioning method can be considered as direct use of one of three basic options, or as a combination of the same options. The three basic options may be expressed as,

i) Complete Dismantlement. Also known as Unrestricted Site Use (USU) or Stage 3 decommissioning (ref. 2).

ii) Storage with Surveillance (SWS). Also known as Stage 1 decommissioning (ref. 2) or Mothballing (ref. 3).

iii) Restricted Site Release (RSR). Also known as Stage 2 decommissioning (ref. 2) or Entombment (ref. 3).

Decommissioning methods and schedules chosen or recommended in the world to date (ref. 1, 4) use one or a combination of these basic options. Variation in dismantlement timing and storage periods produces a wide range of individual decommissioning methods and schedules.

The basic options transfer differing degrees of responsibility for public protection onto future utility operators or public administrations.

Complete dismantlement terminates any ongoing responsibilities. It is designed to leave the nuclear generating station site in a condition suitable for unrestricted use. All nuclear materials and structures are removed.

Storage with surveillance demands an active protective role, for an indefinite period, from those with future responsibility for the site. This option entails monitoring and guarding the intact nuclear plant for an indefinite period, after the nuclear fuel and heavy water have been removed. No future use can be made of the nuclear portion of the site except storage of the inoperable nuclear plant. The non-nuclear portion of the site can only be used under radiation protection constraints.

Restricted site release demands that a limited protective role be assumed by those with future responsibility for the site. Parts of the site may be released for use under radiation protection constraints. This option entails removal of the nuclear fuel, heavy water and some radioactive materials and structures. Those remaining on the site are encased in permanent structures intended to protect the public by retaining radioactive materials indefinitely. Deliberate and concerted effort would be required to gain access to radioactive materials within.

Immediate dismantlement means removal of all radioactive materials from the site as rapidly as reasonably possible after the nuclear generating station has been permanently shut down.

The need to consider immediate dismantlement is supported by social reasons and practical engineering reasons.

The social advantages of immediate dismantlement are;

1) Responsibility for future guardianship of the site is eliminated.

2) An industrial site is available for reuse for the public benefit.

The practical engineering reasons concern safety and availability of staff. In the case of immediate dismantlement, trained and experienced operating personnel will be available to assist with preparation of detailed, practical decommissioning plans. Deferral of dismantlement requires that new technical staff must be recruited and trained before dismantling is begun.

Deferral of dismantlement also requires maintenance of large amounts of documentation for use when dismantling occurs. The documents requiring preservation are the technical records and specifications of the plant. They are required for training newly recruited staff and for use when dismantling is in progress. The costs of deferring complete dismantlement by 30 years have been studied by Ontario Hydro and reported in reference 1. The costs of deferring complete dismantlement by 500 years have also been studied and are reported in reference 7.

3.0 SUMMARY OF FINDINGS

Decommissioning of Pickering NGS A by immediate dismantlement is estimated to cost:

(i) $201 million in 1980 dollars

(ii) 3300 man-rem

These estimated amounts would be spent over the nine years which are estimated as necessary to perform expeditious and cost-effective dismantling of Pickering NGS A.

Decommissioning Bruce NGS A by the same method is estimated to cost $228 million in 1980 dollars.

For Pickering NGS A the reference case of deferring dismantlement by 30 years (Ref. 1) was estimated to cost $162 million in 1980 dollars, and 1,824 man-rem.

Table 1 shows estimated cash expenditures by year and activity for Pickering NGS A.

Table 2 summarizes dollar expenditures for Pickering NGS A.

Table 3 summarizes dollar expenditures for Bruce NGS A.

Table 4 summarizes radiation dose expenditures for Pickering NGS A.

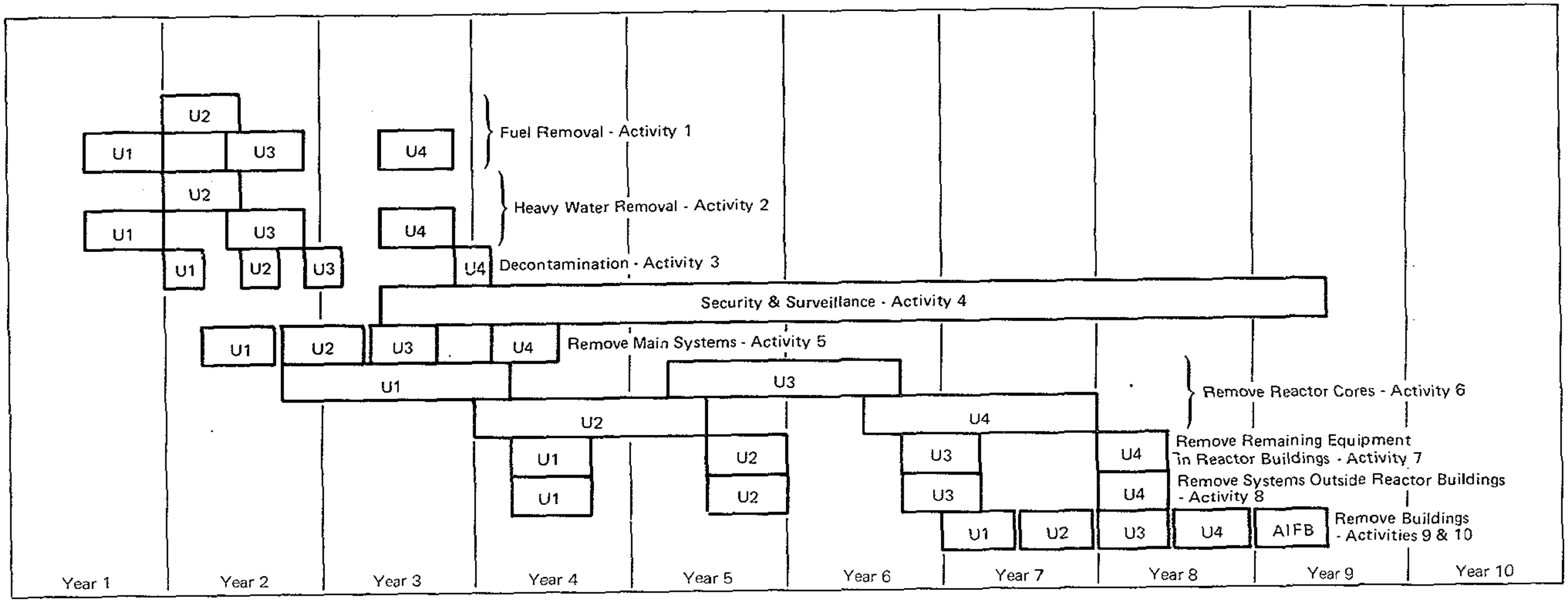

FIGURE 1
Activities Chart
Pickering NGS A
Decommissioning by Immediate Dismantlement

TABLE 1
Pickering NGS A
Decommissioning by Immediate Dismantlement
Cash Expenditure Distribution - 1980 Dollars
($ 000)

Activities \ Year(s)	1	2	3	4	5	6	7	8	9	Total
Fuel Removal (Act. 1)										
Labour	1 980	1 620	810	8	30					4 448
Materials & Equipment	215	430	216	–	–					861
										5 309
Heavy Water Removal (Act. 2)										
Labour	38	370	191	147						746
Materials & Equipment	215	215		–						430
Transportation & Disposal	–	–	–	72						72
										1 248
Decontamination (Act. 3)										
Labour		1 268	633	634						2 535
Materials & Equipment		3 510	65	65						3 640
Transportation & Disposal		1 794	717	359						2 870
										9 045
Security & Surveillance (Act. 4)										
Labour			125	200	200	200	200	200	100	1 225
										1 225
Dismantle Systems Inside Reactor Buildings (Act. 5 & 7)										
Labour		1 500	1 500	1 100	100	50	50	100		4 400
Materials & Equipment		2 930	2 929	1 953	–	–	–	–		7 812
Transportation & Disposal		1 500	1 500	1 075	75	37	38	75		4 300
										16 512
Dismantle Reactor Cores (Act. 6)										
Labour		317	1 267	1 583	1 583	1 583	1 267			7 600
Materials & Equipment		14 629	2 515	3 144	3 144	3 144	2 515			29 091
Transportation & Disposal		2 176	8 702	10 878	10 878	10 878	8 702			52 214
										88 905
Dismantle Systems Outside Reactor Buildings (Act. 8)										
Labour				350	350	175	175	350		1 400
Materials & Equipment	–	–	–	150	150	75	75	150		600
Transportation & Disposal				1 050	1 050	525	525	1 050		4 200
										6 200
Remove Reactor Vaults (Act. 9)										
Labour							360	360		720
Materials & Equipment	–	–	–	–	–	–	3 440	3 440		6 880
Transportation & Disposal							2 375	2 375		4 750
										12 350
Remove Reactor Buildings & Ancillary Buildings (Act. 10)										
Labour							2 928	2 928	113	5 969
Materials & Equipment	–	–	–	–	–	–	16 634	16 634	87	33 355
Transportation & Disposal							1 107	1 108	50	2 265
										41 589
	2 448	32 259	21 170	22 768	17 560	16 667	40 391	28 770	350	182 383
Contingency allowance @ 10%										18 217
Total cost in 1980 dollars										200 600

TABLE 2
Pickering NGS A
Decommissioning by Immediate Dismantlement
Summary of Estimated Costs in 1980 Dollars
($ 000)

Activity	Labour	Equipment & Materials	Transport & Disposal	Totals
Fuel Removal	4 448	861	N/A*	5 309
Heavy Water Removal	746	430	72	1 248
Decontamination	2 535	3 640	2 870	9 045
Security and Surveillance	1 225			1 225
Dismantling Buildings† (includes reactor buildings, reactor vaults and ancillary buildings)	6 689	40 235	7 015	53 939
Dismantling Systems (includes reactors)	13 400	37 503	60 714	111 617
				182 383
Contingency Allowance @ 10%				18 217
Total				200 600

* Irradiated fuel disposal costs are assumed to be paid from the Operations budget.

† Refers to buildings housing nuclear systems, and those handling nuclear materials.

TABLE 3
Bruce NGS A
Decommissioning by Immediate Dismantlement
Summary of Estimated Costs in 1980 Dollars
($ 000)

Activity	Labour	Equipment & Materials	Transport & Disposal	Totals
Fuel Removal	4 892	916	--	5 808
Heavy Water Removal	829	476	79	1 384
Decontamination	2 813	4 039	3 310	10 162
Dismantling Buildings (includes reactor buildings and fuelling duct)	10 531	55 931	9 038	75 500
Dismantling Systems (Includes reactors)	14 180	37 699	61 410	113 289
Security and Surveillance	1 500			1 500
				207 643
Contingency Allowance @ 10%				20 757
Total				228 400

TABLE 4
Pickering NGS A
Decommissioning by Immediate Dismantlement
Summary of Radiation Dose Expenditures
Man-rem for Entire Station

Activity	On-site Doses	Transportation & Disposal Doses	Totals
Fuel Removal	200	N/A	200
Heavy Water Removal	13	—	13
Decontamination	168	40	208
Security and Surveillance	—	N/A	—
Dismantling Buildings (including reactor vaults)	90	24	114
Dismantling Systems —			
- Systems Outside Reactor Building	20	12	32
- Reactor Cores	2 480	47	2 527
- Remaining Systems Inside Reactor Building	175	39	214
Total			3 308

4.0 METHODOLOGY OF STUDY

The study summarized in this report was based on Reference 1. Reference 1 studied dismantlement of Pickering NGS A after storing the shutdown station for 30 years.

The cost of each immediate dismantlement activity was calculated for Pickering NGS A in one of three ways:

- use of a cost figure from Reference 1 where the same activity occurred in both immediate and deferred dismantlement under the same conditions;

or, modification of a cost figure from Reference 1, where the same activity was performed under different conditions;

or, original calculation of a cost figure where new or significantly different activities were identified compared to Reference 1. In such cases, rates for labour, material, transportation and disposal were those used in Reference 1.

Assumed work methods and cost calculation methods followed those of Reference 1 as much as possible.

Summary estimates for decommissioning Bruce NGS A were prepared by extrapolating costs for Pickering NGS A in the ratio of the material sizes of Bruce and Pickering. This was the method used in reference 1 for estimating decommissioning costs for Bruce NGS A.

5.0 RATIONALE FOR CHOSEN ACTIVITY SEQUENCE

The major activity groups required for immediate dismantlement are shown in Fig. 1 'Activities Chart'. Reasons for their occurrence and timing are given here.

Reactor Shutdown Sequence

The four reactors are assumed to be shut down on the anniversaries of the dates on which they went into service. This is a reasonable assumption. It avoids the sudden removal of the entire Pickering NGS A generating capacity from the power system. The shutdown dates are indicated on the activity chart as the beginning of fuel removal operations for each unit.

Activity 1 Fuel Removal

The inventory of irradiated fuel must be removed to the irradiated fuel bay (IFB) for safe storage and continued cooling. This is done using the normal fuel handling equipment, very soon after each unit is shut down. The operation takes six months for each reactor.

Activity 2 Heavy Water Removal

The heavy water is removed from the reactor systems for purification and reuse. This operation can begin as soon as the reactor shuts down. The final operation is removal of heat transport heavy water. This must wait until fuel removal is complete, and may then be done rapidly. The activities chart therefore shows heavy water removal as the same duration as fuel removal.

Activity 3 Decontamination

This activity is necessary for two reasons. The first is to reduce radiation and contamination levels before dismantling begins. The second is to isolate and fix the distributed fission and activation products in a form suitable for safe disposal. Some common services such as the IFB must be decontaminated as well as the individual units. The cost and extent of decontamination operations for the common services is relatively minor. They are therefore, not separated from decontamination of the individual units. A period of three months is estimated for each unit.

Activity 4 Security and Surveillance

After the shutdown of the last unit, security and radiation surveillance costs are charged to decommissioning. These costs continue until the site is suitable for unrestricted use.

Activity 5 Remove Main Systems

Decontamination cannot entirely eliminate radioactive contaminants from the majority of the unit systems. It is cost effective and good radiation safety practice, to reduce radiation levels still further before performing the majority of dismantling activities inside the reactor building. This is achieved by removing radioactive systems such as the heat transport system and moderator system. After those systems have been removed, equipment which could physically impede reactor dismantling is taken from the reactor building. Activity 5 is expected to take six months.

Activity 6 Remove Reactor Cores

In this case, 'reactor core' means all equipment contained in the reactor vault, the reactivity mechanisms deck and any headers and feeders remaining after Activity 5 above. Dismantling a reactor core requires flooding the vault and using remote handling equipment to minimise radiation doses. This activity is estimated to take 18 months for each reactor. Few other operations can be conducted in the reactor building during this activity. Termination of reactor dismantling leaves the reactor building free of radioactive systems.

Activity 7 Remove Remaining Equipment in Reactor Building

After completing reactor dismantling, the only radioactive materials remaining in the reactor building are the activated reactor vault concrete and some residual surface contamination remaining after systems removal activities. Any equipment remaining in the reactor building is now removed. This prepares the reactor building for demolition.

Activity 8 Remove Systems Outside Reactor Building

These systems contain equipment designed for supplying services to the reactor building. Removal of these services can commence when reactor removal is complete. A few services will be required until activity 7 is complete. Therefore activities 7 and 8 are shown as ending together. Each activity is estimated to take six months.

Activity 9 Remove Buildings

The buildings demolished are:

- Ancillary Buildings: Heavy Water Upgraders, Auxiliary irradiated Fuel Bay (AIFB), Reactor Auxiliary Bay and IFB including fuel ducts;
- Reactor Buildings: These include demolition and shipment of the radioactive concrete and embedded parts of the reactor vault;
- Vacuum Building: Although this building must remain until Pickering NGS 'B' has ended its service life, the cost of its removal is charged to Pickering A. Other common buildings, such as the Service Building, will be charged to Pickering NGS 'B' decommissioning. This method of apportioning the decommissioning cost of buildings common to Pickering NGS A and B is the method used in reference 1.

The AIFB will be removed last of all, after its irradiated fuel inventory has cooled sufficiently to allow shipping it to a disposal facility.

6.0 RATIONALE FOR DOLLAR EXPENDITURES

All comments in this rationale use the 30 year deferred dismantlement costs as a reference case. A 'cost increase', for example, means that immediate dismantlement is more expensive for the given activity than if dismantlement were deferred by 30 years.

6.1 Fuel Removal (Activity 1).

Methodology and Costs identical to reference case. Operating conditions are exactly the same; cost remains at $5.309 million.

6.2 Heavy Water Removal (Activity 2).

Methodology and Costs identical to reference case. Operating conditions are exactly the same; cost remains at $1.248 million.

6.3 Decontamination (Activity 3).

Preparation and process costs identical to reference case; cost remains at $6.175 million. Transportation and disposal costs increase because little time is available for allowing radioactive decay of decontamination wastes. The reference study assumed storage of the wastes inside reactor buildings during the 30 year deferral period. Wastes must be transported in shielded shipping containers, and then buried in deep storage at a cost of $12,500 per cubic metre. Transportation and disposal costs increase to $2.870 million, from $0.800 million in the reference case.

6.4 Security and Surveillance (Activity 4).

Annual cost is assumed to be $200,000, as in the reference case. This activity is required for six years instead of the 36 years required by the reference case. The total cost is reduced from $7.2 million to $1.225 million.

6.5 Systems Removal

6.5.1 Systems inside Reactor Building

6.5.1.1 Reactor Cores (Activity 6).

These are permitted little time for radioactive decay before removal commences. Labour costs are increased because greater use of remote handling techniques, and erection of shielding require (a) greater manpower and (b) slower work methods. These result in increased waiting times and higher payroll costs. Very active components must be cut into smaller pieces so that heat dissipation limits during shipping are not exceeded. Very well shielded flasks must be used for in-station handling of core segments. Preparations for shipping must employ further remote handling techniques.

Consequently,

- labour costs are estimated to increase from $3.8 million to $7.6 million;
- transportation and disposal costs increase from $37.8 million to $52.214 million;
- remote handling and other equipment costs increase from $7 million to $14 million. This figure is consistent with simple versions of remote handling equipment used in reactor repairs.

6.5.1.2 Remaining systems inside Reactor Building. (Activities 5 and 7)

No time is permitted for radioactive decay. Even after decontamination, systems contain residual fission and activation products necessitating respiratory protection (as a minimum) for personnel during dismantling operations. General gamma radiation fields are estimated to be about 7 times higher than the reference case. Greater use of time-consuming radiation protection measures is required.

Consequently,

- labour costs increase from $2.2 million to $4.4 million;
- materials costs increase by 35% to $7.812 million to cover more extensive use of radiation protection equipment and procedures;

Transportation and disposal costs remain at $4.3 million; dismantled systems still remain in the low activity category for burial.

6.5.2 Systems Outside Reactor Building (Activity 8).

Because of the short decay period, contamination and low level gamma radiation fields will be more widespread than in the reference case. Increased use of radiation control procedures and the requirement for additional packaging materials increase removal costs from $1.5 million to $2 million.

An estimated 200m³ of spent IX resin from the Reactor Auxiliary Bay resin storage tanks will require burial at the distant disposal site. This results in transportation and disposal costs increasing from $2.135 million to $4.2 million.

6.6 Buildings Removal (Activities 9 and 10)

Only the costs for reactor vault dismantlement change; the radioactive vault concrete is permitted little time for radioactive decay. Work methods must change drastically to permit removal of the inner layer of radioactive concrete while maintaining a high level of radiation safety. Remote methods must be used, with strict contamination control of radioactive concrete dust. Disposal will require tightly sealed containers.

Consequently, for the reactor vaults,

- labour costs increase from $0.18 million to $0.72 million;
- equipment cost and material increase from $3.52 million to $6.88 million;

- transportation and disposal costs increase from $3.75 million to $4.75 million to pay for higher quality shipping containers and shipping methods which require more extensive radiation protection measures.

Demolition and removal of the remaining buildings is done by the same methodology and under very similar conditions to the reference case. Cost for this activity is $40.329 million. This figure does not include $1.26 million for sealing the reactor buildings for storage. Such a cost was included in the reference case costs for building dismantlement.

7.0 RATIONALE FOR RADIATION DOSE EXPENDITURES

All comments in this rationale use the 30 year deferred dismantlement doses as the reference case. Relative quantifiers such as 'double' or 'increase' are comparing a dose estimate for an immediate dismantlement activity with the dose for the same activity in the reference case.

7.1 Fuel Removal (Activity 1).

Methodology and operating conditions identical to reference case. Dose expenditure remains at 200 man-rem.

7.2 Heavy Water Removal (Activity 2).

Methodology and doses identical to reference case. Operating conditions are identical; dose expenditures remain at 13 man-rem.

7.3 Decontamination (Activity 3).

Preparation and process doses identical to reference case; doses remain at 168 man-rem. Transportation doses increase from 20 man-rem to 40 man-rem because the decontamination wastes are shipped off site immediately after decontamination is completed. Gamma dose rates from the wastes are therefore about 50 times greater than in the reference case, in which the wastes are stored in reactor buildings on site for 30 years to permit their radioactive decay before shipping. In the immediate dismantlement case, gamma dose rates from the wastes will be greater than 10 rem/hour. This necessitates the use of shielded shipping containers, with a consequent reduction in payload for each shipment of wastes. The number of trips is estimated as double the number required in the reference case. Assuming that gamma dose rates to the truck drivers remain the same as in the reference case, shipping dose rates double from 20 man-rem to 40 man-rem.

7.4 Security and Surveillance (Activity 4)

Security and surveillance activities will take place in areas of the site having very low dose rates. Dose expenditures are therefore expected to be negligible. No dose expenditure is budgeted for these activities.

7.5 Systems removal

7.5.1 Systems inside Reactor Building

7.5.1.1 Reactor Cores (Activity 6)

Unshielded reactor core components will exhibit gamma dose rates about 50 times greater than the reference case. Water shielding used during sectioning of calandria, dump tank and thermal shield can readily limit dose rates in personnel occupied areas during the operation, to twice those of the reference case. This assumption is reasonable in the light of dose rates observed in irradiated fuel bay operations. Extensive use of remote handling techniques can limit doses during removal of other reactor components, and during all shipping preparations, to twice the reference doses.

Consequently,

- doses for sectioning and removal of calandria, dump tank and end shield increase from 180 to 360 man-rem per reactor;
- doses for removal of remaining reactor components increase from 130 to 260 man-rem per reactor.

Total dose for removing all reactor cores becomes 2480 man-rem.

Shipping doses increase 25% to 47 man-rem because of increased number of shipments. This is because the decay heat from some activated steel reactor components is sufficient that the steel mass in each shipment must be reduced in order to avoid exceeding heat dissipation limits of the shipping flask.

7.5.1.2 Remaining Systems inside Reactor Building (Activities 5 and 7).

Reference 1 assumes very gamma low dose rates from these operations. Some dose rates are close to natural background dose rates. Dose rates will be greater in immediate dismantlement because of the elimination of the 30 year radioactive decay period. It is not realistic to increase the reference dose rates by a factor of 50 or more for immediate dismantlement. Based on estimated station maturity dose rates and a decontamination factor of 50, dose rates in the reactor building will be on average about seven times those in Reference 1. No significant changes in work methods are assumed.

Dose expenditure is therefore increased sevenfold to 175 rem for dismantling and removal, for the total of all these systems in the station. Shipping doses will not change; the number of shipments, the shipment destination, and dose rates to drivers remain unchanged.

7.5.2 Systems Outside Reactor Building (Activity 8).

Certain systems will have dose rates in the millirem/hour range because systems are permitted very little time for radioactive decay. As a result, dismantlement doses increase from 3.2 to 20 man-rem for the station, to accommodate higher dose rates from these systems. Transportation doses increase from 6 man-rem to 12 man-rem. The additional dose expenditure results from shipping 200 m^3 of IX resin to a radioactive waste disposal site in shielded shipping containers. In the reference case, resin shipments incurred no dose expenditure since dose rates to drivers of trucks transporting the resin were estimated to be negligible. The resin was assumed in the reference case to have decayed to low activity levels during the 30 year site storage period.

8.0 REFERENCES

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