Prepared By: Thomas Ross / 04-04-97
Project Leader — Date

Approved By: ______________________ / ________
RD Management — Date

CONCEPTUAL DESIGN FOR
RD MODIFICATION APPROVAL (RMA) NO. 97-01,
"IMPERVIOUS LINER FOR THE HFBR SPENT FUEL STORAGE CANAL"

Revision 0

April 1997

[FINAL DRAFT]

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1.0 REASON FOR MODIFICATION

1.1 Recently, tritium concentrations in excess of drinking water standards were found in a sample taken from a groundwater monitoring well located in close proximity to the HFBR confinement building. In response to these initial findings, the groundwater monitoring was expanded by the addition of numerous permanent and temporary (called "geoprobes") monitoring well points. These additional groundwater monitoring efforts detected a plume of tritium contamination extending significant distances southward from the HFBR confinement building.

1.2 While the exact source of the tritium contamination has yet to be determined, subsequent measurements of groundwater tritium concentration, review of some well water monitoring historical data, and corroborating canal leakage models, indicates that leakage from the HFBR spent fuel storage canal (canal) is the most probable source of the groundwater contamination. Therefore, in order to eliminate the canal as the source of actual, potential, or future tritium contamination in the groundwater, an impervious liner, with leak detection and collection capability, is to be added to the canal.

1.3 As secondary benefits to the installation of the canal liner, it is anticipated that the liner will also facilitate improvements in canal cleanup activities and eliminate potential future problems from continued concrete sloughing and pool debris.

2.0 SCOPE OF MODIFICATION

2.1 This Conceptual Design specifically addresses the design fabrication, and installation of an impervious liner, with leak detection and collection capability, in the HFBR Spent Fuel Storage Canal.

2.2 To assist in the development of a conceptual design for the canal liner and leakage detection system, the services of Raytheon Engineers & Constructors, Inc. (Raytheon) have been retained as a consultant to the Reactor Division. Raytheon's conceptual design activities, documented in a report entitled "An Impervious Liner for the HFBR Spent Nuclear Fuel Storage Canal," are included with this conceptual design package as an attachment and shall be considered an integral part of the conceptual design. (This document shall therefore be referred to as the Raytheon Report.)

2.3 Canal Internal Structures and Appurtenances

2.3.1 It is recognized that several of the canal internal structures and appurtenances will require alteration or replacement as a result of the addition of an impervious liner to the canal. This is due to the reduction of the clear space between canal walls. Those canal internal structures and appurtenances initially identified as being potentially affected are as follows:

a. Shipping Cask/Canal Strike Plate Assembly.
(Refer to drawing HFBR-M-135.)

b. Long Term Spent Fuel Storage Racks.
(Refer to drawing BR62-0101-0.)

c. 49 Element Basket Long Term Spent Fuel Storage Rack.
(Refer to drawing HFBR-M-749.)

d. Deep Pit Spent Fuel Storage Rack.
(Refer to drawing HFBR-M-196.)

e. Deep Pit Seismic Restraint and Spent Control Rod Blade Storage Rack.
(Refer to drawing HFBR-M-196.)

f. Spent Fuel Element Retard Chute.
(Refer to drawing ME-107-345.)

g. Removable Deep Pit Grating.
(Refer to drawing E4653-174.)

(i) It is recognized that should the Deep Pit Grating require alteration, the HFBR Operations Group would like the reconfigured grating to have the capability of being removed in two separate pieces rather than the single, large assembly which currently exists. The feasibility of this change to the grating configuration can be addressed when the certainty for the alteration or replacement of the grating is better understood. (See also paragraph 2.3.2 below.)

h. Removable Platform at Elevation 93 ft-0 in.
(Refer to drawing E4653-174.)

i. Canal Saw bridge.
(Refer to drawing BR65-0200-39.)

j. Canal Rolling Bridge.
(Refer to drawing E4653-174.)

2.3.3 The need for, and extent of, alteration or replacement of those canal internal structures and appurtenances identified in paragraph 2.3.1, above, will not be known with any degree of certainty until the preliminary design phase. Therefore, it is intended that either the alteration or replacement of the affected items be incorporated into the modification package (final design) for the canal liner or separate, associated projects (Reactor Division Modification or Maintenance/Replacement Approvals) be initiated once the extent of the reduction in interior canal space is better understood.

2.3.4 With respect to the existing spent fuel storage racks, it is the intent of this modification to restrict the loss of clear distance between the canal walls to no more than the approximately one foot "free board" space which currently exists on the outboard edge of the long dimension of the existing spent fuel storage racks. This will prevent the loss of spent fuel storage capability (by reduction of the number of elements which can be stored in each rack), permit reuse of the existing boron stainless steel spent fuel storage baskets, and preclude alteration of the present spent fuel storage configuration(s) which would affect the existing nuclear criticality evaluations.

3.0 DESIGN CRITERIA

3.1 Design of the canal liner and leak detection system is governed by the applicable portions of DOE Order 5480.30, "Nuclear Reactor Safety Design Criteria," dated January 19, 1993 and the "Agreement Between Brookhaven National Laboratory and County of Suffolk," dated September 23, 1997. This "1987 Agreement" invokes the environmental requirements of the Suffolk County Sanitary code, Article 12, "Toxic and Materials Storage and Handling Controls," as amended December 16, 1992.

3.2 Design requirements, performance criteria, proposed layout and arrangement, and evaluations specific to the canal liner and leakage detection system are covered in the Raytheon Report (see paragraph 2.2, above) which is provided as an attachment to this Conceptual Design and, therefore, not repeated here.

3.3 Other Considerations

3.3.1 DOE Order 5480.30 provides requirements for spent fuel handling and storage facilities which may not be specifically addressed in the Raytheon Report (see paragraph 2.2 above). Specifically, these requirements can be grouped into four categories: Fuel and Radioactive Waste Storage, Prevention of Criticality in Fuel Storage and Handling, Monitoring of Fuel and Radioactive Waste Storage, and Fuel Storage and Handling Systems Heat Removal Capability.

3.3.2 Fuel and Radioactive Waste Storage

a. Fuel storage and handling systems shall be designed to ensure adequate safety under normal operations, anticipated operational events (AOEs), and design basis accidents (DBAs). The design of the canal liner and leak detection system for these conditions is addressed in the Raytheon Report. For those canal internal structures and appurtenances affected by the addition of a liner, assessments for these conditions are described in the HFBR SAR and its references. These assessments will be revisited, as necessary, in the canal liner modification package (final design) or the individual RD projects which implement any required alterations or replacements.

b. Capability of the canal liner and leak detection system to permit periodic inspection and testing of components is addressed in the Raytheon Report. It is anticipated that the presence of the canal liner will not affect the feature of being able to remove canal internal structures and appurtenances from the canal to facilitate any required inspection, testing, or maintenance.

c. Suitable shielding for radiation protection is maintained by the quantity of water kept above the stored spent fuel elements. The capability to maintain the canal water at the present normal operating level is not impacted by the presence of a canal liner. However, this will be further addressed in the final design.

d. Appropriate confinement and filtering systems are already present in the HFBR. The addition of the canal liner does not affect these capabilities.

3.3.3 Prevention of Criticality in Fuel Storage and Handling

a. Criticality prevention, within the HFBR spent fuel storage canal during fuel storage and handling, is achieved by the use of favorable geometry(ies) and passive engineering safety features. All spent fuel is stored in either the uncut fuel storage rack (stainless steel) or in boron stainless steel spent fuel storage baskets which are kept in aluminum and/or stainless steel storage racks. These rack/basket configurations have been reviewed for criticality prevention and found to be acceptable.

b. As previously discussed in paragraph 2.3.4, above, the addition of the canal liner and leak detection system will not alter the geometry(ies) or passive safety features currently in use for the prevention of criticality during spent fuel storage and handling. Therefore, existing criticality prevention measures will not be adversely affected. Verification that the existing criticality prevention measures have not been compromised will be obtained and included in the modification package (final design) prior to installation of the liner.

3.3.4 Monitoring of Fuel and Radioactive Waste Storage

a. As part of the modification package (final design), evaluation and assessments will be made to assure that appropriate measures have been provided in the fuel and radioactive waste storage areas of the lined canal to detect conditions that may result in the loss of residual heat removal capability and excessive radiation levels, and to initiate appropriate safety actions.

3.3.5 Fuel Storage and Handling Systems Heat Removal Capability

a. The existing Canal Circulating Water System (CCWS) currently contains sufficient measures to protect coolant inventory and remove residual heat from the canal under the necessary plant conditions. Interface between the canal liner and the piping associated with this system is described in the Raytheon Report. It is anticipated that the addition of the canal liner and leak detection system will have no adverse effect on the capability of the CCWS to perform its coolant inventory protection and residual heat removal functions. This will also be further addressed as part of the final design.

4.0 APPLICABLE CODES AND STANDARDS

4.1 Those applicable codes and standards to be invoked during the design, fabrication, and installation of the canal liner and leak detection system are discussed in the Raytheon Report.

4.2 Applicable codes and standards governing the alteration or replacement of those canal internal structures and appurtenances will be addressed in the canal modification package (final design) or the separate associated projects (see paragraph 2.3.3, above) implementing any necessary changes to these components.

5.0 ALARA CRITERIA

5.1 The preliminary review of the ALARA criteria has been performed and the completed "Engineering ALARA Design Guide," as required by RD APM 4.13 has been provided as an attachment to the conceptual design.

5.2 Since the purpose of this modification is not to achieve a reduction of radiation exposures to facility personnel, an ALARA cost benefit analysis, in accordance with the BNL Radiological Control Manual, is not required.

6.0 INSTALLATION CRITERIA

6.1 Installation processes, constraints, and restrictions for the canal liner and leak detection system are discussed in the Raytheon Report. It is anticipated that the HFBR will have confinement integrity broken and, because of the large amount of in-place welding required, the exit air filter system will be placed in the "Bypass" mode for the duration of liner installation activities.

6.2 Because it is currently intended that canal liner installation be performed with all spent fuel removed from the canal, any technical safety requirements associated with canal water level, spent fuel placement, and other spent fuel handling considerations will not be in effect during the installation process.

7.0 SAFETY CLASS, QUALITY LEVEL, AND UNREVIEWED SAFETY QUESTION

7.1 Safety Class and Quality Level

7.1.1 The canal liner, and those portions of the leak detection and collection system which are integral to the canal liner (for example, attached to the liner by welding), are considered to be Quality Level QL-3 and Safety Class SC-3/IC-3 in accordance with the RD Quality Assurance Manual Section QAM-2.2, "Classification of HFBR Safety Items."

7.1.2 Those portions of the leak detection and collection system that are not integral to the canal liner, which are intended to serve as an alarm indication only, can be treated as non-nuclear safety related just as the existing canal water level instrumentation. The Quality Level and Safety Class of these portions of the leak detection and collection system can be classified as QL-4 and NNS, respectively.

7.1.3 As required by QAM-3.1, "Seismic Criteria," the canal liner will be designed as a seismically qualified system due to its becoming an integral part of the spent fuel storage canal structure. All portions of the leakage detection system that are integral to the canal liner (see 7.1.1, above) will also be designed as seismically qualified. Those portions of the leak detection/collection system which are not nuclear safety-related (QL-4/NNS) will be designed so that their failure, as the result of a seismic event, will not prevent adjacent seismically qualified systems from performing their safety function.

7.1.4 Quality Level and Safety Class for those canal internal structures and appurtenances will also be determined in accordance with QAM-2.2. Review of QAM-2.2 and its associated appendices (QAM-2.2.1 through QAM-2.2.3) indicates that none of these components identified in paragraph 2.3.1 above is classified with a Quality Level and Safety Class higher than QL-3/SC-3.

7.1.5 For the reasons described above, the overall Quality Level and Safety Class for this modification will be QL-3 and SC-3/IC-3. Those portions of the project that differ from this quality level and safety class will be specifically identified, with justification, in the modification package.

7.2 Unreviewed Safety Question

7.2.1 An Unreviewed Safety Question Determination (USQD) has been prepared, reviewed, and approved for this Conceptual Design in accordance with Reactor Division APM-2.1. The USQD, which concluded that the Conceptual Design does not involve an unreviewed safety question, is on file with the RD Safety Evaluation Group.

8.0 AFFECTED DOCUMENTS

8.1 Those documents potentially affected by the proposed modification are identified in the following paragraphs. More specific information, including markups of the proposed document changes, regarding the actual changes to the listed documents will be provided in the modification package (final design).

8.2 Facility Design Drawings

8.2.1 D4653-101, "Architectural Plan - Equipment Level."

8.2.2 E4653-121, "Core Structure Foundation - Plan."

8.2.3 E4653-121A, "Core Structure Foundation - Bottom Reinforcement."

8.2.4 E4653-121B, "Core Structure Foundation - Top Reinforcing, Sections and Details."

8.2.5 E4653-121C, "Core Structure Foundation - Sections and Details."

8.2.6 E4653-132, "Equipment Level - Cave Door Framing Details."

8.2.7 E4653-174, "Canal Bridge, Platform, and Gamma Facility Cover."

8.2.8 E4653-301, "Plan, Piping - Equipment Level Filters and Water Purification Area."

8.2.9 E4653-303, "Plan, Piping - Equipment Level Shutdown and Thermal Shield Area."

8.2.10 E4653-55B, "Electrical Power - Equipment Level, in Floor Slab."

8.2.11 E4653-56B, "Electrical Power - Details, Sheet 2 of 5."

8.2.12 HFBR-M-300, "Spent Fuel Canal Storage Plan."

8.2.13 HR32-090-02, "Thermal/Biological Shields/Canal Cooling Water Systems . iping and Instrumentation Diagram."

8.2.14 HR32-132-01, "Canal Level, Channel LA307."

8.2.15 ME-107-372, "Canal Layout."

8.2.16 Additionally, those drawings describing the canal internal structures and appurtenances (see paragraph 2.3.2, above) are also potentially affected by the proposed modification. Any necessary changes to these drawings will be identified as part of the canal liner modification package (final design) or those separate associated projects initiated to implement the required changes.

8.3 Safety Analysis Report

8.3.1 Supplementary information for Section 7.7[*], entitled "Fuel Handling," of the HFBR Safety Analysis Report (SAR) will have to be updated as a result of the proposed modification to reflect the addition of the canal liner and leak detection system.

[*] - SAR section designations are as they appear in the "Guide to the HFBR Safety Analysis Report," Revision 17 dated February 1997.

8.3.2 It may be necessary to also update the above mentioned, and possibly other, SAR section(s) as a result of the need to alter or replace some of the canal internal structures and appurtenances. Should this be necessary, the affected SAR section(s) will be identified in the canal liner modification package (final design) or any separate associated projects (modifications or maintenance/replacements) initiated to implement the changes to these items.

8.3.3 Any required updates to the SAR will be made in accordance with the procedure contained in QAM-6.3, "Technical Safety Requirement/Safety Analysis Report Revisions."

8.4 **Technical Safety Requirements**

8.4.1 Review of the HFBR Technical Safety Requirements (TSRs) concluded that no changes are required as a result of this proposed modification. However, a final determination will be made as part of the modification package (final design) for the canal liner. Should any TSR changes be required, they will also be made in accordance with QAM-6.3.

8.5 **HFBR Operations Procedure Manual**

8.5.1 OPM-2.3, "Fuel Handling and Storage Safety Rules and Limits."

8.5.2 OPM-3.11, "Corrective and Emergency Procedures During Fuel Discharging Operations."

8.5.3 OPM-10.1, "Canal Health Physics and General Safety Restrictions."

8.5.4 OPM-10.2, "Spent Fuel Handling Instructions."

8.5.5 OPM-10.3, "Canal Abnormal Conditions Procedures."

8.5.6 OPM-10.4, "Canal Water System Operating Procedures."

8.6 **HFBR Plant Description Manual**

8.6.1 PDM-6.28, "Leak Detection Systems."

8.6.2 PDM-9.3, "Fuel Discharging, Rotation, and Discharging Procedures."

8.6.3 PDM-10.1, "Principles or canal Area Operating Procedures."

8.7 **RD Quality Assurance Manual**

8.7.1 Section 2.2 of the Reactor Division quality Assurance Manual (QAM-2.2, "Classification of HFBR Safety Items") and its associated Addenda QAM-2.2.1, "HFBR Mechanical Items," and QAM-2.2.2, "HFBR Instrumentation and Control Systems," will require updating as a result of the addition of the canal liner and leak detection system.

8.8 Master Equipment List

8.8.1 As part of the proposed modification, the Reactor Division Master Equipment List (MEL) will be updated to reflect all changes to HFBR systems and components. Master Equipment List changes will be implemented in accordance with Maintenance Management Program Procedure (MMP) 2.5, "The Master Equipment List."

9.0 INTERFACE ORGANIZATIONS

9.1 Conceptual design activities are being performed by Raytheon Engineers and Constructors, Inc. as consultants to the BNL Reactor Division under Task Order 3 to Contract 822081. It is anticipated that the further design and engineering of the canal liner and leak detection system will also be performed by a consultant. For ease of project coordination, and maintenance of the project schedule, some of the redesign of canal internal structures and appurtenances (see paragraph 2.3.1, above) may be incorporated into the consultant's scope for the detailed design and engineering phase.

9.2 The installation of the canal liner is part of the HFBR Restart and Upgrades Project and has been assigned Work Breakdown Structure (WBS) Activity No. 2.1.1. As a result, the responsibilities of the various BNL organizations interfacing with the canal liner modification are identified in the following paragraphs.

9.2.1 Reactor Division

a. RD Engineering Group - Overall canal liner project support and coordination. Also, design responsibility for those canal internal structures and appurtenances not incorporated into the consultant's scope of work.

b. HFBR Health Physics - Responsible for Health Physics support for the canal liner project including any ancillary shipping, draining, and cleanup activities. Any required staff, equipment, or capabilities augmentation necessary to support these activities shall be the responsibility of HFBR Health Physics and the Safety & Environmental Protection Division (S&EP).

9.2.2 HFBR Tritium Remediation Project

a. There are several interfaces between the HFBR Tritium Remediation Project (TRP) and the canal liner modification that are important to defining the schedule and costs for the liner task. These interfaces are described in the following paragraphs.

b. <u>Ship Fuel and Control Rod Blades (WBS 1.2.3)</u>
This activity is responsible for the removal of all spent fuel elements, spent control rod blades, and other reactor irradiated nuclear materials (RINM) from the canal.

c. <u>Fuel Pool Water Management (WBS 1.2.2)</u>
This activity is responsible for the removal of all existing canal internal structures and appurtenances and storing them for re-use or disposing of those no longer needed; cleaning, vacuuming, and decontamination of the canal; draining of the water from the canal and either storing it for re-use or disposing of it; and refilling the canal, with either the stored canal water or replacement water, after liner completion.

9.2.3 Central Shops Division

a. The CSD may be utilized to prefabricate liner sections. However, this will be further evaluated during the progression of the project beyond the conceptual stage.

b. CSD will also be utilized for the alteration of, or fabricating replacements for, canal internal structures and appurtenances. It is also anticipated that those items which only require very minor alteration may be worked by the RD Maintenance Group and/or Operations Group Day Crew.

9.3 It is anticipated that the bulk of fabrication (if BNL CSD is not used) and installation activities will be performed by an outside contractor yet to be determined. These determinations will be made during the early stages of preliminary design immediately following approval of the conceptual design.

10.0 COST AND SCHEDULE

10.1 Cost

10.1.1 Costs specific to the canal liner and leak detection system design, fabrication, and installation have been estimated and are included in the Raytheon Report.

10.1.2 However, there are some costs which were outside the Raytheon scope for conceptual design activities. These costs (in FY 97 dollars) are itemized in the paragraphs below.

a. Remove and ship spent fuel, spent control rod blades, and other RINM. (The costs for these activities are controlled by those responsible for WBS Activity 1.2.3 of the HFBR Tritium Remediation Project and are, therefore, not included in the costs associated with the proposed liner modification.)

b. Temporary canal water storage facilities and/or canal water disposal. (The costs for these activities are controlled by those responsible for WBS Activity 1.2.2 of the HFBR Tritium Remediation Project and are, therefore, not included in the costs associated with the proposed liner modification.)

c. Remove canal internal structures and appurtenances. Store those to be re-used and dispose of those to be replaced. (Costs accounted for as described in 10.1.2.b, above.)

d. Draining, vacuuming, cleaning, and decontaminating the canal. (Costs accounted for as described in 10.1.2.b, above.)

e. Refilling the canal. (Costs accounted for as described in 10.1.2.b, above.)

f. Alteration or replacement of affected canal internals and appurtenances (see paragraph 2.3.1, above), $445,000.

g. Return those canal internals and appurtenances which were stored for re-use, $16,600.

h. Project management and support, $280,000. (These are the costs associated with those BNL or RD activities necessary to coordinate and support the activities of the design, fabrication and installation consultants/contractors to be used in the project.)

10.1.3 Combining the above costs, the total estimated cost for the liner project is as follows:

Raytheon Estimated Costs	**[later]***
BNL Estimated Costs	**$ 741,600**
TOTAL Estimated Costs	**[later]***

* This figure does not include any BNL G&A burden on the costs estimated by Raytheon and nor does it include any escalations for spending in succeeding fiscal years. Therefore , the total costs may differ from any estimates previously given which may have taken these factors into account.

10.2 Schedule

10.2.1 The Raytheon Report includes schedules for the remaining design, along with fabrication and installation of the canal liner and leakage detection system. For those support activities solely within BNL scope, schedules will be developed to interface with the necessary portions of the Raytheon prepared schedule and maintain the projected liner completion date.

CONCEPTUAL DESIGN FOR RD MODIFICATION APPROVAL 97-01, "IMPERVIOUS LINER FOR THE HFBR SPENT FUEL STORAGE CANAL"

ENGINEERING ALARA DESIGN GUIDE

Yes	No	N/A	Item
			I. Materials
X			A. Were materials selected to reduce the formation of activated corrosion products?
X			B. Are materials resistant to radiation effects?
X			C. Are rough surface finishes avoided?
X			D. Are proper coating systems used (decontaminable) as appropriate?
			II. Facilities and Location
			A. Fluid systems containing radioactive materials
		X	1. Is floor drain back flooding prevented?
		X	2. Are porous seals avoided on floor drains?
		X	3. Are floors sloped to floor drain?
		X	4. Have provisions for back flushing of lines been considered?
		X	5. Were long radius elbows used when 90° fittings were necessary?
X			6. Are sampling points located remotely or shielded from high radiation areas?
X			B. Were radiation surveys reviewed for the area where the materials/items will be installed?
X			C. Are the new installations located away from hot spots and high radiation areas as much as possible?
	X		D. Does the new installation affect maintainability of existing items?
	X		E. Should existing instrumentation/operating station be moved?
X			F. Should permanent shielding be installed around the new equipment?
		X	G. Should there be provisions for the installation of temporary shielding?
X			H. Were instruments/gauges located in a low background area?
X			I. Were instruments functionally grouped to minimize operator exposure time?
	X		J. Will this device generate a radiation field?
	X		K. Does another location exist which would result in lower doses?
X			L. Will there be any releases of radioactivity to the environment; can they be mitigated?

Review Completed [signature] 04-03-97

Project Leader **Date**

DRAFT CONCEPTUAL DESIGN REPORT

IMPERVIOUS LINER FOR THE HIGH FLUX BEAM REACTOR SPENT FUEL STORAGE CANAL

FOR BROOKHAVEN NATIONAL LABORATORY
BY RAYTHEON ENGINEERS AND CONSTRUCTORS, INC.

April 4, 1997

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Raytheon Engineers & Constructors

April 4, 1997
HFBR-3-E.2

Mr William J Brynda
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SUBJECT: CONTRACT NO. 822081
TASK ORDER #3
DRAFT CONCEPTUAL DESIGN REPORT FOR AN
IMPERVIOUS LINER FOR THE
HFBR SPENT FUEL STORAGE CANAL

Dear Mr Brynda:

Enclosed are 38 copies of the subject Conceptual Design Report.

We have sent nine (9) copies directly to the persons shown in the distribution list at the end of this letter.

This report identifies requirements, compares different Liner System alternatives and describes a recommended design concept. Preliminary cost and schedule estimates, a risk analysis and a list of activities for the later titles are also provided.

The report concludes that it is feasible to install a Liner System at the HFBR that satisfies the DOE requirements, the applicable portions of the Suffolk County Sanitary Code and the Brookhaven National Laboratory's scope of work.

Please provide us with your comments on this report by April 21, 1997. We plan to incorporate comments and issue the final report on May 5, 1997.

If there are any questions on this report please call (516) 344-5193.

Very truly yours,

J Costello

J J Costello
Project Manager

JJC/na
Enclosures (38)

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LIST OF ACRONYMS AND ABBREVIATIONS

ACI	American Concrete Institute
A/E	Architect/Engineer
AISC	American Institute of Steel Construction
ALARA	As Low As Reasonably Achievable
ANS	American Nuclear Society
ANSI	American National Standards Institute
AOE	Anticipated Operational Event
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASNT	American Society of Nondestructive Testing
ASTM	American Society for Testing Materials
AWS	American Welding Society
BNL	Brookhaven National Laboratory
B&PV	Boiler and Pressure Vessel
CAM	Continuous Air Monitor
CFR	Code of Federal Regulations
DAC	Derived Air Concentration
DBA	Design Basis Accident
DBE	Design Basis Earthquake
D&D	Decontamination and Decommissioning
DEAR	Department of Energy Acquisition Regulation
DOE	Department of Energy
EPRI	Electric Power Research Institute
ES&H	Environmental Safety and Health
HEPA	High Efficiency Particulate Air
HFBR	High Flux Beam Reactor
HVAC	Heating, Ventilation and Air Conditioning
HWRF	Heavy Water Reactor Facility
I&C	Instrumentation and Control
IEEE	Institute of Electrical and Electronics Engineers
ICNNS	I&C Non-Nuclear Safety
ISO	International Standards Organization
LOCA	Loss of Coolant Accident
LWR	Light Water Reactor
MIL-Q	Military Quality Specification
NDE	Non-Destructive Examination
NEMA	National Electric Manufacturers Association
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NNS	Non-Nuclear Safety
NQA-1	Nuclear Quality Assurance
NRC	Nuclear Regulatory Commission
NUREG	NRC Publication

ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Act
PC	Protective Clothing
psig	pounds per square inch gage
QL	Quality Level
RADPRO	Radiation Protection
RD	Reactor Division
RG	Regulatory Guide
RWP	Radiation Work Permit
SAR	Safety Analysis Report
SC	Safety Class
SCC	Stress Corrosion Cracking
SCSC	Suffolk County Sanitary Code
S&EP	Safety and Environmental Protection
SOW	Scope of Work
SRP	Standard Review Plan
SS	Stainless Steel
SSE	Safe Shutdown Earthquake
TDS	Total Dissolved Solids
VE	Value Engineering
WBS	Work Breakdown Structure

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The results of the Conceptual Design for an impervious liner with leak detection capability for Brookhaven National Laboratory's High Flux Beam Reactor (HFBR) Spent Nuclear Fuel Storage Canal are presented. The Conceptual Design, prepared by Raytheon Engineers & Constructors, Inc., includes identification of requirements, comparison of alternatives, description of a recommended design concept, schedule analysis, cost estimates, risk analysis and a list of activities for the later phase of the work.

The conclusion of this report is that it is feasible to install a Liner System at the HFBR that satisfies DOE and BNL requirements and satisfies applicable portions of the Suffolk County Sanitary Code. The Liner System can be installed, tested and accepted 5 to 9 months following the removal of the spent nuclear fuel from the canal, depending primarily on the number of shifts worked per week. The cost for the recommended design alternative, excluding BNL costs, is estimated to be $5.52 million, including a 15 percent contingency. The cost estimates and schedules presented are considered to be representative of those issued during preliminary design. Key design parameters, detailed sketches, material quantities and a construction approach support the cost/schedule estimates.

The installation of an impervious canal liner is the best way to assure that no tritium is released to the environment by leakage or seepage from the HFBR spent fuel storage canal.

1.0 INTRODUCTION

1.0 INTRODUCTION

This report documents a conceptual design of an impervious liner with leak detection capability for the High Flux Beam Reactor (HFBR) spent fuel storage canal. The existing spent fuel canal is an embedded concrete structure, extending 20 feet to 30 feet into the soil beneath the equipment floor at elevation 93 ft. The perspective view of the canal is shown in Figure 1-1.

Figure 1-2 shows the plan of the existing canal and its internals. The canal consists of a main storage area, deep pool area, cutting area and cask loading area. Structures in the main storage area include the long-term fuel storage racks (7 total), the 49-element basket long-term fuel storage rack, the four, six, twenty-one, and forty-nine element storage baskets. Also included are the 30-cell uncut fuel element storage rack, the storage rack guard, the heavy cover, and the heavy cover support structure.

Structures in the deep pool area include the six-element leaking fuel storage basket, the storage rack, the seismic restraint for this rack, and the removable grating cover at elevation 73′-3".

The remaining structures in the canal include retard chute, shipping cask/canal strike plate assembly, stand for fuel element baskets, cut fuel ends basket, canal wall shield assembly, fuel cut-off saw, removable platform at elevation 93 ft. and movable canal bridge.

Raytheon Engineers & Constructors, Inc. has performed the conceptual design work under contract number BNL 822081 in accordance with Brookhaven's Scope of Work dated February 7, 1997 and amendment dated March 14, 1997.

Conceptual design of the Liner System is part of Work Breakdown Structure (WBS) element 2.1.1 under the HFBR Restart and Upgrades Project.

Interfacing BNL organizations for installation of the Liner System include:

- HFBR Tritium Remediation Project
  - Source Management
  - Plume Remediation
  - Communications and Project Support

- Reactor Division
  - Plant Management
  - Operations
  - Operations Support
  - Safety Evaluation
  - Environmental Safety and Health
  - Quality Assurance
  - Compliance
  - Reactor Instrumentation
  - Reactor Technology
  - Engineering

- Training and Procedures
- Health Physics

- Safety and Environmental Protection Division
- Central Shops Division
- Contracts and Procurement Division

The mission of the Liner System is to assure that no tritium or other radionuclides are released to the environment by leakage from the HFBR spent nuclear fuel storage canal.

Conceptual Design efforts included the following major activities:

- Develop a scope definition that satisfies system objectives.

- Identify all requirements needed to support detailed design.

- Assess a range of alternatives that sufficiently differ in characteristics such as materials, methods of installation and cost, so as to offer reasonable choice in selecting the most suitable alternative.

- Describe the most suitable alternative in sufficient detail to: facilitate progressing to detailed design; validate feasibility; confirm proper interface with canal internal structures, systems, and operating practices; identify risks and contingency plans; and define activities for the next phase of work.

- Develop a conceptual phase budget estimate and a realistic project schedule for design, fabrication and installation of the recommended Liner System.

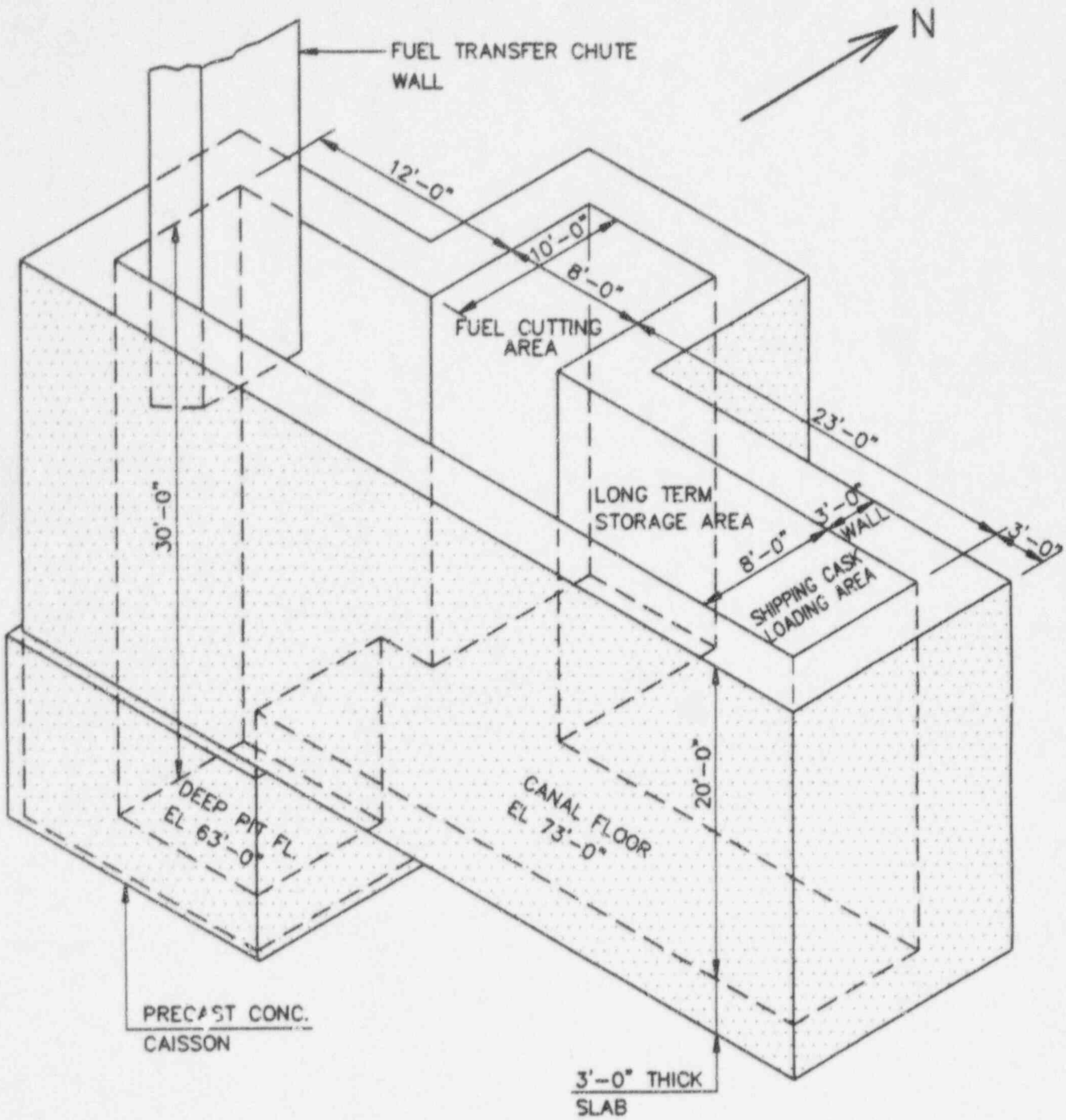
The current planning basis for this report is that all HFBR spent fuel will be shipped offsite by November 1, 1997, and that the Liner System (including leak detection) installation is completed on an accelerated basis, using two 10-hour shifts per day, 6 days per week, by March 1998. Alternate costs and schedules for the most viable options based on a single shift 8 hours per day, 5 days per week are also presented. It is further assumed that the NEPA review of the Liner System will be completed by August 15, 1997.

The governing requirements documents come from DOE Order 5480.30, *Nuclear Reactor Safety Design Criteria*, January 19, 1993, NRC Standard Review Plan (SRP) 9.1.2, *Spent Fuel Storage*, ANSI/ANS-57.2-1983 *Design Requirements for LWR Spent Fuel Storage Facilities at Nuclear Power Plants*, the BNL Scope of Work Description, HFBR Final Safety Analysis Report and the HFBR Technical Safety Requirements Document, and Suffolk County Sanitary Code, Article 12 *Toxic and Hazardous Materials Storage and Handling Controls*.

Five alternative installations were evaluated in detail. Other alternative liner concepts, materials and leak detection and recovery systems were also considered.

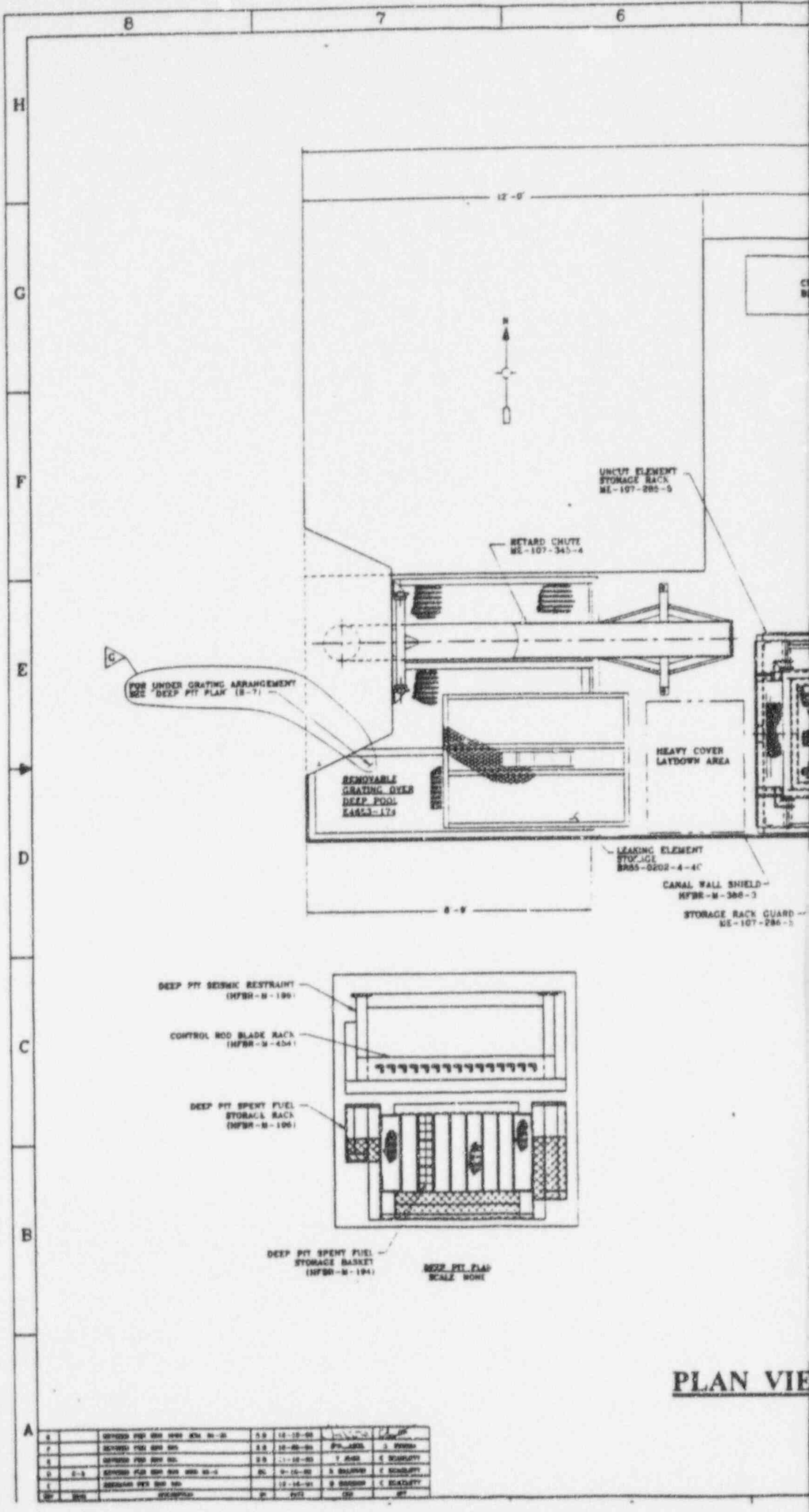
The recommended alternative will consist of a nominal 5/8-inch thick Type 304 stainless steel free-standing liner. The liner will be backed up by an array of stiffeners and the bottom will be supported on a new grout base. The existing concrete walls and floor will be decontaminated, inspected, repaired, grouted and coated to form a second leak-tight barrier.

A small stainless steel-lined sump with pump-out capability is provided at the canal low point. Wherever practical, welds are backed up by welded leak detection channels. Leak detection is provided by sump level detection, and the detection of water and/or tritium in channels. Monitoring and alarm instrumentation are also provided. All work will be performed to appropriate quality standards.



PERSPECTIVE VIEW OF THE EXISTING CANAL

BROOKHAVEN NATIONAL LABORATORY HIGH FLUX BEAM REACTOR SPENT FUEL CANAL LINER PERSPECTIVE VIEW OF THE CANAL				
Raytheon ENGINEERS & CONSTRUCTORS				
DRAWN: B.S.RANA	CHKD: C. SHIH	DATE: 04-02-97	SCALE: 1/8"=1'-0"	DWG NO. FIG 1-1



12'-0"
UNCUT ELEMENT STORAGE RACK ME-107-286-5
RETARD CHUTE ME-107-345-4
FOR UNDER GRATING ARRANGEMENT SEE DEEP PIT PLAN (B-7)
REMOVABLE GRATING OVER DEEP POOL E4453-174
HEAVY COVER LAYDOWN AREA
LEAKING ELEMENT STORAGE BR85-0202-4-40
CANAL WALL SHIELD HFBR-M-388-3
STORAGE RACK GUARD ME-107-286-5
8'-9"
DEEP PIT SEISMIC RESTRAINT (HFBR-M-196)
CONTROL ROD BLADE RACK (HFBR-M-454)
DEEP PIT SPENT FUEL STORAGE RACK (HFBR-M-196)
DEEP PIT SPENT FUEL STORAGE BASKET (HFBR-M-194)
DEEP PIT PLAN
SCALE NONE
PLAN VIE

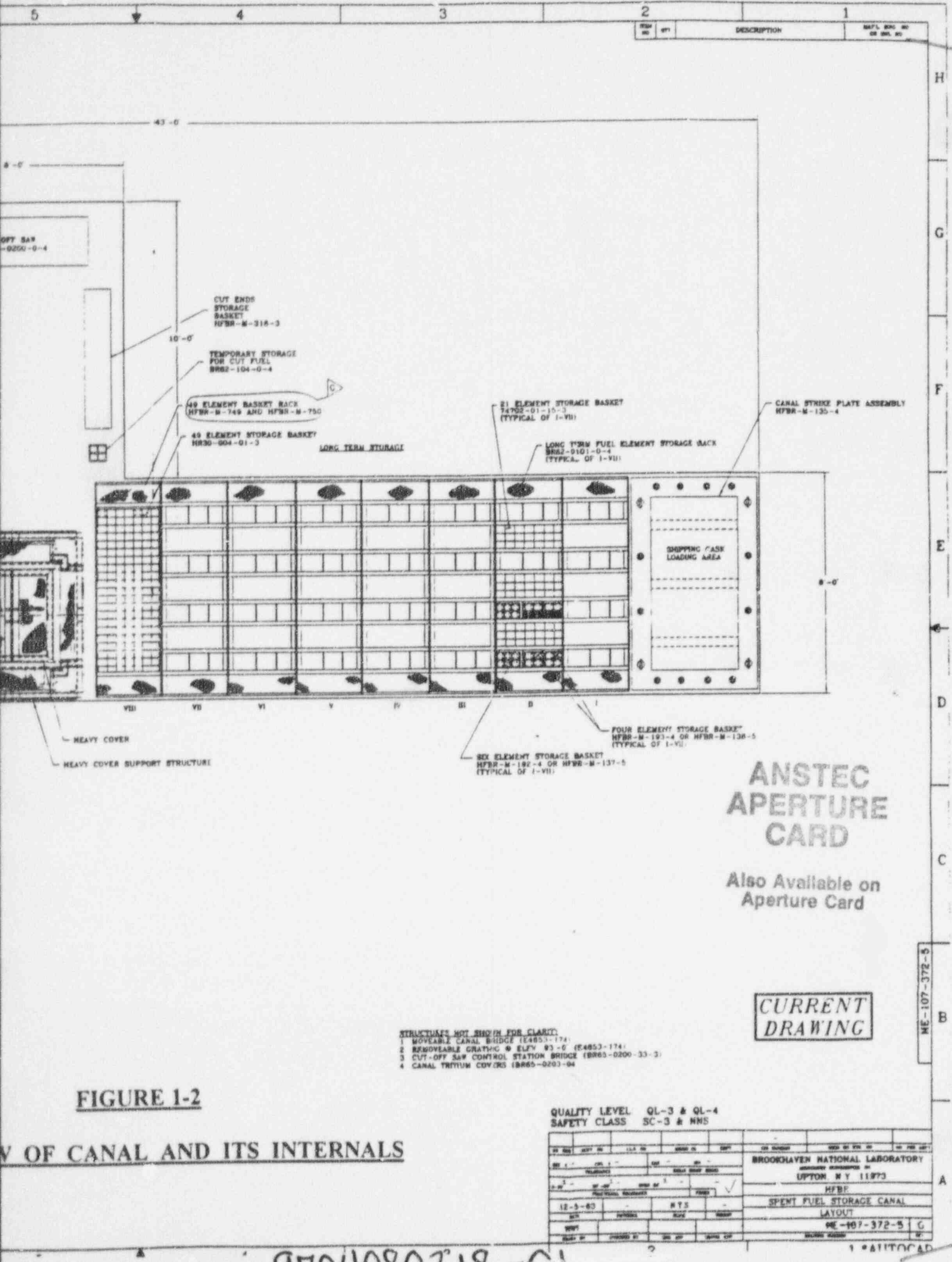


FIGURE 1-2

W OF CANAL AND ITS INTERNALS

9704080218-01

2.0 REQUIREMENTS

2.0 REQUIREMENTS

In this Conceptual Design Report, Raytheon Engineers & Constructors, Inc. provides an assessment of what requirements are applicable to the design of the Liner System including the Leak Detection and Recovery System. It is not the intent of this report to provide a line-by-line comparison of the design against the requirements. During the Preliminary Design effort, a Requirements Document will be developed which will describe in detail how the design satisfies each of the design requirements.

2.1 General Design Requirements

A review of U. S. Department of Energy (DOE), U. S. Nuclear Regulatory Commission (NRC), American Nuclear Society (ANS), Suffolk County and Brookhaven National Laboratory (BNL) documents was undertaken to determine what design requirements are applicable to the Liner and the Leak Detection and Recovery System (hereinafter referred to as the Liner System) This review primarily focused on the design requirements for the Liner System, since the existing storage racks, fuel handling equipment, circulating water system, HVAC, canal monitoring instrumentation, and features for protection from internal and external hazards will be utilized after the Liner System is installed.

2.1.1 Department of Energy

The DOE Orders were assessed to determine which may have applicability to the design of the Liner System and the Leak Detection and Recovery System. Based on this assessment, the following three DOE Orders were determined be potentially applicable and thus were reviewed in detail for design requirements for these two systems:

DOE Order 6430.1A (*General Design Criteria*), dated April 6, 1989;

DOE Order 5480.6 (*Safety of Department of Energy-Owned Nuclear Reactors*), dated September 23, 1986; and

DOE Order 5480.30 (*Nuclear Reactor Safety Design Criteria*), dated January 19, 1993.

DOE Order 6430.1A provides design guidance for the various structures and infrastructure that are located at DOE sites around the country. However, DOE Order 6430.1A states in Division 1 ("General Requirements"), Subsection 0101-1 and in Division 13 ("Special Facilities"), Subsection 1300-1.1; that:

"Reactors and their safety systems shall be sited and designed according to DOE 5480.6."

For this reason, DOE Order 6430.1A is not applicable to the design of the Liner System.

DOE Order 5480.6 was developed to provide guidance on the safe design, construction and operation of DOE reactors. Paragraphs 8a and 8b of DOE Order 5480.6 provide the siting criteria and the

general design criteria for DOE reactors by referencing the NRC requirements for commercial nuclear reactors.

Subsequently, DOE developed DOE Order 5480.30 to provide specific detailed guidance for DOE reactors and this specific guidance superseded Paragraphs 8a and 8b in DOE Order 5480.6. Therefore, with respect to DOE, the design requirements for the Liner System and the Leak Detection and Recovery System are only provided in DOE Order 5480.30.

In DOE Order 5480.30, specific guidance for these two systems is provided in Paragraph 8d(8)(a) (*Specific Design Requirements - Fuel and Radioactive Waste Storage*); and in Attachment 3 (*Preliminary Guidance For Nuclear Reactor Nuclear Safety Design Criteria*), Paragraph 3(8)(a) (*Specific Design Requirements - Fuel and Radioactive Waste Storage*).

Paragraph 8d(8)(a) states:

> "The fuel storage and handling and radioactive waste system shall be designed to ensure adequate safety under normal operations, AOEs [Anticipated Operational Events] and DBAs [Design Basis Accidents]. These systems shall be designed:
>
> 1. With the capability to permit appropriate periodic inspection and testing of components;
> 2. With suitable shielding for radiation protection; and
> 3. With appropriate containment, confinement, and filtering systems."

Applicability - The Liner System and the Leak Detection and Recovery System will be designed to prevent leakage under normal operations, AOEs, and DBAs. These two systems will be designed to permit appropriate inspection and testing, suitable shielding to prevent radiation streaming and appropriate confinement of the spent fuel pool water.

Attachment 3, Paragraph 3(8)(a) states:

> " Storage and handling of nuclear fuel requires that consideration be given to prevent theft, criticality, protection from sabotage or physical damage, and receipt inspection. Wastes should be categorized by activity, half life, and chemical toxicity. The guidance contained in the American Nuclear Society standard, "Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Light Water Reactor Plants," ANSI/ANS-57.2-1983 and the American Nuclear Society Standard, "Design Requirements for New Fuel Storage Facilities at Light Water Reactor Plants," ANSI/ANS-57.3-1983, although written for light water reactor facilities, is generally applicable to all water-cooled DOE reactors, regardless of size. Additional guidance can be obtained from NUREG-0800, Section 9.1.1, [i.e., Standard Review Plan (SRP) 9.1.1], "New Fuel Storage," and Section 9.1.2 [SRP 9.1.2], "Spent Fuel Storage."

Applicability - The Liner System and the Leak Detection and Recovery System will be designed to the following applicable requirements of SRP 9.1.2 and ANSI/ANS-57.2-1983.

SRP 9.1.2

See Section 2.2.2

ANSI/ANS-57.2-1983

See Section 2.2.3

2.1.2 Nuclear Regulatory Commission

NUREG-0800, Standard Review Fıan (SRP) 9.1.2 (*Spent Fuel Storage*), Revision 3 (July 1981), provides overall guidance for the liner. The SRP also references Regulatory Guide (RG)) 1.13 (*Design Objectives for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Stations*), RG 1.29 (*Seismic Design Classification*), and ANS 57.2/ANSI N210-1976 (*Design Objectives for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Stations*). It should be noted that since the issuance of the SRP, ANS 57.2/ANSI N210-1976 was superseded by ANSI/ANS-57.2-1983. It is common industry practice, which is acceptable to NRC, to use the latest version of the standard in question. With respect to the Regulatory Guides, the latest versions are:

RG 1.13 Revision 1 (December 1975)

RG 1.29 Revision 3 (September 1978)

In addition, NUREG-0800, SRP 3.8.4 (*Other Seismic Category I Structures*) Section II (*Acceptance Criteria*), Revision 1 (July 1981), and Appendix D (*Technical Position on Spent Fuel Pool Racks*), Revision 0 (July 1981) provide additional seismic criteria.

Applicability - The Liner System and the Leak Detection and Recovery System will be designed to the following applicable requirements of

ANSI/ANS-57.2-1983

See Section 2.2.3

SRP 3.8.4 (*Other Seismic Category I Structures*)

Section II (*Acceptance Criteria*)

Subsections II.A; II.B; II.C; II.E;

Subsection II.2 (*Applicable Codes, Standards, and Specifications*);

Subsection II.3 (*Loads and Load Combinations*);

Subsection II.4 (*Design and Analysis Procedures*);

Subsection II.5 (*Structural Acceptance Criteria*);

Subsection II.6 (*Material, Quality Control, and Special Construction Techniques*);

Subsection II.7 (*Testing and Inservice Surveillance Requirements*); and

Appendix D (*Technical Position on Spent Fuel Pool Rack*), Section *4 (Loads and Load Combinations*).

SRP 9.1.2 (*Spent Fuel Storage*)

Section II (*Acceptance Criteria*)

Subsections II.1; II.2; II.4; and II.6.

RG 1.13 (*Design Objectives for Light-Water Reactor Spent Fuel Storage Facilities at Nuclear Power Stations*)

Section C (*Regulatory Position*)

Subsections C.1; C.5.c; and C.6

RG 1.29 (*Seismic Design Classification*)

Section C (*Regulatory Position*)

Subsections C.1; C.2; C.3; and C.4.

2.1.3 American Nuclear Society

Current commercial nuclear industry guidance is provided by the American Nuclear Society (ANS) standard ANSI/ANS 57.2-1983 (*Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Light Water Reactor Plants*).

Applicability - The Liner System and the Leak Detection and Recovery System will be designed to the following applicable requirements of ANSI/ANS-57.2-1983:

Section 5 (*Facility Performance Requirements*)

Subsection 5.1 (*Spent Fuel Storage and Cask Handling Pools*)

Subsection 5.6 (*Electrical Power, I&C and Communications*).

Section 6 (*Design Requirements*)

Subsection 6.1 (*Spent Fuel Storage and Cask Handling Pools*)

Subsection 6.6 (*Electrical Power, I&C and Communications*)

2.1.4 Suffolk County

Suffolk County does not have any requirements directly addressing the Liner System and the Leak Detection and Recovery System. However, the applicable requirements of Suffolk County Sanitary Code (SCSC) Article 12 (*To[illegible] and Hazardous Materials Storage and Handling Controls*), dated December 16, 1992, Section 760-1210 (*Underground Storage Facilities*) will be utilized.

Applicability - The Liner System and the Leak Detection and Recovery System will be designed to the following applicable requirements of the SCSC Article 12, Section 760-1210:

Subdivision A (*New Storage Facilities*)

Item 1. All new storage facilities used or to be used for the underground storage of toxic or hazardous materials shall be designed and constructed in a manner which will, in the opinion of the Commissioner, provide the maximum reasonable protection available against leakage or spillage from the facility due to corrosion, breakage, structural failure, or other means. Double-walled or equivalent facilities are required for all toxic or hazardous materials, except for tanks for the storage of on-premises heating oil at residential homes. For these, single-walled, non-corrodible facilities may be used. Acceptable designs for tanks include cathodically protected steel; glass fiber reinforced plastic; or other equivalent design approved by the Commissioner.

Subdivision B (*Existing Storage Facilities*)

Item 2. It shall be unlawful for any person to substantially modify or cause the substantial modification of any existing underground storage facility or part thereof without complying with the provisions of Subdivision A and all regulations and standards promulgated thereunder.

Subdivision C (*Single-walled Non-corrodible Facilities*)

Item 1. Single-walled non-corrodible facilities with leak detection and overfill protection must be upgraded to meet the secondary containment requirements of new construction. It shall be unlawful to use or maintain the existence of any facility of this description beyond January 1, 2010 for the storage of any toxic or hazardous material which is not adequately protected with a secondary containment system.

Subdivision F (*General Provisions and Requirements*), Item 5

Item 5. It shall be unlawful not to maintain any secondary containment system for underground storage in a dry condition except for tanks that utilize a fluid-filled space between the tank walls for leak detection. Any liquid which enters a secondary containment system shall be removed within 24 hours, the source determined and corrected, and a permanent record of the event made and kept available for inspection by a Department representative.

Subdivision G (*Monitoring and Leak Detection*)

Item 2. All underground storage facilities or parts thereof, except those for residential homes, must be provided with means of monitoring frequently and accurately for any leakage and spillage that might occur. All leak detection systems and tanks shall be monitored by the facility operator at least on a weekly basis and the results recorded and kept with the product records. Leak detection and monitoring can be provided by an electrical continuous leak detection system; visually operated or float operated alarms for tanks in pits; or fluid level detectors for double-walled facilities or other equivalent design approved by the Commissioner. Permanent records of all monitoring shall be kept for a period of five (5) years.

The requirements of Subdivision G, Item 2 are supplemented by the requirements in Section 3.0 of *Leak Detection Alarm System Requirements for Toxic/Hazardous Material Facilities*, Amended May 1989 and issued by the Suffolk County Bureau of Hazardous Materials. This regulation requires a leakage alarm system with an annunciator that can be heard and seen by the facility operator.

2.1.5 Brookhaven National Laboratory

BNL requirements for the Liner and the Leak Detection and Recovery System are provided in Appendix A, " Scope of Work Description, Conceptual Design of an Impervious Liner for the HFBR Spent Fuel Storage Canal," dated February 7, 1997, as amended March 14, 1997 and in the HFBR Safety Analysis Report (as amended and supplemented) and the HFBR Technical Safety Requirements Document. In addition, the design of the Liner System and the Leak Detection and Recovery System must not adversely affect the HFBR confinement leak rate.

Applicability - The Liner and the Leak Detection and Recovery System will be designed to the applicable BNL requirements. In addition, the design of the Liner System will not adversely affect the HFBR confinement leak rate. Conflicts, if any, with the Scope of Work Description and the requirements of DOE, NRC, ANS and/or Suffolk County will be brought to the attention of BNL with a formal documented resolution.

2.2 Codes and Standards

The conceptual design of the impervious liner for the HFBR spent fuel storage canal is performed in accordance with DOE Order 5480.30, *Nuclear Reactor Safety Design Criteria*, dated January 19, 1993. This DOE Order provides general design requirements for DOE nuclear reactor facilities and specific design requirements for nuclear safety-related systems and components including the fuel

handling and storage, and radioactive waste storage. Attachment 3 of this DOE Order further provides preliminary guidance for nuclear reactor nuclear safety design criteria, which endorse ANSI/ANS-57.2-1983, *Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants* and US NRC Standard Review Plan NUREG-0800, SRP 9.1.2, *Spent Fuel Storage* as applicable guidance for the design of spent fuel storage facility.

ANSI/ANS-57.2-1983 Paragraph 6.1.1.1 states that the following codes and standards are references as an acceptable level of design and construction for spent fuel storage and cask handling pools:

- ASME B&PV Code, Section III, Subsection NF
- ANSI/ACI 349-80 (for concrete structures)
- ANSI/A58.1-1982, *Minimum Design Loads for Building and Other Structures*
- ANSI/AWS D1.1-1983
- ANSI/AWS D1.4-1979 (welding of reinforcing steel)
- AISC S326-1980
- ANSI/ASME B31.1-1980 (for piping design)

ANSI/ACI 349-80 and ANSI/AWS D1.4-1979 are applicable for the design of reinforced concrete structures, which does not apply to the Liner System utilization of the existing canal concrete structure. ASME B&PV Section III, Subsection NF is used for the design of the supports for components such as fuel racks and supports for cooling and water treatment system, therefore, is not applicable for the design of liner assembly.

Paragraph 6.1.1.2 of ANSI/ANS-57.2-1983 also states that materials shall be selected based on the following codes and standards which represent an acceptable level of capability to meet design requirements:

- AISI Steel Product Manual
- AISC S326-1980
- ASME B&PV Section III, Subsection NF
- ASTM A588
- ANSI/ASME NQA-1-1983

For the same reason described above, ASME B&PV Section III, Subsection NF is not applicable. The ASTM A588 is not applicable, since material A588 is not considered as the liner material.

Paragraph 6.6.1.1 of ANSI/ANS 57.2 requires electrical and I&C components and systems to be designed to the American National Standards National Electrical Safety Code, ANSI/IEEE C2-1977 and National Electrical Code, ANSI/NFPA 70-1981.

Based on the above discussion, the applicable codes and standards for the design of HFBR spent fuel canal liner system are summarized as follows:

- AISC S335-1989, Specification for Structural Steel Buildings -- Allowable Stress Design, Plastic Design

- ANSI/AISC N690-1994 (AISC S327), Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities
- ANSI/AWS Dl.l-1996, American Welding Society Structural Welding Code - Steel
- ANSI/ASME NQA-1-1989, Quality Assurance Program Requirements for Nuclear Power Plants
- ANSI/ASCE 7-95, Minimum Design Loads for Building and Other Structures
- ANSI/IEEE C2-1990 American National Standard Electrical Safety Code
- ANSI/NFPA 70-1996 National Electric Code

AISC S335-1989 is the latest version of AISC S326-1980 for the design, fabrication and erection of structural steel for buildings. The ANSI/ASCE 7-95 is the latest version of ANSI/A58.1-1982, for minimum design loads for buildings and other structures. The latest version for the steel welding code is ANSI/AWS D1.1-1996. It is a common practice, which is acceptable to the NRC, to use the latest version of the applicable codes.

ANSI/AISC N690 is equivalent to AISC S335, and specifically applicable to the nuclear safety-related steel structures. This design code has specific design provisions in using the stainless steel material. Since AISC S335 does not have explicit design provisions for using the stainless steel, it is supplemented by the ANSI/AISC N690 code, for the design of the liner assembly.

Per ANSI/ANS-57.2 standard and NUREG-0800, SRP 9.1.2, the spent fuel canal structure shall be designed to Seismic Category I requirements. NUREG-0800, SRP 3.8.4 ("Other Seismic Category I Structures"), provides the overall guidance for the design and fabrication for the Seismic Category I structures other than the reactor containment and its internals. The above codes and standards are acceptable per the guidance delineated in NUREG-0800, SRP 3.8.4.

In addition, the following codes and standards are applicable for civil construction design requirements.

- ASME
  - B&PV Sections IX and II
- ASTM Standards
  - ASTM C597, *Standard Test Method for Pulse Velocity Through Concrete*
  - ASTM C805, *Standard Test Method for Rebound Number of Hardened Concrete*
  - ASTM D4258, *Standard Practice for Surface Cleaning Concrete for Coating*
- *ACI Standards*
  - ACI 318, *Building Code Requirements for Reinforced Concrete*
  - ACI 350, *Environmental Engineering Concrete Structures*
  - ACI 503.4, *Standard Specification for Repairing Concrete with Epoxy Mortars*
  - ACI 504R, *Guide to Sealing Joints in Concrete Structure*
  - ACI 515.1, *Guide to the use of Waterproofing Dampproofing, Protective, and Decorative Barrier Systems for Concrete*

- ANSI Standards
  - ANSI N512, *Protective Coatings for the Nuclear Industry*

2.3 Conduct of Work Requirements

2.3.1 Quality Assurance Requirements

The Quality Assurance Program for the Reactor Division is based upon the requirements of:

- 10 CFR Part 830.120, *Quality Assurance Requirements*
- G-830.120, Revision 0, *Implementation Guide for Use of 10CFR Part 830.120, Quality Assurance*
- DOE Order 5700.6C, *Quality Assurance*
- ASME NQA-1 *Quality Assurance Requirements for Nuclear Power Plants*

Items and services have varying degrees of quality requirements. HFBR items and services are classified in regard to relative safety, reliability, and performance based on quality levels which establish the level of control necessary for verification to assure item quality. Individual systems or components have been classified as falling within the predefined Quality Levels (QL-1, QL-2, QL-3, QL-4) and subclassifications, such as Safety Classes - SC-1, 2, 3, IC-1, 2, 3, and Nonnuclear - NNS, ICNNS and NSE. The Spent Fuel Pool Liner has been classified as QL-3, SC-3 in accordance with the HFBR Mechanical System, Component or Structure classification. The classification was established by BNL based upon:

- BNL 50831-II - Design Guide for Category II Reactors, Light and Heavy Water Cooled Reactors, May 1978
- HFBR Technical Specifications for Operation at 60 MW, July 1982
- BNL 7661 - Final Safety Analysis Report on the Brookhaven High Flux Beam Research Reactor, Volumes I and II and Addendum.

The quality program is applied under the DOE graded approach method with primary emphasis on achieving a high degree of operational success, recognizing safety, environmental protection, reliability and performance. In addition to nuclear industry standards, other recognized quality consensus standards are applied where appropriate. For the procurement of equipment, materials and services associated with Spent Fuel Pool Liners, the following quality standards may apply:

- ASME Section IX - *Welding and Brazing Qualification*
- ASNT-TC-1A - *Recommended Practice for Nondestructive Personnel Qualification and Certification*
- MIL-Q-9858 *Quality Program Requirements*
- ISO-9001 *Quality Assurance Model for Quality Assurance in Design/Development, Production, Installation and Servicing*

Program provisions for the control of suspect/counterfeit products are based upon Assistant Secretary of Nuclear Energy Memorandum "Information on Suspect Parts" dated 5 December 1990, and

DOE/EH-0266 "DOE Quality Alert" issue 92-4 dated August 1992. Suspect/counterfeit products are reported in accordance with DOE Order 5000.3 "Occurrence Reporting and Processing of Operations Information."

Hazardous materials are governed by DOE Order 5480.3 *Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substance and Hazardous Waste.*

2.3.2 Health and Safety

The Health and Safety Requirements for radiation protection are provided by the DOE under 29 CFR 835, for the protection of radiation workers and DOE Order 5400.5 for the protection of the public and the environment. The implementation of these requirements and industrial safety requirements at HFBR is the Health and Safety Program established by the BNL. The Liner System installation will adhere to the programs implemented by BNL. Procedures and work packages that address these program requirements will be developed.

Work will be in accordance with approved BNL Radiation Work Permits (RWPs) based on a Health Protection Work Plan and issued in accordance with BNL Radiation Control Manual and supporting administrative procedures.

2.3.3 Radiation Dose and ALARA Considerations

Selection of material, components and equipment will be properly qualified for the radiation level under which it will be exposed.

Data on radiation levels to which equipment and structures in the canal are exposed will be developed during preliminary design.

Conformance with the ALARA and radiation dose design criteria will ensure the integrity of the design throughout the expected operational life of the canal. To ensure that all radiological concerns have been covered, a formal ALARA review will be conducted during the design phase and during installation and construction of the liner. An ALARA check list will be implemented. This ALARA check list will be incorporated into an ALARA review procedure which will include Raytheon's ALARA design requirements and BNL Environmental Safety & Health Standard 3.3.0, "BNL ALARA Program Guidelines."

Radiation control and ALARA are the responsibility of all personnel involved with the design, planning, and installation of the liner. Implementation of the requirements lies with the BNL Health Physics Department. They will provide health physics technicians and supervision for the design review, planning and installation of the pool liner. All work will be performed in accordance with approved RWPs issued by BNL Health Physics who will serve as a liaison to ensure that the highest quality radiation control is a part of all work planning and implementation. Radiation control "hold points" will be used in liner installation procedures to further ensure that the Health Physics Department is informed of and observes critical stages of the work.

2.3.4 Procurement, Fabrication and Construction

The procurement of permanent plant materials will be in conformance with the Project's Quality Assurance manual for materials and services. Based on current design, the spent fuel canal liner is considered a safety-related component - Quality Level III. The components are to be procured from an approved vendor with an established quality program. Engineering specification(s) will be developed to address technical requirements for safety-related materials to be purchased. BNL will review and approve these specifications to ensure all attributes and levels of verification have been addressed prior to procurement activities. Non-safety-related materials/components will be purchased in accordance with industry standards and design documents will be inspected for compliance upon receipt.

The fabrication/construction of the spent fuel canal liner will be performed under an approved quality program(s). The welding activities are to conform to current AWS D.1.1 requirements. Welding Procedures Specifications can be qualified or pre-qualified in accordance with AWS D.1.1 and/or in accordance with ASME Section XI as an acceptable alternate. Procedure(s) will be required to be developed and approved for all fabrication and construction activities. The required procedures are to be identified and developed during preliminary design. Approval of these procedures should be completed during the detailed design phase and should support early schedule activities for construction. Engineering Specifications are to be in place and approved by BNL prior to release for purchase. As much as possible, existing BNL procedures will be used for construction activities. This approach can reduce schedule impact and a significant cost avoidance since the procedures have been previously developed, approved and in place. The utilization of existing BNL welding procedure specifications would require the contractor to perform qualification tests for welders, but would assure continuity between existing organization.

Design considerations which will support construction and fabrication should:

- Minimize the number of support stiffeners to reduce labor cost
- Minimize plate thickness for full penetration welds and/or allow the use of fillet welds for plate-to-plate joints
- Minimize the use of flare-bevel welding and/or filet welds with angles greater than 90 degrees (obtuse)
- Reduce the number of horizontal stiffeners between vertical members to reduce labor and utilize product forms which will not require unique fit-up conditions other than "T - Lap -Butt" configurations
- Reduce the number of plate welds by utilizing plate sizes only limited by access and crane capacity
- Reduce the number of coating types and applications which may be functionally redundant and increase cost and schedule impact

2.3.5 Testing, Surveillance and Inspection

Testing will be performed in accordance with governing codes and engineering specifications. Testing/Inspections can be defined in two phases, phase 1 being during installation of specific non-

destructive examinations (i.e., visual, liquid penetrant testing, vacuum box testing, sonic/echo pulsing examination, adhesion testing, hydrostatic, pneumatic, megger, continuity tests, hi-pot) will be performed during construction. Phase 2 will be functional/integrated testing of components to ensure component/system function. The phase 2 testing will be performed under the jurisdiction of BNL based on component/system parameters defined within the work package and engineering documents. Phase 2 is usually performed by a start-up team comprised of operations, plant engineering and contractor personnel.

Surveillance of components after turnover to the client for operation, will be identified in the final Design Report, with recommended periods and attributes. These recommendations are to address current plant practices and methods of identification (i.e., technical safety requirements) and manufacturer's recommendations.

Surveillances or audits will be performed by the responsible quality assurance organization during the engineering, procurement and installation phases of the project to assure compliance with the QA manual.

2.3.6 Maintenance

The maintenance of the new spent fuel canal liner will be in accordance with HFBR procedures. Additional requirements will include periodic cleaning of the leak detection sump and repair of any damage to the canal liner.

2.3.7 Safeguards and Security

The safeguards and security considerations for this project are limited. The primary consideration is that modification work does not introduce any unanalyzed security issue during normal plant operation (e.g., interference with surveillance equipment, impact to required area lighting). The current recommendation is to allow controlled access to the equipment areas through the truck bay for equipment and personnel. Security approval for unescorted access within the plant will require a screening process to be in place which supports mobilization of craft and support personnel. Ingress and egress routes will be coordinated with the BNL Safeguards and Security Division for all personnel and equipment that must be taken into and removed from the HFBR confinement. In addition, the selected design options must not impede the use of the 30-cell uncut fuel element storage rack heavy cover and alarm. To date, no other safeguards and security constraints have been identified.

3.0 DESCRIPTION OF ALTERNATIVE LINER SYSTEMS

3.0 DESCRIPTION OF ALTERNATIVE LINER SYSTEMS

A number of alternative liner concepts were investigated. These included steel wallpaper concepts, aluminum liners, fiberglass and hydrostatic concepts, as well as double steel wall and single steel wall concepts with and without removal of the existing tile. Four of these alternatives were selected for detailed evaluation. A fifth, Option E was added after discussion with Suffolk County.

Based on the canal liner design requirements described in Section 2.0, the five design alternatives, options A, B, C, D, and E are developed. These alternative options are depicted in sketches SK-B-01 through SK-B-12 which are provided in Appendix B. These options are variations of different types of containment barrier, support schemes, leak detection systems, and canal concrete treatment methods. The primary design features for these alternatives are summarized as follows:

Option A :

- Two steel liner plates with stiffeners provided between outer and inner plates.
- No lateral support except at canal top and bottom elevations.
- 1/2 inch gap provided between outer liner plate and existing canal tiles.
- Grout provided at the bottom between the outer liner plate and canal concrete floor surface
- Existing canal tiles left in place.
- Annular space between two liner plates drained to a sump for leak detection and recovery.

Option B:

- Two steel liner plates with stiffeners provided between outer and inner plates.
- Outer liner plate embedded into the canal concrete walls with grout to provide a positive lateral support.
- Grout provided at the bottom between the outer liner plate and canal concrete floor surface
- Existing canal tiles and concrete setting removed.
- Annular space between two liner plates connected to a sump for leak detection and recovery.

Option C:

- One inner liner plate with stiffeners and leak detection channels provided on the back of liner plate.
- No lateral support except bearing against strip plates which are anchored to the canal walls
- Grout provided at the bottom between the liner plate and canal concrete floor.
- Existing canal tiles left in place with detection and repair of local cracks in the tiles or concrete.
- Leak collection channels. Unsealed channels connected to a sump for leak detection and recovery.

Option D :

- One liner plate with stiffeners and leak detection channels provided on the back of liner plate.
- Grouted space between the liner plate and canal walls to provide a positive lateral support.
- Grout provided at the bottom between the liner plate and canal concrete floor.
- Existing canal tiles and concrete setting removed.
- Leak collection channels. Unsealed channels connected to a sump for leak detection and recovery.

Option E :

- One liner plate with stiffeners and leak detection channels provided on the back of liner plate.
- No lateral support except bearing against strip plates which are anchored to the canal walls.
- Grout provided at the bottom between the liner plate and canal concrete floor.
- Existing canal tiles and concrete setting removed.
- Canal concrete surface treated with waterproof cementitious material and/or epoxy coating.
- Leak collection channels. Unsealed channels connected to a sump for leak detection and recovery.

In addition to the above five options, two low cost variations of Option C were investigated. In the first variation, the single liner is designed as a "wallpaper" type liner assembly with the liner supported directly by the existing tile walls and the welded channels backing up the welds omitted. This variation was rejected because of its lack of leak detection and collection capability. In the second variation, the channels and sump are replaced by a barrier of clean water filling the annular volume between the liner and the tiled canal wall. Leak detection is accomplished by analyzing the water in the annulus for tritium. This variation was rejected because the water barrier will not remain clean. It will gradually become tritiated by isotopic exchange with the tritiated water already absorbed into the concrete canal walls. Leak detection ability will therefore become unreliable.

The concept of injecting water into the sandy soil foundation under the HFBR facility to prevent water leaking out of the canal was also evaluated. This concept was not further considered because of potential problems with foundation settlement and building stability.

The primary design features for all five options are summarized in Table 3-1. Detailed descriptions of these primary design features are presented in Section 3.1.

Table 3-1: Liner Design Features for Five Options

Option	Containment Barriers	Support Schemes	Concrete Treatment	Leak Collection
A	• Two liner plates as barriers • Concrete wall/floor as additional barrier	• Grout on floor for vertical support • Lateral support at top and bottom elevations	• Repair concrete cracks or loosened tiles	• Annular space between two liners • Sump
B	• Two liner plates as barriers • Concrete wall/floor as additional barrier	• Grout on floor for vertical support • Embedded outer liner plate for lateral support	• Remove tiles and mortar, and repair concrete cracks	• Annular space between two liners • Sump
C	• One liner plate and concrete wall/floor as barriers • Leak detection channels as additional barrier	• Grout on floor for vertical support • Bearing on strip plates for lateral support	• Repair concrete cracks or loosened tiles	• Channels welded to back of liner along weld joints • Sump
D	• One liner plate and concrete wall/floor as barriers • Leak detection channels as additional barrier	• Grout on floor for vertical support • Embedded liner plate for lateral support	• Remove tiles and mortar, and repair concrete cracks	• Channels welded to back of liner along weld joints • Sump
E	• One liner plate and impervious concrete wall/floor as barriers • Leak detection channels as additional barrier	• Grout on floor for vertical support • Bearing on strip plates for lateral support	• Remove tiles and mortar, and repair concrete cracks • Concrete surface with cementitious and/or epoxy coatings	• Channels welded to back of liner along weld joints • Sump

3.1 Liner Design Features

3.1.1 Containment Barrier

Options A and B have two liner plates which provide two layers of steel containment barriers in addition to concrete walls/floor. Options C, D and E provide one layer of steel containment barrier and utilize the existing concrete wall/floor as the second containment barrier. Structural channels or angles welded on the back of the steel liner plate behind all shop-fabricated weld joints and accessible field weld joints to provide an additional containment barrier and enhance leak detection.

3.1.2 Liner Assembly Support Schemes

OPTION A. The outer liner assembly of Option A is supported vertically by the concrete grout at the bottom. The vertical loads are transferred from the inner plate to the stiffeners between the inner and outer liner plate and then to the concrete floor through the grout. This liner assembly is free-standing with no lateral supports except at the canal top and bottom elevations. There is a 1/2-inch gap between the existing tile surface and the outer liner plate. This gap is provided to accommodate

the installation of the liner assembly. This free-standing liner assembly can withstand any lateral loads by itself without a need for concrete wall backing.

OPTION B. Similar to Option A, the liner assembly for Option B consists of two liner plates and stiffeners between the liner plates with the same vertical load-carrying components. However, instead of being free-standing, the outer liner plate of Option B is anchored into the concrete wall with welded stiffeners and grouting. The existing canal tiles and approximate 2 inches of concrete setting will be removed to provide the space for the anchor embedment. This option provides a positive connection between the outer liner plate and concrete wall, and forms a continuous lateral support for the liner assembly.

OPTION C. For Option C, the liner assembly consists of a single liner plate with vertical and horizontal stiffeners and is supported vertically by the liner plate which lies on the concrete grout surface of the canal floor. The liner assembly is free-standing without lateral concrete grout backing. However, strip plates, which are anchored to the existing concrete wall, are provided to support lateral bearing loads transferred from the stiffeners.

OPTION D. Similar to Option C, the liner assembly for Option D consists of one single liner plate and stiffeners on the back of the liner plate. However, instead of using the strip plates for the lateral support, the space between the concrete surface and liner plates are grouted so that all stiffeners are embedded in the concrete. This option provides a positive connection between the liner plate and concrete wall, and, therefore, provides a continuous lateral support.

OPTION E. Option E has a similar support scheme as Option C both for vertical and lateral loads. This option includes the removal of the existing ceramic tile and associated mortar bed grouting and sealing of the exposed concrete surface with water-resistant coating.

A comparison of construction activities is given in Table 3-2.

Table 3-2: Comparison of Construction Activities

Activities	Option A	Option B	Option C	Option D	Option E
Liner Thickness	5/8"-5/8"	5/8"-1/4"	5/8"	1/4"	5/8"
Tile/Concrete Removal	None	Yes	None	Yes	Yes
Epoxy Coatings	None	None	None	None	Yes
Liner Grout Backing	None	Yes	None	Yes	None
Inside Dimension Liner	7'-2-1/2"	7'-3-1/4"	7'-4 "	7'-8"	7'-8"
Embedded Strip Plates	None	None	Yes (4)	None	Yes (2)
Stiffener Spacing	2'-0"	2'-0"	2'-6"	2'-6"	2'-6"
Floor Grout	Yes	Yes	Yes	Yes	Yes
Concrete Repair	As Required	As Required	As Required	As Required	As Required
Wall Surface Grouting	None	None	250 sq. ft.	None	3200 sq. ft.
Canal Ledger Angle	As Installed	Part. Removed	As Installed	Part. Removed	Part. Removed

3.1.3 Concrete Treatment

For Options B, D and E, the existing ceramic tiles and mortar bedding, approximately two inches thick, will be removed before the liner installation. The concrete surface will be tested and inspected for apparent signs of concrete cracks and repaired. Since the tiles will not be removed for Options A and C, the concrete crack testing, inspection and repair will be done based on the existing condition of the tile surface.

In all options, the existing canal floor wili be grouted to provide a proper slope for the collection of water leakage, should any occur, and to provide proper support for the liner assembly. In addition, grout will be placed on the concrete walls for Options B and D after the concrete walls are repaired. For Option E, the concrete wall surfaces will be treated with cementitious and/or epoxy coating to provide a leak-tight barrier and a better surface for decontamination. The concrete surface treatment is not included for Options B and D, since their concrete walls are grouted.

3.1.4 Radiological Considerations

Section 4.2.3 of the HFBR Plant Description Manual requires 12 inches of water to shield the concrete wall and prevent excessive thermal stress and cracking of the concrete from stored spent fuel. This requirement is repeated as "the equivalent of twelve (12) inches of water" in the BNL Scope of Work description included in Appendix A. All of the proposed alternatives will result in some reduction of shielding water between the stored spent fuel and the wall. Table 3-3 presents the shielding thickness provided by the liner and air space and the water thickness eliminated as a result of liner installation.

To minimize dose to the concrete, the optimal combination would occur when the air space is reduced, the thickness of stainless steel is increased and the water reduction minimized. Since the air provides almost no shielding, Option A would be the best alternative because it contains the most shielding material. For the current conceptual design level, Table 3-4 compares the gamma energy fluence rate received at the concrete wall for each option and to the present configuration for one-day old fuel elements.

Table 3-3: Shielding Comparison

Option	Air Space	Stainless Steel Liner Total	Water Reduction
A	3-1/2"	1-1/4"	4-3/4"
B	2"(1)	7/8"	4-3/8"
C	3-1/4"	5/8"	4"
D	0(2)	1/4"	2"
E	3-3/8"	5/8"	2"

(1) 3-1/2" of the air space to be filled with grout
(2) 3-3/4" of the air space to be filled with grout

Table 3-4: Gamma Energy Fluence Rate

Option	Stainless Steel Liner Total (cm)	Water Reduction (cm)	Energy Fluence Rates (Mev/sq cm/sec)
A	3.175	12.065	2.5890E+12
B	2.2225	11.1125	3.3740E+12
C	1.5875	9.8425	4.0540E+12
D	0.635	5.08	3.4190E+12
E	1.587	5.08	2.9660E+12
Present Configuration	0	0	4.4300E+12

The estimates are based on a model which takes into account the amount of water removed, the thickness of stainless steel, the air space and grout. The computer code Microshield, Version 4.0, was used. Based on the above results, all options provide sufficient shielding to result in a lower energy fluence to the concrete wall of the canal than the 12 inches of water requirement. Further analysis will be performed during preliminary design to determine the heating load due to gamma flux on the liner.

The proposed alternatives also present another radiological consideration. There is a potential for gamma streaming for the options which have large air spaces. Gamma streaming occurs when radiation is transported through media with different densities and when multiple scatter takes place. Streaming is characterized by the reflection or scatter of gamma or neutron radiation on wall or surfaces, also known as albedo effect. The proposed options have the potential for creating gamma streaming due to the fact that the liner installation creates two reflecting surfaces with an air space in between. These two parallel surfaces promote multiple gamma scatter which can be projected in the upward direction. The options with high probability of gamma streaming are those which have larger air gaps. However, radiation exposure due to the streaming that may result from any of the options will be minimized by including a shielding barrier at the top of the canal over the air space. Additional detailed Monte Carlo analysis will be necessary to verify that the final design does not create gamma streaming that may increase the normal operating dose at the upper areas of the canal.

3.1.5 Liner Material

The liner plate shall will be corrosion-resistant and provide sufficient structural strength under the specified temperature and radioactive environment. Several different materials have been investigated for spent fuel canal liner applications, including stainless steel, which is commonly used in the spent fuel pools of nuclear power plants, carbon steel and glass fiber reinforced plastic. The materials comparison is summarized in Table 3-5.

Stainless steel Types 304 and 304L both provide high corrosion resistance and are proven for nuclear applications. Type 304 has less material cost and higher yield strength than Type 304L. Type 304L is superior in stress-corrosion cracking resistance; however, this is not critical in the liner application since preconditions such as high weld stress and chlorides do not exist. Therefore, stainless steel Type 304 is a better material than Type 304L for the liner plate.

Carbon steel such as A-36, combined with corrosion-resistant coating, may achieve the same degree of corrosion resistance as stainless steel and has a lower material cost. However, it requires periodic inspections and maintenance which would disrupt operations and be more costly than stainless steel. In addition, the structural strength of stainless steel Type 304 is comparable to that of carbon steel. Overall, stainless steel Type 304 is more suitable than carbon steel.

Other materials have also been investigated for the liner, including glass fiber reinforced plastic, stainless steel Type 316, and aluminum. Glass fiber reinforced plastic material has the following disadvantages: difficult to fabricate for the canal configuration; low material strength; and questionable radiation resistance. Stainless steel Type 316 was eliminated because it is too expensive. Aluminum was investigated but was rejected because of its inferior welding capability and strength.

From this materials comparison, it can be concluded that stainless steel Type 304 is the most suitable material for the liner plate.

For Options C, D, and E, stiffeners and leak detection channels, which are welded to the back of the liner plate, are not exposed to water and, therefore, do not require a corrosion-resistant material. However, stainless steel is chosen for the leak detection channels to provide corrosion protection all the time including for the unlikely event of inner liner leakage. There are no corrosion problems for the welding between stainless steel and carbon steel. Carbon steel such as A-36 can be used for the liner stiffeners and the embedded strip plates. This is also applicable to all stiffeners and strip plates for Options A and B.

Table 3-5: HFBR Canal Liner Potential Materials Comparison

Material Type	Pro	Con
Stainless Steel Type 304	• High corrosion resistance • Comparable yield strength to A36 • Less cost than Type 304L • Proven for similar nuclear application •	• Higher material cost than A-36
Stainless steel Type 304L	• High corrosion resistance • High stress corrosion cracking resistance • Proven for similar nuclear application	• Higher material cost than Type 304 or A-36 • Lower yield strength than Type 304
Carbon Steel A-36 with Coating	• Lower in material initial cost than stainless steel • Good yield strength	• Higher inspection and maintenance cost than Type 304 and Type 304L
Glass Fiber Reinforced Plastic	• Lower in raw material cost than stainless steel	• Difficult to fabricate for the canal configuration • Low material strength • Questionable radiation resistance • High friction coeff. for rack interaction
Aluminum 6061-T6	• Galvanic corrosion is negligible • Equally durable as stainless steel but far less expensive	• Welding prep time, cleanliness is tedious • Low strength at weld joints, require more material • Heavier surface oxide thickness than stainless steel, may cause decontamination problems

3.2 Leak Detection and Recovery System

The Liner Leak Detection and Recovery System is designed to provide early detection, annunciation, and location of liner damage or weld failures that result in water leakage. The system also provides the ability to collect and recover leakage to prevent leaked water from being released to the environment.

The following options were evaluated:

Collection options

1. Leakage is drained to a central sump.

2. Channels are welded to the back of welds where ever practicable to contain leakage and drain to localized mini-sumps. Final assembly welds are backed by channels to convey any leakage to the central sump, but these channels can be welded to the liner on one side only since the back of the weld joint is inaccessible.

The single sump option is incorporated into all liner options since it facilitates the use of a simple and cost-effective continuous detection and alarm system and has the ability to recover leakage at a much higher rate than the mini-sumps in the welded channel

Welded channels are incorporated only in the single liner options (Options C, D and E) as an additional level of confinement. This option permits more localized detection of and recovery from weld failures on all but final field assembly welds. For the final assembly welds, the unsealed channels convey leakage to the central sump without challenging the concrete secondary confinement. Welded channels are not used for the double liner options (Options A and B) since the outer stainless steel liner provides secondary confinement equivalent to the inner liner, and the concrete canal provides a tertiary confinement. Therefore the additional cost of the channels is not justified for Options A and B.

<u>Leak Detection Options</u>

1. Central sump bubbler tube level detector operates continuously and alarms in the control room.

2. For welded channels, a collection tube extends from the low point drainage location (mini-sump) to a valve and a transparent collector above the level of the pool surface. A second penetration permits the channel to be pressurized. Each collection subsystem is sealed except for this tubing and is pressurized to detect and collect leakage.

3. Gas flow from each sealed channel subsection is periodically passed through an airborne tritium detector.

4. Gas flow from each sealed channel subsection is periodically passed through a bubbler or cold trap to condense water vapor. Collected water is counted in a liquid scintillation detector to determine tritium concentration.

The sump level detector meets all regulatory detection and alarm requirements and is used in all liner options. For the sealed welded channels, pressurization is used to detect and recover leakage for the single wall liner options. The tritium detectors can be added as an optional means to detect leakage at a very early stage. The airborne detector provides immediate detection at sufficient sensitivity for use with current canal tritium concentrations. Liquid scintillation is more sensitive and uses existing instruments, but requires off-line laboratory analysis. Tritium detection may not be reliable for central sump detection in the single wall liner options due to outgassing of previously absorbed tritiated water from the concrete.

Leak Localization Options

1. Sealed channels in single wall liner options are pressurized sufficiently to observe bubbles rising in the canal from the point of leakage.

2. For the double wall liner options, the annular space between the liners is pressurized sufficiently to observe bubbles rising in the canal from the point of leakage.

3. A vacuum box leak detector is used over the suspected weld areas.

Pressurization of the area behind the suspected weld is simple and effective. It is the preferred method for the sealed channel areas in the single wall liner options. The required pressure is however too high for use in the larger areas of the double wall liner options. Therefore, this method was rejected for the double liner options. The vacuum box method is applicable to those areas not adaptable to the pressurization methods.

Recovery Options

1 A water-powered ejector jet pump is used to recover leakage from the central sump. An auxiliary pump on the equipment floor is required to supply pressurized canal water.

2. A mechanical sump pump is used to recover leakage from the central sump.

3 Pressurization of sealed channel subsection forces leakage up the collection tube extending from the low point mini-sump to the top of the liner.

For recovery of leakage from the central sump, an ejector minimizes the cross section area required for access from the canal surface level to the sump. This option therefore minimizes the potential for radiation streaming. A mechanical sump pump would require a larger access area, but has the advantage of not requiring additional canal water or an auxiliary pump. The jet pump option was chosen for the conceptual design, but an evaluation of the mechanical pump option will be made during preliminary design. Pressurization will be used for leakage recovery from the sealed channel mini-sumps.

4.0 COMPARISON OF ALTERNATIVES

4.0 COMPARISON OF ALTERNATIVES

The five liner designs described in Section 3.0 are now evaluated using a structured decision making process. Each alternative's strengths and weaknesses are considered in an objective manner in order to select the best overall design. The "best" design was determined to be Option E since it satisfies not only the DOE and NRC requirements but also those of Suffolk County and BNL. As an additional evaluation, Expert Choice™ software was used to quantify the alternatives' relative ranking. The program supports the conclusion that Option E is the best choice, with three of the other four options being almost as good.

4.1 Liner System Comparisons

Preliminary analysis indicates all alternative designs are structurally adequate to meet the applicable codes and standards. Table 4-1 summarizes the advantages and disadvantages of each alternative design.

The liner assembly based on two liner plates with stiffeners in between is structurally stronger than the one based on the single liner plate. If the liner assembly is partially or fully embedded into the canal concrete walls, then it will provide better structural stability in resisting the lateral loads such as seismic and hydrostatic. However, a stronger and more stable structure is usually more susceptible to thermal loads.

The alternatives with free-standing or partially lateral supported, Options A and C, have the advantage of leaving canal tiles intact. However, the net canal space, the distance from liner face to face, is reduced. This will affect the interface requirements such as the space to accommodate existing fuel racks. As shown in sketch SK-B-01 (in Appendix B), the distance from face to face of the inner liner plate for Option A is 7'-2 1/2", which is the narrowest among all alternatives.

Compared with Option A, Option B provides a more positive connection between the liner plate and concrete wall, therefore, the thickness of the outer liner plate as well as the space between the inner and the outer liner plates can be reduced. Therefore, Option B has advantages in saving some material quantities and larger net canal space over Option A. However, it requires some effort to remove the existing contaminated surface tiles and concrete.

Option D provides a positive connection between the liner plate and concrete wall, therefore, it can save some liner assembly material and provides larger canal net space. However, it has disadvantages in the cost associated with removing existing tiles and concrete.

For Options A and B, the space between outer and inner liner plates can be utilized as the leak detection channel, therefore, no weld back-up channels are required. In Options C, D and E, the leak detection channels, which are built up with the structural angels along the liner plate weld joints, are used to collect leakage and serve as an additional containment barrier. No leak detection channels are required in areas other than the weld joints, because the stainless steel liner plate is a proven corrosion resistant material and will be purchased and fabricated in accordance with requirements for the nuclear safety-related Seismic Category I structures. If there is any potential leakage in the liner

plate, it will occur at the weld joints or result from observable physical damage. It should be noted that Option D, a single liner with leak detection channels, is a proven design commonly used for the spent fuel pool liner in commercial nuclear power plants.

The design of liner assembly for Option E is similar to Option C except that the existing tiles and concrete are removed. Because of this, Option E has a larger canal net space than Option C. In addition, the canal wall concrete surfaces for Option E are treated with cementitious waterproofing and epoxy to provide additional leak-tight containment and better surface condition for decontamination. This is the advantage of Option E over Option D, which has a similar design in providing a larger canal space. Option E is judged to be equivalent to Options A and B and superior to Options C and D in satisfying the double containment requirement of the Suffolk County Sanitary Code.

All options meet the applicable design requirements of DOE, NRC and ANS. Only Options A, B and E satisfy Suffolk County Sanitary Code requirements. Therefore, Options C and D are unacceptable. Options A and B excessively reduce the working area of the canal. Option A may require completely new strike plate design and new fuel racks. Therefore, Option E is the most viable option.

Table 4-1

Design Comparison of Five Alternatives

Options	Advantages	Disadvantages
A	• Two stainless steel liners • Good for horizontal seismic load resistance • Satisfies Suffolk County Sanitary Code	• No concrete backing for vertical load transfer • High material and installation cost • Reduces canal net space and less shielding of concrete • Longer schedule
B	• Two stainless steel liners • Good for horizontal seismic load resistance • Satisfies Suffolk County Sanitary Code	• Tiles and shotcrete removal cost • No concrete backing for vertical load transfer • High thermal loads • High material and installation cost • Longest Schedule
C	• Easiest installation • Lowest material and installation total cost	• One stainless steel liner without treated concrete as a secondary barrier • Canal net space and less shielding of concrete • May not fully satisfy Suffolk County Sanitary Code requirements
D	• Proven design for commercial nuclear power plants • Lower material and installation total cost	• One stainless steel liner without treated concrete as a secondary barrier • Tiles and shotcrete removal cost • Grout around the canal walls cost • May not fully satisfy Suffolk County Sanitary Code requirements
E	• One stainless steel line • Existing concrete floor/walls coated and sealed • Low material cost • Satisfies Suffolk County Sanitary Code	• Tiles and shotcrete removal cost • Higher overall cost

4.2 Liner System Comparisons Using Expert Choice™

The five liner assembly designs were also evaluated using a formal decision-making program. Expert Choice Inc. software was used to enhance and confirm the decision-making process by providing a structured framework to synthesize the judgments of the multi-discipline design team.

The design team consists of eleven engineers and managers grouped as follows: three civil engineers, a project engineer, a nuclear safety and licensing engineer, a construction engineer, a project manger, a health physics practitioner, a process engineer, a nuclear engineer and a cost/schedule engineer. One of the civil engineers is an independent reviewer. The team members reviewed the descriptions and drawings of each of the five design alternatives.

The team identified thirteen requirements and desirable attributes as key criteria in choosing the best design alternative. These criteria are shown across the top of the sample evaluation form (Table 4-2).

A subset of the group, consisting of those who were most familiar with the criteria, priorities and issues, established the "weighting factors" for each of the criteria. Each member of the team then individually completed the evaluation form, based on the attribute ranking shown on Table 4-3.

In order to objectively compare the five alternatives, an Expert Choice™ model was constructed. The model uses an analytic hierarchy process to apply comparative strength judgments to each of the thirteen criteria, and synthesize a relative ranking of the alternatives.

The model starts with the goal of choosing the best liner for the HFBR canal. The thirteen criteria needed to achieve this goal are grouped into five major categories: Regulatory Requirements, Engineering, Construction, Worker Doses, and Cost/Schedule (Figure 4-1). The regulatory requirements category includes judgments related to acceptance by DOE, NRC, Suffolk County and BNL-Reactor Division. The engineering category contains judgments related to design base accidents, seismic events, leak detection, thermal and radiation requirements, and impact on HFBR operations. The construction category contains judgments related to decommissioning and decontamination (D&D) and constructibility of the new liner. The worker doses category is used solely for judgments regarding worker doses. The cost/schedule category contains all judgments with regard to cost and schedule.

The five categories were further split into the thirteen criteria as appropriate. Each of the thirteen criteria was then assigned the weighting factor determined earlier. The five alternatives were then added under each of the thirteen criteria such that the strengths and weaknesses of each alternative would be properly weighted.

The evaluation forms were collected from each of the team members. Following the Expert Choice™ manual, the geometric mean of all eleven members was used to establish relative ranking among the various alternatives, with highest preference given to those alternatives having the highest mean.

After all the inputs were made, the program synthesized a relative ranking of the five alternatives by assigning a numeric value to each. The numeric ratings are normalized so that all the ratings total 1.0. Each alternative is then assigned a numeric rating based on it's performance in each of the criteria and the criteria's weighting factor.

Option E was chosen as the best alternative based on the team input with a pie chart rating of 0.218. Option D was a close second with rating of 0.214. Option A was the next best choice with a 0.214 rating, followed by Option B with a 0.201 rating and Option C with a 0.171 rating. Quantitatively, the top four options are within 10% of each other.

The sensitivity feature of the software was used to determine the extent to which the results are dependent on the criteria weighting factors. The program also has the ability to factor in changes to any of the designs which may then change the final ranking. It is notable that Options D and E are the top two choices in nearly all plausible scenarios, but Option E is clearly superior relative to the Suffolk County requirements.

As a second check to the process, the rating feature of the Expert Choice™ program was used to individually rate the alternatives based on each of the team members judgments. Each person's individual rating of the alternatives was then combined with the other team members to determine an overall best choice. The scores were combined using five statistical methods: arithmetic mean, arithmetic mean with high and low scores discarded, geometric mean, geometric mean with high and low scores discarded, and median rating. In each of the methods, the five alternatives held the same relative positions as described in the previous paragraphs.

As a byproduct of the alternative ranking process, a summary of the relative strengths and weaknesses as determined collectively by the team is created. The strengths and weaknesses of each alternative, as perceived by the group, are presented below in order of the alternative ranking.

Option E was collectively judged to be very strong in meeting regulatory requirements. Among the engineering and constructibility criteria, this option was judged as moderate to strong versus the other alternatives. Two of its weaknesses were in worker doses and costs, although Option B was judged the weakest in these two criteria.

Option D was judged to have only moderate strength in the regulatory category primarily due to weaknesses in Suffolk County and BNL-RD concerns. The engineering and constructibility judgments were moderate. Worker doses, cost and schedule were all judged above average.

Option A was judged to be moderately strong in meeting regulatory requirements. For the engineering criteria, it was judged weak in meeting the BNL impact on operations criteria and moderate in the other engineering criteria.

Option B was judged moderate to strong with respect to regulatory requirements. The engineering judgments were split with DBA and seismic stability judged as the strongest alternative, leak detection and thermal life moderate and below average in impact on HFBR operations. Constructibility, D&D, worker dose, cost and schedule judgments rate this as the weakest of the alternatives that satisfy the Suffolk County requirements.

Option C was judged the weakest in meeting all three regulatory criteria. This option was judged to have the weakest leak detection and thermal life, and weak to moderate performance in the other engineering criteria. Strong showings in constructibility, worker doses, cost and schedule prevented this option from being dismissed entirely, albeit these areas have been determined to have a lower weighted value than regulatory and engineering issues.

4.3 Schedule Comparisons

Appendix C shows the accelerated schedules for Options A through E. The accelerated schedules are based on two 10-hr shifts, 6 days a week. Other schedule assumptions are given in Section 5.6. The completion dates (i.e., turnover to BNL) are as follows:

Option A	3/20/98
Option B	4/13/98
Option C	3/14/98
Option D	3/23/98
Option E	3/29/98

Options A and B require much more plate welding. Options B, D and E require tile and grout removal and repair. Option E takes slightly longer than Option D since it has the best waterproofing treatment. Options A and C only require partial tile and grout removal and repair in order to install embedded stiffener plates.

Schedule differences are not considered to be a strong differentiator among the options.

In addition, at BNL request, a schedule comparison was performed based on one 8-hour shift, 5 days a week for Options A, B and E. Comparisons for Options C and D were not required by BNL. The following are the resultant dates of this review:

Option A	7/21/98
Option B	9/10/98
Option E	8/6/98

4.4 Cost Comparisons

Cost is one of several objectives that was used to determine the relative ranking of Options A through E. The purpose of this section is to provide the cost data for each of the five options, and is intended for use as the basis upon which comparative analyses may be performed.

Appendix D includes the estimators' spread sheets for Options A through E. The estimating methodology and basis of estimate elements common to all options are described in Section 5.7.

The cost drivers for the differences among the options are materials, extent of tile and grout removal and repair, pre-fabrication potential and installation hours. The total project cost, excluding BNL costs, for the options based on an accelerated schedule are given below. The BNL costs do not change significantly for the various options.

Option A $4.54 million

Option B $5.15 million

Option C $4.61 million

Option D $5.26 million

Option E $5.52 million

The two steel liner cases, Options A and B, are the most expensive. Options C and D have a lower cost than Option E, however, as discussed above, Options C and D are unacceptable relative to the requirements of Suffolk County.

Option E, the preferred installation, is the most expensive. A large contributing factor is the removal of tile and grout utilizing a specialty contractor. The direct costs associated with the double-stainless liners was significant and additional liner welding was required, but these costs (for Options A and B) did not offset cost associated with tile/grout removal and coatings selected for Option E. In addition, Option E required welding of leak chase channels while Options A and B did not require leak chase due to the dual stainless steel liners. However, there is a potential cost to BNL if the 7'-2 1/2" width dimension for Option A would require extensive modification or replacement of the existing fuel racks, seismic rack restraint, or would limit fuel storage capacity and fuel handling operation. The tangible value for these items was not available at the time of this report.

4.5 ES&H Assessment

All the options presented, meet the applicable design requirements of DOE, NRC, ANS and BNL to provide for the design of the Liner and the Leak Protection and Recovery System. However, the additional design requirements imposed by the Suffolk County Sanitary Code Article 12, Section 760-1210 makes Option E the most viable choice.

4.6 Conclusion

Based on the above technical evaluations, cost/schedule comparisons, and decision-making models, Option E is the recommended approach, and it will be described in detail in Section 5.

Table 4-2

EVALUATION OF ALTERNATIVE OPTIONS

(SAMPLE EVALUATION FORM)

Option	Degree of Meeting Requirements of DOE/NRC	Degree of Meeting Requirements of Suffolk County	Degree of Meeting Requirements of BNL-RD (SOW)	Ability to withstand DBA/s and Beyond DBA's (e.g., load drops)	Impact on BNL Operations (e.g., pool space, confinement leak test)	Relative ease of D&D	Degree of Pre fab & Constructibility	Minimized Worker Doses	Ability to Withstand Seismic Events and Beyond	Expected Ability to meet lifetime (thermal, Rad) requirements	Confidence in achieving 3/98 Schedule	Assurance of leak detection capability	Relative costs	Score
Weight	10	10	10	8	8	4	5	7	8	7	5	8	10	
A														
B														
C														
D														
E														

TABLE 4-3: Example of Attribute Ranking

HIGH (SCORE 10 POINTS)

There is high confidence that the requirement or desired level of performance will be satisfied or exceeded. This confidence is based on previous successful implementation, scoping calculations, comparison to similar designs, or other appropriate measure or basis of comparison for the attribute.

MEDIUM - HIGH (SCORE 8 POINTS)

There is a medium to high confidence that the requirement or desired level of performance will be satisfied. This confidence is based on experience, and/or engineering judgement.

MEDIUM (SCORE 6 POINTS)

There is medium confidence that the requirement or desired level of performance will be satisfied. Confirmatory calculations, studies or tests are required.

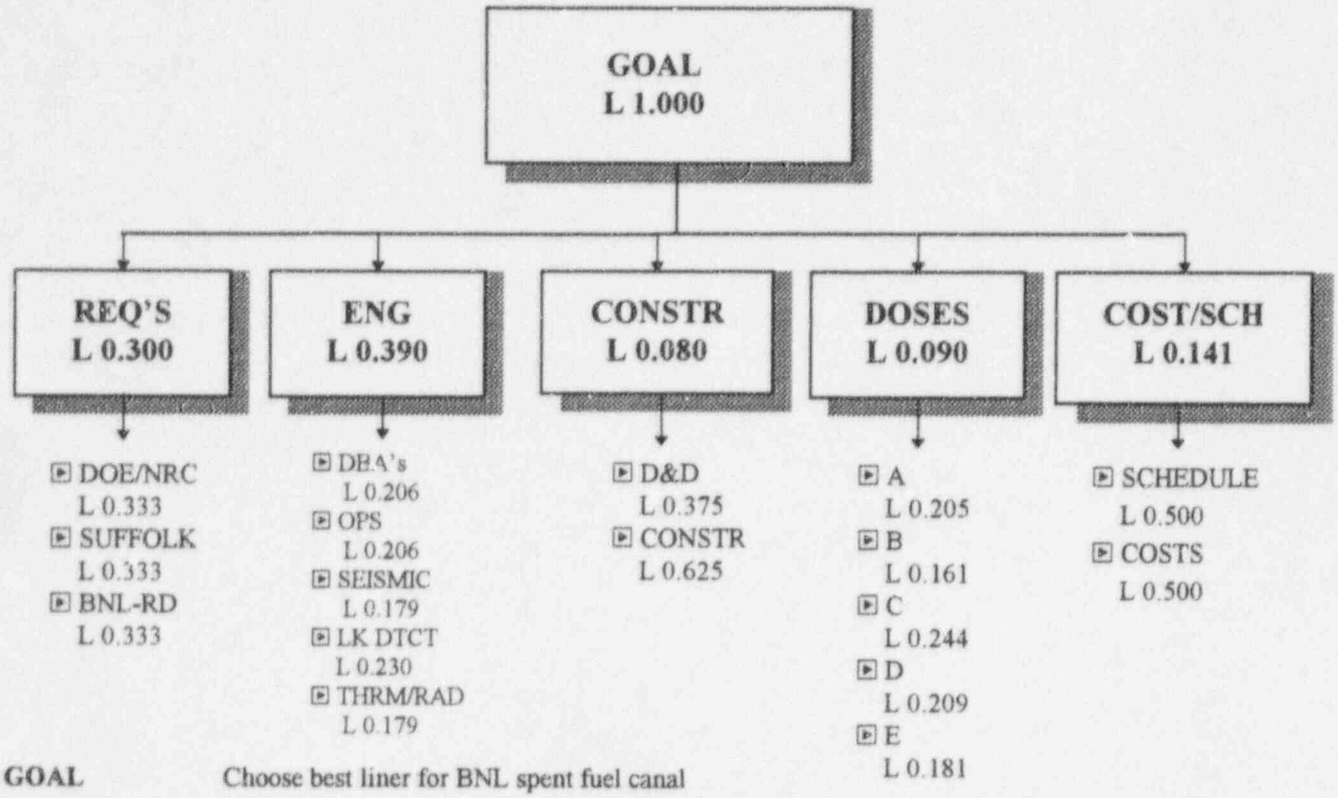
MEDIUM - LOW (SCORE 4 POINTS)

There is a definite need for further studies, calculation, scale model testing to confirm that the requirements or desired level of performance will be satisfied.

LOW (SCORE O POINTS)

There is a lack of confidence that requirements or level of performance will be satisfied .

Figure 4-1
Choose Best Liner for BNL Spent Fuel Pool



GOAL	Choose best liner for BNL spent fuel canal
A	Double liner, pipe/tubes, repair local cracks
B	Double liner, pipe/tubes, repair cracks and add grout
BNL-RD	Degree of meeting requirements of BNL-RD
C	Single liner, channels, repair local cracks
CONSTR	Degree of pre-fab and constructibility
COST/SCH	Relative costs and confidence in achieving 3/98 schedule
COSTS	Relative costs
D	Single liner, channels, repair cracks and add grout
D&D	Relative ease of D&D
DBA's	Ability to withstand DBA's and beyond DBA's (e.g., load drops)
DOE/NRC	Degree of meeting requirements of DOE and NRC
DOSES	Minimized worker doses
E	Single liner, channels, repair cracks and add grout and coating
ENG	Ability to meet leak and therm/rad reqs and withstand accidents
LK DTCT	Assurance of leak detection capability
OPS	Impact on BNL operations (e.g., pool space, confinement leak test)
REQ's	Degree of meeting DOE/NRC, Suffolk County, and BNL-RD requirements
SCHEDULE	Confidence in achieving 3/98 schedule
SEISMIC	Ability to withstand seismic events
SUFFOLK	Degree of meeting requirements of Suffolk County
THRM/RAD	Expected ability to meet lifetime thermal/radiation requirements
L	LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT

5.0 RECOMMENDED LINER SYSTEM CONCEPTUAL DESIGN

5.0 RECOMMENDED LINER SYSTEM CONCEPTUAL DESIGN

5.1 DESIGN

5.1.1 Liner Assembly

The liner assembly for the recommended alternative, Option E, consists of one stainless steel liner with leak detection channels. Lateral support is provided by embedded strip plates. The existing tiles and grout have been removed and replaced by a waterproof cement and coated with epoxy. Option E is designed to satisfy the codes and standards described in Section 2.0. The following subsections describe the design loads, load combinations, structural acceptance criteria and analysis approaches for the design of the liner assembly. In addition, the existing condition of reinforcement in the canal concrete structure is also addressed.

The conceptual design calculations for the recommended alternative show that the overall concept of Option E is feasible and the design can meet the structural acceptance criteria. Detailed calculations will be developed during the preliminary and final engineering/design stages.

5.1.1.1 Design Loads and Load Combinations

The design loads for liner assembly are in accordance with NUREG-0800, SRP 3.8.4, ANSI/ASCE 7-95, and BNL requirements in Attachment 1 of "Task Order No. 3." They are summarized as follows:

1. Dead Loads (D) Weight of liner system and attachments.

2. Live Loads (L)

   a) Weight of fuel elements and structures in the canal, including racks, storage baskets, strike plate assembly, restraint structure, canal saw, etc.

   b) Water Normal - El. 92'-0"
      Maximum - El. 93'-0"
      Minimum - El. 84'-0"

3. Seismic Loads (E')

   Design Basis Earthquake (DBE) represented by the floor response spectra at equipment level

4. Thermal Loads (T_o, T_a)

   a) Normal canal water temperature (T_o)

      122°F circulating water temperature at heat exchanger outlet.

b) Accident canal water temperature (T_a)

212°F with loss of canal cooling

5. Cask drop loads (R)

a) Postulated cask drop accident at cask shipping area. Cask weight 25 kips dropped from a height of 25 feet above strike plate or 28 feet 9 inches above canal bottom.

b) Drop of the heavy cover on the canal bottom in the heavy cover laydown area.

c) Drop of a six-element spent fuel storage basket loaded with six cutoff spent fuel elements from a height not greater than 10 feet below the normal canal water level.

6. Containment test pressure (P_t)

2 psi

The design load combinations are per NUREG-0800 SRP 3.8.4, including Appendix D, and are listed below:

Load Combination		Category
a)	D+L	Normal
b)	D+L+E'	Extreme
c)	$D+L+T_o$	Normal
d)	D+L+R	Abnormal
e)	$D+L+P_t + T_o$	Normal
f)	$D+L+E'+T_a$	Abnormal Extreme

5.1.1.2 Acceptance Criteria

The acceptance criteria for the liner stress and strain are per ANSI/AISC N690-1994 with limitations specified in Appendix G of NUREG-1503.

5.1.1.3 Seismic Analysis

The liner assembly will be designed as a Seismic Category I structure. The seismic analysis and design of the liner assembly will be performed in accordance with the acceptance criteria for the Seismic

Category I structures other than the reactor containment and its internals for commercial nuclear power plants as delineated in NUREG-0800, SRP 3.8.4. This seismic design criteria is equivalent to or more stringent than the provisions for Performance Categories 3 and 4 (PC-3 & PC-4) components of DOE nuclear facilities specified in the DOE standard, DOE-STD-1020-94 (Ref. 6).

The seismic induced loads considered for the design of the liner assembly include the inertia forces applied at the liner assembly, hydrodynamic loads, and the interface seismic loads from the fuel racks and other attachments. The interface loads will be discussed in the next subsection.

The seismic inputs for the determination of the seismic inertia forces and hydrodynamic loads are the modified floor response spectra generated for the BNL HFBR facility in Ref. 1. The Design Basis Earthquake (DBE) floor response spectra were generated for future seismic design and evaluation of HFBR systems and components, which are equivalent to those for Safe Shutdown Earthquake (SSE) used in the design of commercial nuclear power plants. The floor response spectra at the equipment level as shown in Figures 5-1 and 5-2 are used for the design of liner assembly. The applicable damping value associated with the DBE response spectra for the design of liner assembly, which is a welded steel structure, is 4 percent based on NRC Regulatory Guide 1.61. However, for the determination of the water slosh mode effects, a 1/2 percent damping will be used.

The hydrodynamic pressure applied to the liner assembly are determined based on the approaches presented in References 2, 3, 4, and 5. The effects of flexibility of liner plate will be considered in determining the seismic loads.

5.1.1.4 Fuel Rack and Other Structure Interface Loads

The fuel racks inside the HFBR canal are free-standing without positive connections to the canal floor or walls. The fuel racks may slide or tilt during the postulated seismic events. In addition to the dead weight, the fuel racks will transfer the resulting frictional forces to the canal floor and impact loads on the walls due to potential overturning of the rack during seismic events, if possible. These rack interface loads are derived based on the following seismic evaluation reports and associated calculations:

RP-2241-BNL-001, *Seismic Evaluation of Structures Within Spent Fuel Storage Canal Phase 1*, dated 5/27/94.

RP-2241-BNL-002, *Seismic Evaluation of Structures Within Spent Fuel Storage Canal Phase 2* dated 8/16/94.

RP-2241-BNL-003, *Seismic Evaluation of Structures Within Spent Fuel Storage Canal - Phase 3*

5.1.1.5 Cask Drop Loads

In the cask loading area of the canal, there is a strike plate assembly to protect against the impact of a cask drop into the canal during cask handling. In the event of such cask drop, the impact load is

POINT	FREQ(HZ)	ACCELERATION(G) 2% DAMP	5% DAMP	7% DAMP	PERIOD
	0	0	0	0	
A	2.5	2.6	1.79	1.48	0.400
B	3.5	2.6	1.79	1.48	0.286
C	5	1.29	0.89	0.77	0.200
D	7	1.29	0.89	0.77	0.143
E	8.5	1.06	0.71	0.64	0.118
F	10.5	1.06	0.71	0.64	0.095
G	12	0.42	0.36	0.34	0.083
H	34	0.42	0.36	0.34	0.029

MODIFIED HFBR HORIZ FLOOR SPECTRA
EQUIPMENT LEVEL

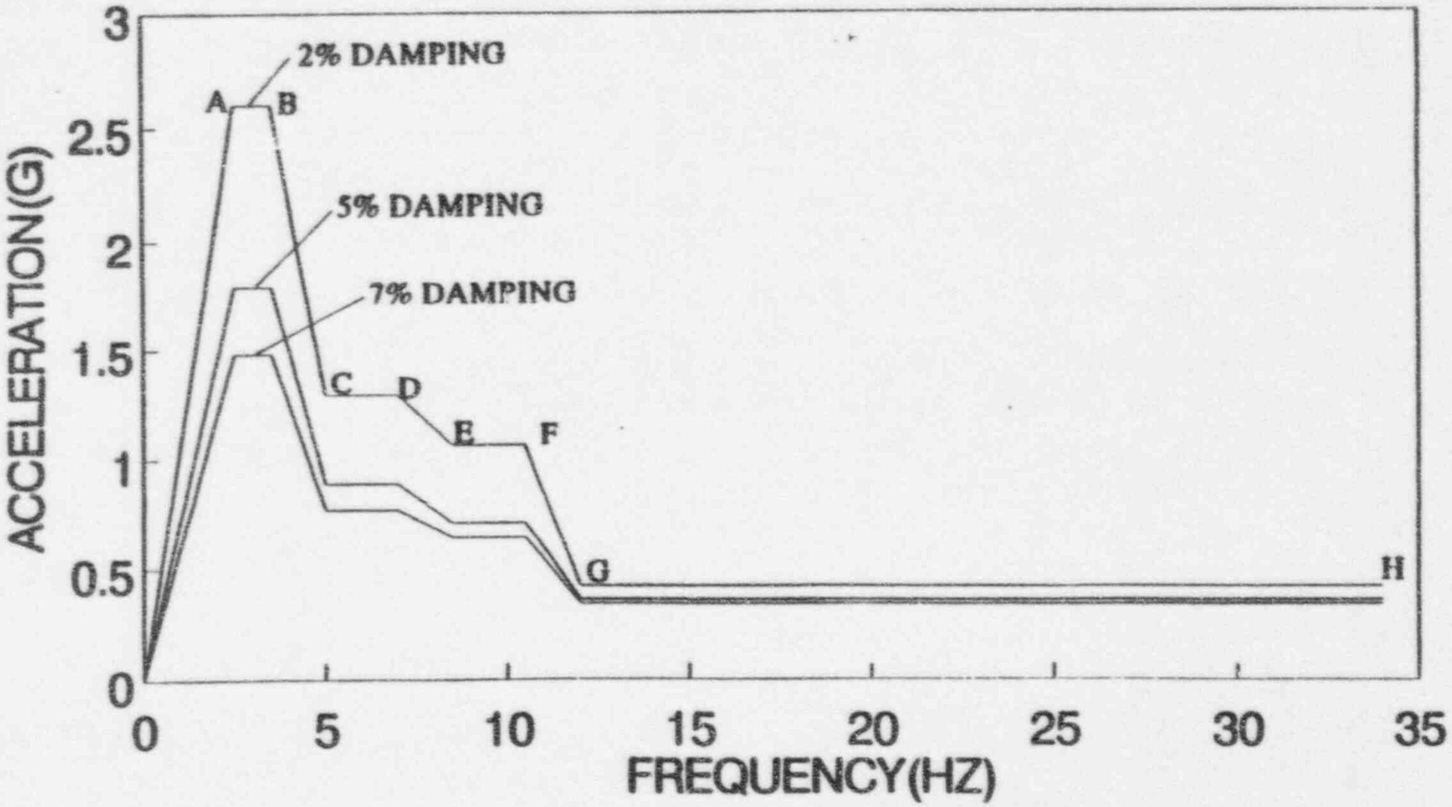
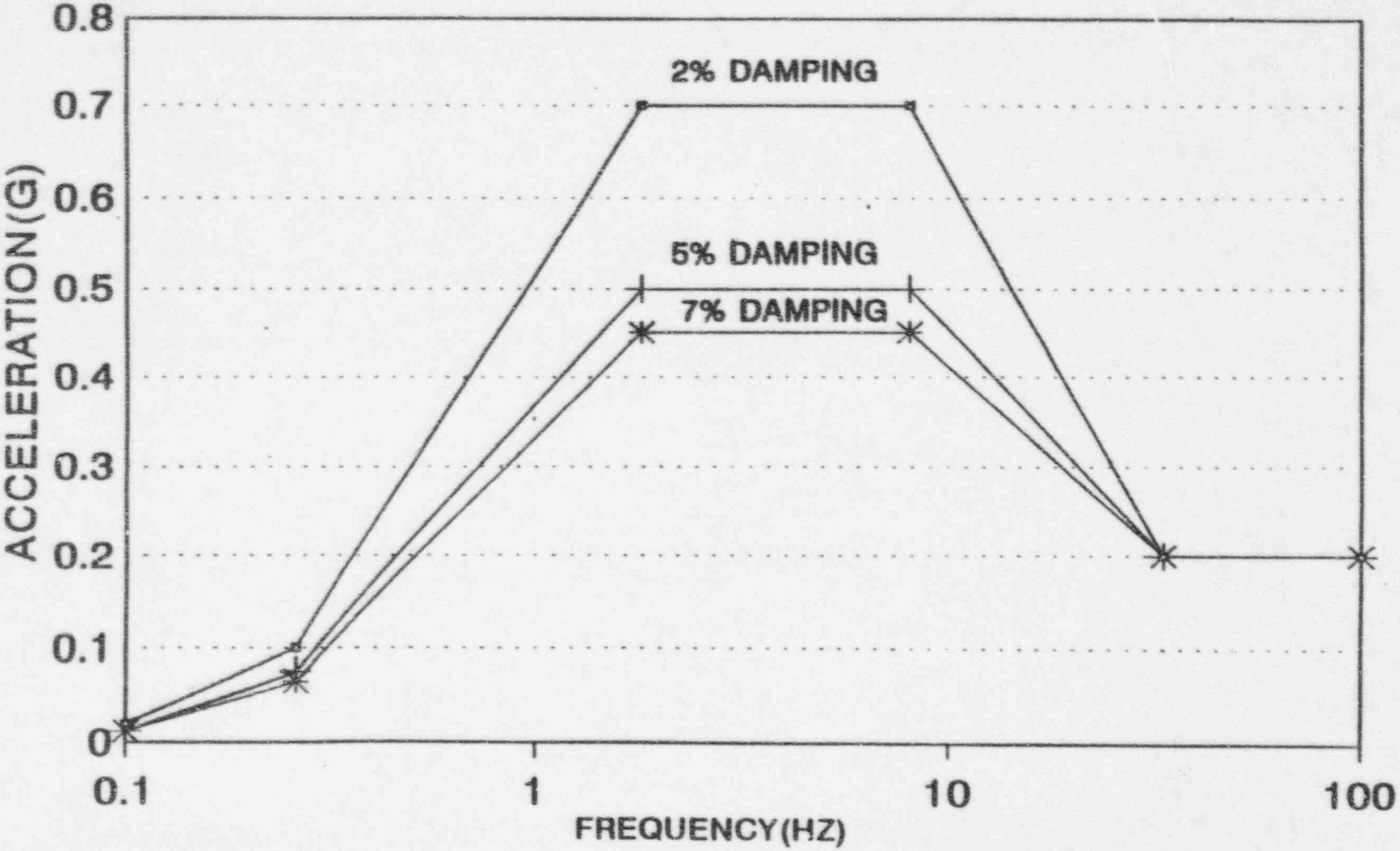


FIGURE 5-1

HFBR VERTICAL SPECTRA 70TH PERCENTILE ANCHORED @ 0.2g

BASED ON NEWMARK AND HALL SPECTRAL SHAPE



USE FOR EQUIPMENT LEVEL, CELL WALLS AND BIO-SHLD WALLS @ EXPER AND OPS LEVEL

FIGURE 5-2

transferred from the strike plate assembly to the liner a mbly. The design of the liner plate assembly at the cask handling area may require potential incre in the rack pad area. The equivalent static load is derived based on the energy and momentum balance method for the design of the liner assembly. The potential drops of fuel baskets and heavy cover in various locations will also be considered in the liner detailed design.

5.1.1.6 Thermal Loads

The following temperature conditions were considered for the conceptual design and will be the basis for design of the liner assembly:

Normal canal water temperature is 122°F

Loss of Cooling System Condition - water temperature is 212°F

The forces and stresses in the liner assembly due to the above thermal loads will be calculated based on the liner and stiffener boundary conditions. The critical components in the liner assembly including liner plate and anchorage will be evaluated for these thermal load effects.

5.1.1.7 Assessment of Existing Condition of Reinforcement in Canal Concrete Structure

The canal environment is demineralized water, with a pH ranging from 5.5 to 6.5 due to atmospheric CO_2 absorption. High purity demineralized water is virtually free of chloride and sulfate ions and has negligible total dissolved solids (TDS). Sulfate can directly attack non-sulfate-resistant portland cement (e.g., C150 Type I) concrete. Chlorides tend to permeate through cracks and corrode the steel reinforcement. This causes expansive corrosion products (rust) that exceed the tensile strength of the concrete and crack and spall the reinforced concrete structure. However, since the demineralized water contains negligible chloride or sulfate ions, the concrete walls and floor embedded rebar should not be affected. In addition, the slightly acidic demineralized water should have no adverse effects upon the rebars. Cured concrete has pH 12 to 13, which passivates and protects the rebar from corrosion. In the absence of corrosive ions such as chloride, this mildly acidic water would not affect the strongly alkaline concrete, thus maintaining the carbon steel passivity. Even if pure aerated water somehow reached the rebar the high surrounding alkalinity would continue to inhibit steel corrosion.

The reinforced concrete canal walls and floor are shielded and protected from the demineralized water by 3/8" thick ceramic tiles and mortar over a 1-1/2" to 2" thick base of shotcrete reinforced with welded wire fabric. Additionally, the rebar has a concrete cover of 1" minimum. Hence, the high purity water must pass through 3/8" tiles, 1-1/2" to 2" shotcrete and minimum 1" concrete cover before reaching the rebar, either through permeation or cracks.

For the above reasons, the existing concrete rebar should be in good condition, mainly due to the canal water chemistry and thick ceramic tile and shotcrete plus concrete cover over the steel rebar. Even if there is any corrosion occurring in the rebar, it would be limited to a localized area. The canal structure is a minimum 3-foot thick reinforced concrete and is embedded below grade. The structural integrity of the canal is unlikely to be impaired by the localized rebar degradation. As discussed in the

following paragraph, the canal concrete structure will be tested and inspected before the installation of the liner assembly. If any significant rebar degradation in detected during the inspection, a recommendation will be made for assessing the canal concrete structural integrity.

5.1.2 Concrete Treatment

5.1.2.1 Condition Assessment of Existing Concrete

Prior to removal of ceramic tiles, existing 3-ft thick concrete components of the canal walls and floor slab will be inspected by using visual and non-destructive examination (NDE) methods to assess the concrete uniformity, soundness and to identify internal distress planes, such as cracking, unbounded construction joints and delaminations, as described herein.

5.1.2.1.1 Visual Inspection

After dewatering of the spent fuel pool, a thorough visual inspection of the tiled wall and the floor surfaces of the pool will be performed. Areas of the pool where tiles may have fallen off will be inspected for defects in mortar bedding. At the conclusion of the visual inspection, sketches will be prepared to define areas of unsound concrete.

5.1.2.1.2 Non-Destructive Testing

The visual inspection of the pool surfaces will be supplemented by non-destructive examination (NDE) to determine:

- Presence, location and extent of internal distress within the reinforced concrete walls and floor slab.
- Condition of embedded reinforcing steel (corrosion).
- Condition of construction joints and expansion joints (if any).
- Delamination at the mortar/concrete interface.

NDE techniques utilizing ultrasonic pulse velocity and impact-echo methodologies have been widely used for the last 15 years to evaluate deficiencies, including cracks, in concrete. The NDE methods have been used for mapping of cracks on many commercial nuclear plant structures and at DOE facilities.

The impact-echo system is composed of three major components, a portable computer with a data acquisition card connected to a combined impactor and a receiving transducer.

In this method a transient stress pulse is introduced into the tested structural element by mechanical impact at a grid point. This pulse travels as dilatational (P-) and distortional (S-) waves and along the surface as a Rayleigh (R-) wave. The P- and S- waves propagate into the structure along spherical wavefronts, and are reflected by internal cracks and voids or interfaces and by the external boundaries of the structure. A displacement transducer, located close to the impact point, is used to monitor the surface displacements caused by the arrival of these reflected waves. These waves are, in turn,

reflected at the free surface, and they propagate back into the test object to be reflected again by internal interfaces or boundaries. Therefore, a transient resonance condition is set up by multiple reflections of the waves between the free surface and internal defects or external boundaries.

The non-destructive testing will be performed from the interior of the canal. The specific testing pattern and composition of testing programs will be established on site.

Upon completion of field work the acoustic pulse echo pattern will be analyzed by computer to provide a map of internal discontinuities in canal concrete. A report including a drawing will be prepared to delineate the possible defects in concrete such as internal cracks, voids, rebar corrosion and deterioration in concrete.

It is anticipated that the field work for this task will be completed in approximately one week.

5.1.2.2 Removal of Existing Ceramic Tiles and Mortar Bedding from Walls

Removal of the existing 3/8 inch thick ceramic tiles and 1-1/2 - inch to 2-inch mortar bedding will be performed in accordance with a written procedure and by conventional methods to minimize micro-cracking of the base concrete that will remain in place.

During removal, visual inspection of the exposed wall concrete will be performed to correlate the surface defects with the NDE results and to locate the existing construction/expansion joints, as well as the embedded inserts. Particular attention will be given to the condition assessment of the anchorages and the soundness of the underlying concrete. Additional inspection by impact hammers may be required to further delineate any areas of high porosity and low strength concrete. Unsound concrete and existing joint materials of the construction/expansion joints will be removed to expose sound concrete.

5.1.2.3 Treatment Finishes

The unsound concrete and other defects within the existing walls and floor slab of the fuel pool will be treated with proven repair material and methods to restore the integrity of the concrete. The existing concrete surfaces will be additionally treated with two layers of surface coatings, consisting of a waterproofing and a epoxy/polyurethane coating system to assure a impermeable barrier. The later coating system is to assure a decontaminable surface.

Table 5-1 lists the recommended materials for treatment of the existing concrete. The tabulation includes application/use as well as attributes/benefits for each material. A brief discussion of each material and treatment is given below. Sketches SK-A-14 and -15 in Appendix B show the sequence for concrete treatment.

Table 5-1: Recommended Repair Materials for Spent Fuel Canal Concrete Treatment

Materials	Application/Use	Attributes/Benefits
Concressive 1370 Sika dur 35 Hi-Mod LV	Pressure injection of cracks	- Low viscosity 2-component liquid epoxy - Suitable for structural bonding of cracked concrete - Resistant to high levels of nuclear radiation - Heat deflection temperature 120°F
Sikaflex - 1a/15LM	Construction Joint Repair	- One component polyurethane elastomeric non-sag sealant - Easy to apply (caulking gun) - Capable of up to 100% joint movement - Excellent adhesion to concrete NuKlad 750A/760A
Nu-Klad-750A/760A*	Expansion Joint Repair	- Excellent polyurethane elastomer sealant - Allows up to 200% joint movement - Suitable for moving joints
Nu-Klad--965*	Honeycombs/Voids Repair	- Acrylic modified cement - Excellent for repairing deteriorated concrete - Can be trowelled down to a feather edge
Sika Top 126 Plus*	Honeycombs/Voids Repair	- Polymer modified 2-component cementitious mortar - High bond and adhesion to concrete - Low permeability
XYPEX VANDEX	Waterproofing coating	- Cementitious coating penetrates concrete through crystallization process - Resistant to Gamma radiation - Easy to apply (bristle broom) - Suitable for saturated concrete surfaces - Resistant to acid attack/ corrosion - Compatible with subsequent epoxy/polyurethane coating system
Amerlock 400/Amerthane 487	Epoxy/Polyurethane Coating System	- Amerlock 400 epoxy suitable as barrier coat - Amerlock 487 polyurethane elastomeric membrane allows up 500% elongation to bridge possible cracks in the underlying coatings - Spray application - Easy to decontaminate surface

*Materials will be used subject to the actual field requirement.

5.1.2.3.1 Repairs of Cracks

The repairs of existing cracks will be performed in accordance with a written procedure which will include the requirements for materials, equipment and injection ports. As a minimum the injection of a epoxy will address the following:

- surface preparation
- setting up of injection ports and spacing
- sealing of exposed crack surface
- sequence of injection starting from the lowest elevation
- clean-up of wasted material
- evaluation

A pilot test program may be required to establish the injection parameters including spacing of ports, pressure requirements and the depth of penetration.

For cracks 1/16 - inch in width or greater, epoxy resin such as Concressive 1370, manufactured by Master Builders, or Sikadur 35, Hi-Mod LV, manufactured by Sika Corporation, will be used. Concessive 1370 has been successfully used for repairs of cracks and to withstand radiation exposure and in-service temperature conditions anticipated for the spent fuel canal concrete.

5.1.2.3.2 Construction Joint Repair

The repairs of existing construction joints will be performed in accordance with a written procedure which will include the requirements for materials, surface preparation, application and curing.

For non-moving construction joints Sikaflex la, manufactured by Sika Corporation, or equal, will be used. This material offers polyurethane based non-sag sealant suitable for horizontal and vertical construction joints. For moving joints Sikaflex-15 LM, manufactured by Sika Corp, or equal, will be used. This material offers a high performance polyurethane elastomeric sealant which is capable of up to 100 percent a joint movement.

The repair procedure will include:

- Routing out joint in a u-shaped slot.
- Removing all loose material and exposing sound concrete.
- Priming the prepared joint surface.
- Applying joint repair material

5.1.2.3.3 Expansion Joint Repair

The repairs of expansion joints if exposed will be performed in a manner similar to Section 5.1.2.3.2 above.

The material for the repair will be Nu-Klad 750A/760A, manufactured by Ameron. The material allows up to 200 percent joint movement.

5.1.2.3.4 Honeycombs or Voids Repairs

The surfaces of existing concrete, where any honeycombs or voids are indicated, will be repaired in accordance with a written procedure.

Nu-Klad 965, manufactured in Ameron or Sika Top 126 Plus, manufactured by Sika Corporation, will be used to repair defects. It is an acrylic modified cement, which can be applied in varying thicknesses as required.

5.1.2.3.5 Cementitious Crystalline Waterproofing

The surface treatment of existing concrete vertical walls and horizontal slab surfaces will be performed in accordance with a written procedure which will include the requirements for materials, surface preparation application and curing. The procedure will include:

- Preparing concrete surfaces to be free of coatings and foreign matter.
- Roughening existing surfaces by waterblasting or other approved method.
- Wetting the concrete surfaces with water and removing excess water immediately prior to application
- Applying two coats of cementitious crystalline waterproofing, in accordance with the manufacturer's recommendations.

Cementitious crystalline coating will be XYPEX Waterproofing manufactured by XYPEX Chemical Corp, VANDEX Waterproofing, or equal. XYPEX is a unique chemical treatment for the waterproofing and protection of concrete. It consists of portland cement, treated silica and active proprietary products to form crystalline formation which migrates throughout the pores and capillary tract of concrete, thus significantly reducing permeability.

XYPEX/VANDEX has been widely used for waterproofing of structures, cooling water intake and discharge conduits, low-level nuclear waste facilities as well as repairs of cracks and construction joints thereby permeability in a significant manner. It is resistant to radiation, acid attack and can be applied on the saturated surfaces of the existing concrete.

5.1.2.3.6 Epoxy/Polyurethane Coating System

After the waterproofing coating has cured, final coating of the walls and slab concrete will be performed using Amerlock 400/Amerthane 487 coating system, manufactured by Ameron. Amerlock 400 is an epoxy coating whereas Amerthane 487 is a polyurethane elastomeric membrane which allows up to 500 percent elongation to bridge any fine cracks in the underlying coating. Both coatings can be spray applied.

The application of the final impermeable barrier will be performed in accordance with written procedure which will include the requirements for materials, surface preparation application, dry film thickness (DFT) and curing.

The Amerlock 400 epoxy mastic coating has been DBA/LOCA tested by ORNL for Service Level I and passed. It has also met Nuclear Coating Service Level II radiation and decontamination requirements which apply to the BNL canal liner. The DBA/LOCA radiation tests were applied up to a cumulative radiation dose of $1. \times 10^9$ rads. After the tests, Amerlock 400 epoxy coating was intact with no defects and only slight discoloration. The final layer of epoxy/polyurethane treatment will provide a surface that can be easily decontaminated.

In the report, *Protective Coatings in the Nuclear Industry*, prepared by Harlan Kline for the American Nuclear Society, the radiation tests for different coating material were summarized. Based on Table IX of this report, the epoxy coating has radiation resistance to cumulative dose from 5×10^9 to 1.0×10^{10} rads in the air environment with no visual damage.

5.1.2.4 Concrete Grout

Concrete grout will be placed on top of the treated concrete floor. The thickness of the cementitious grout will be varied depending on the slope requirement of the leak detection system on the floor. Canal liner modules will be installed while the grout is still wet. Space between the bottom liner and the concrete surface will be fully grouted. The mixture of the grout will be specified with proper consistency and flow.

5.1.3 Leak Detection and Recovery System

The liner leak detection system is designed to provide early detection and location of weld failures or liner damage that result in water leakage. The system also provides an ability to recover any leakage.

With a single wall stainless steel liner all welds, except final subsection assembly welds, will be backed by sealed channels welded behind the weld joints to form leak detection drainage and test paths. The horizontal channels are sloped to insure complete drainage to specific low points. The detection system is subdivided to aid in the localization of the leak source. The welded channels provide a tertiary level of containment for most of the welds. Final assembly welds will be backed by channels to convey any leakage to a central sump but these channels will be welded to the liner on one side of the weld joint only since the back of the weld joint is inaccessible.

Each subsection sealed with a welded channel will have a 1/4-inch collection tube extending from the low point drainage location to a tube cap at the seal plate at the top of the liner. A second tube fitting connects to a short length ending near the top of a channel in the subsection. For periodic monitoring, the tube caps are removed and a valve and transparent water trap are connected to the fitting on the tube that extends to the low point. Nitrogen or instrument air free of tritium is introduced into the other tube.

With the valve closed, the channel is pressurized to about 15-20 psig. The valve on the collection tube is then opened. If any water has collected at the low point it will flow into the trap where it is visible to the operator. For this pumping method to work the diameter of the collection tubing must be kept small to prevent the gas from bypassing the water in the tube.

For increased sensitivity, tritium detection can be used at present pool tritium concentrations. Two optional methods can be used. At present canal tritium concentrations of 0.12 microcuries/ml, these methods have the sensitivity to detect leakage even before sufficient water is collected to be visible and also will confirm that the water came from the canal. The simplest and most sensitive detection method is to pass the exiting gas through a water or glycol bubbler or a cold trap and use liquid scintillation counting on the recovered liquid. In the fastest method, the gas flowing out of the trap can be passed through an EGG-Berthold tritium detector. This method uses existing plant instrumentation.

To pump leakage, the channel area is kept under pressure. The leaking water is forced up the collection tube and back into the canal or a collection trap.

Leakage from the remainder of the liner including unsealed channels is routed through a series of channels to a central leak collection sump located outside the liner at the lowest point of the fuel canal. The detection sump, a 2-inch depression in the collection sump, is limited to a 6-inch diameter to achieve a high detection sensitivity with conventional level detection instrumentation. Water collecting in the sump is detected, its presence alarmed, and its level measured by a dip tube bubbler type liquid level measurement instrument. Accumulated liquid is pumped by a hydraulic ejector. The ejector and the dip tube are compact enough to be located in a corner of the canal. A pipe may be used for lateral support. An ejector was selected instead of a mechanical sump pump to minimize the cross section area required outside the liner for sump access and thus minimize the potential for radiation streaming.

The ejector jet pump can recover up to 7.5 gpm against a 40-ft head when supplied with 8 gpm of water at 90 psig. This water can be supplied by a small pump on the equipment level floor taking suction from the canal. The discharge is returned to the canal, either directly or through water purification facilities. This arrangement is shown on Sketch SK-B-22 (in Appendix B). During preliminary design, the use of small diameter mechanical sump pump will be evaluated.

The dip tube bubbler liquid level measurement instrument, which is shown on Sketch SK-B-21 (in Appendix B), is similar in many respects to the existing canal level instrument,. It has three active components, a rotometer regulator, a Dwyer Magnehelic sump water depth indicator and a Dwyer Model 1800 series pressure switch. The magnehelic depth indicator provides a display near the fuel canal. The pressure switch provides contact closure to drive an annunciator in the control room, and a light near the fuel pool.

All the active components will be mounted in accessible are near the fuel canal. The only portion of the system potentially exposed to radiation will be the stainless steel dip tube. The pressure switch will be in a weather proof (NEMA4) housing so that its function is assured in case of water sprays. The sump level indicator has a scale with a span of 0-10 inches water graduated in increments of 0.2-

inch water. With a 6-inch circular sump, the instrument will start reading with a sump level of 0.5 inch, which is equivalent to 250 ml leakage and will detect a level of change of 0.2 inch-or 100 ml of leakage.

To localize leaks at welds not backed by scaled channels, a vacuum box is used inside the canal. For use under water, the water in the vacuum box would be pumped out to create a vacuum after the box is placed in contact with the wall. A leak would be indicated if there is a continuous pressure rise after the box is isolated from the vacuum pump. For additional sensitivity, the vacuum box can be exhausted through a helium leak detector while helium is flowed into the channel behind the weld being tested. With sufficient helium flow this method should work with unsealed as well as sealed channels. Vacuum boxes can be configured to test right angle and corner welds as well as flat seams. Leaks in other welds are detected by pressurizing the channel to 20-30 psig and looking for bubbles rising in the pool from the point of leakage.

5.1.4 Corrosion Issues

5.1.4.1 Corrosion of Aluminum

Addition of a stainless steel liner will have no adverse effect on corrosion of aluminum components including spent fuel elements. In fact the stainless steel liner, by eliminating contact of the canal water with bare concrete and tile grout, would be expected to result in a decrease in the potential for corrosion of aluminum components. These conclusions are based on the following factors:

1. Stainless steel is used for liners in spent fuel storage pools almost universally in nuclear power reactors in this country except for some of the very early pools. Aluminum racks have been used in these pools in boiling water reactors with excellent results. If there is a galvanic interaction between the aluminum and stainless steel it will occur at the point of contact between the two materials. At Brookhaven's HFBR, the aluminum spent fuel storage racks rest on stainless steel plates that cover the bare concrete floor of the spent fuel canal. When several of the racks were removed in 1979-1980, slight pitting was observed only at these points of contact. Aluminum corrosion test coupons have also showed similar slight pitting only at points of contact with stainless steel. (Ref. 7)

2. In the HFBR, cut fuel elements are stored in boron stainless steel baskets supported by aluminum racks. Each fuel element is stored in its own individual cell. In this arrangement, there is the potential for slight corrosion at the points of contact between the fuel assemblies and the baskets. This has not been a problem to date.

3. The rate of pitting corrosion of aluminum is accelerated by the presence in the water of metals which spontaneously plate out on aluminum. The most common of these are iron, copper, tin, and mercury. These metals plate out locally to form cathodes for local corrosion cells because of a favorable electromotive potential. Current HFBR canal water chemistry parameters include: copper <3 ppb and iron < 1 ppb with a specific resistivity of >1 megaohm-cm. These limits are more stringent than the specifications suggested by Savannah River Site chemists for the proposed

HWRF fuel pool. The HWRF was to be a tritium production reactor using aluminum fuel. (Ref. 8)

4. The Savannah River Site (SRS) has used unlined concrete basins for spent fuel storage. Ions leaching from the bare concrete have put a heavy load on their pool purification systems leading to periods of loss of control of pool chemistry in some of these basins. When fuel remained in the basin for more than six months under these conditions, pitting occurred at points of contact with sludge that collected at the bottom of the basin. (The sludge was another result of the use of bare concrete pools) (Ref 9). Basins with a conductivity in the low 1-3 micro Siemens/cm levels have supported the storage of aluminum clad alloys (Ref. 10).

5. The addition of a stainless liner to the HFBR Spent Fuel Storage Canal should further improve the performance of the existing canal purification system by eliminating contact of the canal water with the bare concrete on the canal floor and the tile grout. These are continuous sources of impurities that leach into the canal water. Elimination of this contact should further increase the already excellent pool water purity and further decrease the potential for fuel cladding corrosion.

5.1.4.2 Corrosion of Stainless Steel Liner

5.1.4.2.1 Corrosion Due to Environment (Canal Water)

Type 304 austenitic stainless steel has a long history of satisfactory service in spent fuel pools. This material has been used extensively in ambient temperature demineralized water service with no reported corrosion problems (Ref. 7).

Austenitic stainless steels are susceptible to stress corrosion cracking (SCC) when sensitized material is subjected to a corrosive environment under sustained high tensile stresses. This could occur at the weld heat affected zones. Type 304 stainless steel weldments are considered resistant to stress corrosion cracking in pool liner service based on the following:

- There is no history of SCC in the large number of commercial reactor spent fuel pools;
- Type 304 stainless steel is not subject to corrosive attack in ambient temperature (operating temperature of 86°F to 120°F) demineralized water;
- Anticipated tensile stresses in the proposed liner are expected to be quite low;
- Good low heat input welding practices should promote a limited heat affected zone that may become only mildly sensitized during the welding process.
- The water chemistry parameters, included in paragraph 5.5 - Canal Water Chemistry of the Scope of Work description, do not indicate that the canal water could be a corrosive environment for the Type 304 stainless steel to be used as a liner.

5.1.4.2.2 Corrosion Due to Dissimilar Metals

Whenever different metals are in contact or electrically continuous in a common electrolyte (water), corrosion can occur. In reviewing the available information, after the Spent Fuel Canal is lined with Type 304 stainless steel, the following different materials could be in contact with the liner, i.e.,

- Aluminum 6061 used for Fuel Storage Racks (Drawing HFBR-M-350-4).
- Carbon Steel (ASTM 47 Structural Steel used for the Strike Plate Assembly Supports (Drawing HFBR-M-135-5)

Aluminum structures in contact with the stainless steel liner will experience some minor corrosion, especially in the areas of contact with the stainless steel.

Carbon steel structures in contact with the stainless steel liner will also experience corrosion in the areas of contact with the stainless steel. Existing carbon steel structures or components may be replaced with stainless steel to reduce the concentration of soluble iron in the canal water.

5.1.4.3 Use of Cathodic Protection for the Stainless Steel Liner in Contact with Canal Water

As indicated above, stainless steel Type 304 has been used extensively in demineralized water with no reported corrosion problems. Since there are no general corrosion problems associated with this type of material in the existing water environment, cathodic protection is not required.

5.1.4.4 Corrosion of Liner Facing Existing Canal Walls and Floor

The proposed Option E indicates that there will be an air space between existing canal walls and stainless steel liner. The bottom of the liner will rest on channels embedded in grout. Under normal operating conditions it is not expected that the liner walls will be in contact with an electrolite, therefore, no corrosion protection measures are required. During the preliminary design phase recommendations will be made to avoid having chemicals in the grout, which if saturated with water could create a corrosive environment for the bottom plate of the liner that will be in contact with the grout.

5.1.4.5 Corrosion of Carbon Steel Stiffeners

The carbon steel stiffeners will be exposed to the air gap atmosphere between the stainless steel liner and the concrete pool. This atmosphere is not considered corrosive and therefor the use of carbon steel is acceptable for this application. Raytheon will however, during the preliminary design phase, conduct a more thorough corrosion evaluation to determine if additional measures should be taken to further increase the corrosion resistance of the carbon steel by either a corrosion allowance or a protective coating system with high radiation resistance.

5.1.4.6 Existing Canal Concrete Structure

During the inspection of the existing canal concrete structures, an evaluation will be made using nondestructive testing methods to determine if the reinforcing of the concrete has been corroding. Although there are no indications that the canal concrete reinforcing is corroding, if corrosion is found, evaluation will be made if cathodic protection can be applied in order to prevent further deterioration of the reinforcing. Application of cathodic protection for the reinforcing will depend on whether the reinforcing is electrically continuous or not and could be provided in the form of thermal spray metalized coating.

5.1.4.7 Grounding

During the preliminary design the existing grounding system will be evaluated and recommendations will be made for feasibility upgrading the system to meet current codes. The liner will be connected to the existing grounding system.

5.2 Design/Regulatory Requirements Matrix

The scope of this design/regulatory compliance matrix is limited to the design of the Liner and Leak Detection and Recovery System. The applicability of the specific requirements delineated in the matrix were discussed in Section 2.1 of this report.

Agency	Requirement	Satisfies	Reference Subsection	Remarks
DOE	DOE Order 5480.30, Paragraph 8d (8)(a), January 19, 1993			
	No or minimal leakage under normal operations, AOEs and DBAs.	Yes	2.4, 3.2, 5.1.3	
	Item 1	Yes	5.1.3, 5.4	
	Item 2	Yes	3.1.4	
	Item 3	Yes	3.0, 3.1	
DOE	DOE Order 5480.30, Attachment 3, Paragraph 3(8)(a), January 19, 1993	Yes	See SRP 9.1.2 and ANSI/ANS-57.2	By complying with the applicable portions of SRP 9.1.2 and ANSI/ANS-57.2, this requirement is met.
NRC	NUREG-0800, SRP 3.8.4, Rev. 1			
	Subsection II.A	Yes	2.2, 2.3.1	
	Subsection II.B	Yes	5.1.1.1, 5.1.1.3	
	Subsection II.C	Yes	5.1.1.1	
	Subsection II.E	Yes	2.2, 2.3.1	
	Subsection II.2	Yes	2.2	
	Subsection II.3	Yes	5.1.1.1	
	Subsection II.4	Yes	5.1.1.3	
	Subsection II.5	Yes	5.1.1.2	
	Subsection II.6	Yes	2.2, 5.1.4	
	Subsection II.7	Yes	2.2, 5.4	
	Appendix D, Section 4	Yes	5.1.1.1	
NRC	NUREG-0800 SRP 9.1.2, Rev. 3			
	Subsection II.1	Yes	5.1.1.1	
	Subsection II.2	Yes	5.1.1.1	
	Subsection II.4	Yes	2.2, 2.4	
NRC	RG 1.13, Rev. 1	Yes	2.2, 2.4	
	Subsection C.1	Yes	5.1.1.1	

Agency	Requirement	Satisfies	Reference Subsection	Remarks
	Subsection C.5.c	Yes	3.0, 3.1, 5.1	
	Subsection C.6	Yes	5.1	
NRC	RG. 1.29, Rev. 3			
	Subsection C.1.1	Yes	5.1.3	
	Subsection C.2	Yes	2.1.2, 5.1.1.3	
	Subsection C.3	Yes	2.1.2, 5.1.1.3	
	Subsection C.4	Yes	2.2, 5.1.1.3	
ANS	ANSI/ANS-57.2-1983			
	Subsection 5.1	Yes	3.1.4, 5.3.4.1	
	Subsection 5.6	Yes	5.1.3	
	Subsection 6.1	Yes	2.2, 2.3, 2.4, 5.1.3	
	Subsection 6.6	Yes	5.1.3, 5.4	
Suffolk County	SCSC Article 12, Section 760-1 210, December 16, 1992			
	Subdivision II.A, Item 1	Yes	2.4, 3.0, 3.1	
	Subdivision B, Item 2	Yes	2.3, 3.0, 3.1	
	Subdivision C, Item 1	Yes	2.4, 3.0, 3.1	
	Subdivision F, Item 5	Yes	3.0, 3.1	
	Subdivision G, Item 2	Yes	3.0, 3.1, 5.1.3	
	Bureau of Hazardous Materials "Leak Detection Alarm System Requirements for Toxic/Hazardous Material Storage Facilities"	Yes	5.1.3	
BNL	Scope of Work, February 7, 1997, as amended	Yes	2.2, 2.3, 2.4, 3.0, 3.1, 5.1.1.1	
	HFBR Confinement Leak Rate	Yes	5.1.2.3	

5.3 Fabrication and Installation

The single wall stainless steel liner sections can be pre-fabricated and erected in place. To facilitate leak detection, the pre-fabrication of the spent fuel canal liner within a shop environment would reduce the number of plate section welds and therefore reduce the number of leak detection channels required. The use of a fabrication shop provides for a more productive and controlled environment than for complete erection within the spent fuel pool canal area. In addition, this approach reduces manhours expended within a radiological controlled area reducing potential radiological dose and potential congestion within a limited work space. However, the truck bay-airlock door located

adjacent to the spent fuel canal liner has a vertical clearance of 14′ and a width restriction of 12′. The pre-fabricated sections must take into account the width, height and depth of each section to be transported through this door, positioning of each section at the canal, and then sufficient clearance to be rigged and positioned within the canal. There are two feasible approaches for installation of pre-fabricated sections. The first approach is to have specific sections pre-fabricated in lower and upper halves. Sketches SK-A-08, -09 and -10 in Appendix B illustrate a plausible phased erection sequence. The spent fuel canal liner used for cutting of spent fuel assemblies could be erected as one section.

Upon installation of the cutting area section the remaining spent fuel canal liner sections could be staged in sequence and installed in lower and upper halves. The next sections to follow would be those in the deep end of the canal. This section will require dimensional verification prior to fabrication due to lack of uniformity at the west end, a concrete projection which houses the retard chute. The bottom of this concrete projection is elevation 84′. With the bottom of the pool at elevation 63′, it is feasible to stage and position this 8′ x 8′ - 6″ x 21′ within the liner. The remaining west wall could be fit and fabricated on the equipment floor to assure constructibility. This approach will require that several of the vertical and horizontal welds not have a pressurized leak detection system. The remaining spent fuel canal sections, 20′ depth, could be installed in lower and upper halves. The method for erection would be to partially lower a section within the canal liner after concrete and coating work has been completed. The horizontal weld would be positioned above 93′ elevation. The lower assembly could be staged on a hydraulic/mechanical jacking system positioned under the assembly on the liner floor. The upper assembly would then be staged over the lower assembly, fit for welding the horizontal welds. Upon completion of the horizontal welds, the leak detection system channel would be welded for this section and capped for pressurization. The vertical stiffeners from the lower half to the upper half would be connected mechanically. The assembled sections would then be rigged from the existing 20-ton monorail and lowered into position. This approach would not allow for the vertical welds to adjacent sections to have pressurized leak chases. The lower horizontal brace would have to be designed to allow for the adjacent sections to fit together. This could be achieved by utilizing a mechanical slip joint.

The second feasible approach would be to erect fully-assembled 20-foot depth sections and upright these sections within the canal area and lower into position. Depending upon the availability of 12-foot plate, whether manufactured or fabricated, could enhance this approach. This approach would require only five to six sections to be fabricated. This alternative would also preclude the use of mechanical connectors for vertical stiffeners as identified in the lower/upper half approach, but will require a more carefully planned rigging and staging plan. The vertical and horizontal welds of adjacent sections would not have fully pressurized leak detection, but this would apply for both approaches and therefore is not a discriminating factor.

The method of tile removal poses a cost impact to the project. The use of a special wire cutting process for tile and concrete removal has significant costs (refer to Section 5.7 for specifics). However, other mechanical means such as shot-crete, high pressure hydro-lasing, or chipping hammers may introduce additional radiological and waste issues. The wire cutting method provides for a reduction in exposure and will minimize potential for air-borne contamination.

Raytheon has investigated the use of qualified waterproofing and epoxy coating systems to provide an impermeable secondary concrete barrier. The cementitious waterproofing agent selected, example being XYPLEX and/or VANDEX, may impact an accelerated schedule based on the period of time required for curing prior to epoxy application systems. The epoxy coating system to be used for Option E alone may assure a qualified seal of the repaired/replaced concrete for an unanticipated leak of the stainless steel liner. The curing time to the cementitious water proofing is currently being evaluated. A mock-up with an adhesion test will be performed during product selection during preliminary design to verify that the selected product line will not increase any allowable air leakage for exposed surfaces during the confinement leak test. The epoxy coatings application will introduce the need for strict environmental controls to be maintained for temperature, humidity and cleanliness to ensure a quality product. Based on the HFBR Safety Analysis Report, the expected temperatures within the confinement area at the Equipment Level are expected to be:

- Winter - 72°F with 50% humidity
- Summer - 80°F with 50% maximum humidity

The installation of strip plates are designed for lateral support of the liner when filled with water. Option E requires two strip plates with an approximate length of 81′ or 162′ total. The current conceptual design for Option E shows a seal cap after partial removal of the existing stainless steel ledger angle. This cap may be required to be increased in thickness to provide additional radiological shielding to preclude gamma streaming and the introduction of an additional radiological source within the canal liner. The removal of the ledger angle to facilitate tile and grout removal increases the potential for airborne contamination. However, the use of standard tools with attached vacuums should preclude any concern during this activity.

The installation of any of the options does not require any new construction techniques. Welding activities will be qualified in accordance with governing codes. The use of specialty contractors is recommended for epoxy applications and for tile/grout and ledger angle removal. The use of an experienced subcontractor for epoxy application would ensure a quality final product, a familiarity with the product line to minimize waste and ensure proper handling of hazardous products.

The existing 20-ton cranes located within the equipment floor area will be required to be functionally tested to ensure operation during lifting activities. The existing 2-ton crane should be removed to allow for additional range in the westerly direction. Due to the potential for airborne contamination during tile/grout removal options, an alternate ventilation system will be required to be in place with the area tented off to preclude spread of potential contamination. The spent fuel canal line size restricts large crew sizes and multiple tasks occurring in parallel.

Option E can be fabricated with standard tolerances. However, prior to final assembly, the installation and plumbness of wall and strip plates are critical to assure proper fit-up.

Several groups of material, equipment and services will be required to be procured and/or rented. Section 5.7 of this report addresses the services and equipment to be obtained through rental or purchase agreements. Based on applications, material is to be procured and receipt inspected in accordance with approved engineering specification and Project Quality Assurance Program based on

its safety/quality applications. Arrangements will be in place to assure storage requirements, segregation of quality and non-quality materials, shelf-life and environmental controls for temperature, humidity, air quality and cleanliness.

5.4 Radiological Controls

5.4.1 General Considerations

To control gamma streaming, shielding will be incorporated into the liner design. Calculations performed during preliminary design will be used to develop a cost-effective configuration. In addition, calculations will be performed to determine integrated dose to epoxy coatings and other radiation sensitive materials.

A Health Protection Work Plan will be developed during preliminary and detailed design to detail specific protective measures and precautions needed to minimize radiation doses. The Work Plan will establish a Radiological Coordination Team composed of representatives from HFBR Health Physics, Safety and Environmental Protection, Reactor Division Engineering Group, and Raytheon. This team will be responsible for the implementation of the Health Protection Work Plan.

In order to determine levels of contamination resulting from tile removal, dose rates during construction, isotopic characterization and volume of radwaste generation, sampling of portions of the concrete wall and tile may be required prior to any dismantling and tile removal.

The following sections describe some of the controls that will be used during construction and incorporated into the individual Radiation Work Permits (RWPs).

5.4.2 Contamination Controls

Personnel contamination controls will be implemented by applying administrative and engineering controls which will be described in the Health Protection Work Plan. If daily worker dose is likely to exceed 20 mrem, Radiation Work Permits (RWPs) will be used to control access into the work areas. Depending on the magnitude of the collective dose, job-specific RWPs will be considered to control entry into contaminated or high dose rate working areas.

Isolation, contamination barriers and personnel decontamination equipment will be used to prevent the spread of radiological contamination. Working areas identified as contaminated areas will be physically isolated by sealing or taping the area with protective barriers or tents. When airborne contamination is identified, engineered systems (i.e., dedicated ventilation controls) will be provided. Airborne radioactivity resulting from tile removal will be controlled with local ventilation, which will be used in conjunction with portable High Efficiency Particulate Air (HEPA) filters. Segregation of equipment will be used to isolate contaminated tools and equipment from clean areas.

5.4.3 Radiological Monitoring

The Health Protection Work Plan will address monitoring requirements for tritium and other radionuclides. Routine monitoring of radiation levels will be performed to identify contaminated areas, airborne radioactivity levels and changes in radiation levels. To prevent the spread of contamination, radiation surveys will be conducted regularly to assess any changes in levels of contamination. In addition to radiation surveys, portable continuous air monitors (CAMs) or air samplers will be used as required to detect any changes in airborne radioactivity levels during construction.

Airborne radioactivity levels will be maintained at values less than one Derived Air Concentration (DAC), as listed in DOE Order 5480.11. Airborne radiation containing 1 DAC results in a committed effective dose equivalent of 100 mrem if inhaled continuously for one work week. Tritium cannot be detected using hand-held frisking equipment or external dosimeters, thus, use of bioassay will be required to determine worker dose. The Health Protection Work Plan will indicate when bioassays are required. HFBR administrative procedures require routine bioassays for personnel who are likely to receive intakes resulting in a committed dose equivalent of 100 mrem or more. The Health Protection Work Plan will include an assessment of the expected radiological levels to determine the frequency of bioassays and whole body counting.

5.4.4 Personnel Protective Equipment and Clothing

The use of protective equipment and clothing will be based on the expected contamination levels and in accordance with HFBR Administrative Procedures Manual, Section 8.3, "Protective Clothing and Frisking at the HFBR." Safety and Environmental Protection (S&EP) group will advise on appropriate protective clothing which would be suitable for the tile removal and liner installation. A protective clothing dress-out area will be selected near the canal area. Use of respiratory devices will be minimized by use of engineered features such as portable HEPA filters which would reduce particulate concentrations.

5.4.5 Radioactive Waste Disposal and Management

BNL's Waste Management and Safety and Environmental Protection groups, in coordination with Raytheon, will prescribe handling, processing, packaging, segregation and storage of radioactive waste and waste minimization guidelines and procedures. These procedures will follow requirements as outlined in BNL ES&H Standard 3.6.0, "Radioactive Waste Disposal, Decontamination and Storage" and HFBR RD Administrative Procedures Manual, Section 8.2, "Processing and Disposal of Radioactive Waste and Contaminated Laundry."

Procedures will be reviewed to assure that waste minimization considerations are incorporated into all construction activities.

5.5 Maintenance and Inspection

Periodic monitoring and maintenance of the stainless steel surface should be performed to preclude any build-up of algae/organic products. The stainless steel liner surfaces will be procured to a 2B finish to promote decontamination activities when required. The annular areas do not allow for easy access for inspections. Consideration will be given to installation of removable plugs at the top for borescope insertion. Periodic leak testing will be performed as described in Section 5.1.3

The maintenance and surveillance of plant instrument systems will be in accordance with current plant practices and based on manufacturers' recommendations, safety/quality level and expected usage. These periodic inspections will be recommended with BNL concurrence during preliminary design. Revisions to Plant Operating Procedures, plant data systems and technical specifications will be prepared by BNL and will be in place prior to turnover as part of the work package.

During fabrication and installation of the Liner System, all welds will be visually examined in accordance with governing codes to assure compliance. Stainless steel liner welds will be examined by liquid penetrant tests. In addition, inner liner welds will be vacuum tested in accordance with ASTM E 515, "Standard Test Method for Leaks Using Bubble Emission Techniques." Alternatively, welds backed by sealed channels can be tested using a helium leak test procedure.

Fabrication and installation activity will be procedurally controlled and documented. These procedures will assure compliance with design configuration, material selection, material storage, methods of installation, acceptance criteria and required hold points.

Waterproofing and/or coating activities will require witness-type inspections throughout surface preparation and coating applications. A qualified inspection team should be assigned during these activities. A preliminary adhesion test will be performed on a completed substrate or similar material to ensure satisfactory product selection.

The leak detection system, tritium detection and level monitoring will be inspected in two phases. The first phase will be standard inspection for subcomponents:

- Continuity, megger, and hi-pot for electrical components
- Phase verification and rotation for pumps, if required
- Process tubing to be pneumatically tested
- Instruments calibrated

Upon completion of the installation, an integrated system test will be developed and the systems verified as functional. The functional system check will verify system response (i.e., annunciation, alarms) to satisfy design parameters.

Piping systems which are modified will require in-service leak testing based on applicable codes. If hydrostatic testing is not practical, a non-destructive examination, such as liquid penetrant testing may be employed.

Upon completion of the spent fuel canal liner and associated systems, a hydrostatic test should be performed, This test will verify the integrity of the liner under operating conditions. A typical method would be to slowly raise the pool level and monitor sump and sealed channels during filing operations with an suitable hold time between levels.

5.6 Schedule Analysis

All options have been scheduled to provide a comparison for review and an idea of the range of the most viable alternates. The schedules are based on two distinct calendars: six (6) days a week/ten (10) hours per day and five (5) days a week/eight (8) hours per day. The schedules for all options and cases are found in Appendix C. The accelerated schedules are defined as satisfying a March 1998 completion date of construction activities; the non-accelerated cases have completion dates that extend to July/August 1998. Specific assumptions and constraints are as follows:

5.6.1 Schedule Assumptions

Scheduling assumptions and constraints common to all cases include the following:

- Spent fuel to be removed from the spent fuel canal liner to be removed by November 1, 1997.
- All remaining items within the spent fuel pool are removed within a week of spent fuel shipment.
- BNL and DOE issue authorization to proceed with Titles I and II, preliminary and final engineering, by May 19, 1997.
- Environmental assessment to be completed by DOE and BNL by August 15, 1997 to allow procurement of long lead time materials.
- BNL and DOE issue approval of Title I, Preliminary Design Report within two weeks of submittal; by August 15, 1997.
- Radiological conditions such as airborne or unidentified contamination issues requiring the use of respirators or other unanticipated measures have not been included within the schedule period.
- Training of personnel prior to work start has been conservatively estimated to be three days for security processing, radiological training and Environmental, Safety and Health issues.
- Based on current information, lay-down areas will be made available for equipment, tools, and fabrication areas adjacent to the canal liner on the equipment level. The 20-ton cranes will be available when needed to perform critical activities by the contractor. No major work conflicts exist which may interrupt canal liner installation.
- As required, inspections and reviews to be performed by third parties (i.e., Suffolk County representatives) with due notification, are supportive of progress during scheduled engineering and construction activities.
- The equipment level truck bay will be available for the access and egress of equipment and personnel.

- An area adjacent to the truck bay on the outside will be available for staging of canal liner sections and to house manual and non-manual personnel.
- The schedule has been developed anticipating no major concrete repair activities will be required upon inspection.

- The schedule bar charts are based on an integrated time-logic sequence. These activities are:

1. Title I - Preliminary Design Report preparation and approval,
2. Bulk material Procurement and receipt,
3. Spent Fuel removal from the canal,
4. Miscellaneous items from the canal removed with water removal and decontamination,
5. NEPA/Environmental approval, and
6. Detailed design is essentially completed and approved prior to initiating fabrication of the spent fuel canal liner.

- To minimize schedule impact, partial shipment of Type 304 stainless steel plate should be scheduled from selected vendors to support pre-fabrication activities and reduce schedule risk. Suppliers' schedules should be closely followed and verified. The remainder of the structural shapes are readily available in large linear feet and at this time do not appear to be the limiting factor.

5.6.2 Schedule Comparison

Appendix C also includes two schedules for Option E, accelerated and non-accelerated, which include BNL review for modifications.

5.6.3 Project Risk Analysis (Schedule)

A project risk analysis and simulation software will be used to assess the Option E schedule developed for the Impervious Liner for the HFBR spent fuel storage canal. The risk assessment will be performed during the review period of the conceptual design report.

5.6.4 Cost Analysis

Option E, the preferred installation, is the most expensive. A large contributing factor is the removal of tile and grout utilizing a specialty contractor. The direct costs associated with the double-stainless liners were significant and additional liner welding was required, but these costs (for Options A and B) did not offset cost associated with tile/grout removal and coatings selected for Option E. In addition, Option E required welding of leak chase channels, while Options A and B did not require

addition, Option E required welding of leak chase channels, while Options A and B did not require leak chase due to the dual stainless steel liners. However, there is a potential cost to BNL if the 7'-2" width dimension for Option A would require extensive modification or replacement of the existing fuel racks, seismic rack restraint, or would limit fuel storage capacity and fuel handling operation. The tangible value for these items was not available at the time of this report.

As previously stated in the report, Options C and D did not technically satisfy Suffolk County requirements and Option B also required tile and grout removal with double-liner fabrication and a significant reduction in width to 7'-3 1/4". Option E, although the most expensive, provides BNL with a very effective spent fuel canal liner.

5.7 Cost Estimates

5.7.1 Estimates for Option E

The capital cost estimate for the repair and modification of the canal has been prepared with costs based on April 1997 labor data as noted in Construction Wage Rates provided by BNL Contracts and Procurement Division (Davis-Bacon). These labor values were utilized to determine total labor cost for two (2) scheduled alternatives for the recommended Option E.

- Accelerated schedule to support a March 1998 construction completion based on an November 1, 1997 spent fuel shipment date completion, and
- A schedule which reflects the same spent fuel shipment date but allows for an extended completion date beyond the March 1998 target date. This estimate is based on a five (5) day a week, eight (8) hours per day.

The estimator's spreadsheets for these two Option E cases are provided in Appendix D. The methodology and basis of estimate are described in detail in Subsection 5.7.3. The level of detail provided is more representative of a preliminary design stage estimate. Key parameters are defined, materials takeoffs and supplier estimates are incorporated. Constructibility reviews and discussions with shops further add to the confidence level of the estimates.

5.7.2 Estimates for Other Options

Appendix D also includes cost estimates for Options A through D which were developed for purposes of comparison by identifying scope of work and materials associated with each option. Engineering provided material take-offs for each of these designs for pricing by established suppliers. These additional estimates further confirm the relative accuracy of the cost estimating performed for this report.

5.7.3 Estimating Methodology

The cost estimating methodology applied in the preparation of the capital cost for the refurbishment of the canal is an approach accepted industry wide. The project team has prepared an estimate that is much more accurate than a "typical" conceptual cost estimate.

The estimate(s) were prepared by working closely with engineering and construction personnel and in accordance with "ground rules" and format agreed upon with BNL. Cost estimates are classified according to their accuracy and the level of available information (e.g., engineering design approximately 10 percent complete). This is not a rough order of magnitude or factored estimate because more than just a few design parameters have been established. Major equipment and materials have been estimated and further design development should not affect (increase or substantially alter) the total estimated cost for any option or the alternate schedules evaluated.

All estimates are prepared consistent with Raytheon Corporate Procedures and are consistent with experience on DOE capital and maintenance projects.

The portion of the cost estimate for which Raytheon was responsible was broken out into the following categories:

1. Direct Construction Costs (material equipment and installation)
2. Indirect Construction Costs
3. Professional Services
4. Contingencies
5. Cost Estimate Exceptions

Descriptions of these categories are as follows:

5.7.3.1 Direct Construction Costs

Material and equipment which remain a permanent part of the plant after construction, and all craft labor installation costs required to install the permanent facilities, i.e., fuel canal liner and leak detection and recovery system.

For work performed by subcontract, it also includes the costs of contractor's indirects, overheads and profit.

a) Material and Equipment - Prices based on market pricing prevailing at the time of the estimate. Bulk materials quantities (i.e., concrete, steel, electrical cable) are based on take-offs from conceptual drawings, descriptions and application of estimating techniques to establish projected material quantities. Material and equipment costs were based on actual cost data obtained from vendors where available, as well as in-house cost data.

b) Installation Costs - Since rehabilitation/repair construction is generally labor-intensive, the estimate for construction was primarily a function of labor costs as opposed to material costs. Consequently there are a number of factors that must be adequately considered to prepare an accurate estimate of construction costs.

Factors which may be incorporated in the productivity rates by the estimator include the following:

A) Planning and Administrative
   1) Construction Plan and Status of Engineering
   2) Schedule Restraints and Considerations
   3) Security and Administrative Rules, Training
   4) Manpower Planning

B) Permits and Operations
   1) Obtaining Permits and Approvals (job orders, fire permit, Radiation Work Permit)
   2) Walkdowns and Punchlists and Considerations

C) Construction Conditions
   1) Access
   2) Congestion - Special consideration needs to be given to crew size required to perform a given repair operation and number of crews able to work in the canal at a given time.
   3) Material Handling - Special handling required for activated materials, including dust suppression.
   4) Tools and Equipment - Set-up required for concrete wire saw.
   5) Hand tools
   6) Cleaning
   7) Special Ventilation

D) Manpower
   1) Craftsman skills
   2) Union rules
   3) Craftsman Availability and Loading
   4) Supervision Skill and Knowledge
   5) Overtime - inefficiencies related to working O. T.

E) Safety
   1) Special Shielding Requirements
   2) Procedures for Construction Relating to ALARA
   3) Craftsmen Protection
      a) Training
      b) Protective clothing and breathing equipment (if required)
      c) Sign in and out
      d) Work time constraints
   4) Fatigue due to environmental conditions (heat stress, respiration) wear
   5) Rigorous cleaning requirements.

F) Specialty Contractors
Several of the estimates address specialty contractors, (i.e., wire cutting for tile/grout removal). Due to specialization of the task and limited suppliers, cost reductions could be realized in a competitive environment. This estimate was not afforded the time to pursue this competitive avenue.

Direct installation costs is the product of the installation workhours determined and the composite wage rate. The composite average hourly wage is the average hourly wage rate cost to the employer of all craft workers up to and including the general foreman engaged in the performance of a specific work item.

The wage rate for any given craft is composed of: the base wage rate, allowance for foreman's rate of pay, plus payroll taxes, fringe benefits, workers compensation and payroll insurance. The craft wage rates are utilized in the development of a composite craft (crew) mix for the construction activities in the direct labor portion of the estimate.

5.7.3.2 Indirect Construction Costs

Indirect construction costs are defined as all costs which cannot be associated with the specific facility or component of the permanent physical plant, i.e., canal subcontractors are responsible for their own indirect construction costs. These requirements include the following:

- Temporary Construction and Consumables
  - Temporary building, trailers, furnishings and equipment
  - Temporary Utilities (installation)
  - Temporary fences
  - Scaffolding
  - Clean-up
  - Material Handling and preservation
  - Consumable construction supplies
- Field Supervision
  - Contractor's support personnel (i.e., cost engineering, schedulers, material and warehouse supervisors, clerical and support personnel.
  - Field office operating expenses
- Construction Equipment Materials and Tools
  - All equipment and tools required for the completion of the direct hire construction, including transportation, rental or purchase coat and maintenance.

The current cost estimate has estimated the majority of tools and equipment to perform these tasks. Prior to completion of the Final Design Report these items will be reviewed and refined. BNL may have some of these tools/equipment available for use which could reduce project indirect costs.

5.7.3.3 Professional Services

A dollar amount, based on current government-approved overheads, G/A, etc., to provide services such as engineering, design, inspection and construction management.

5.7.3.4 Contingency

An allowance for contingencies is included to afford protection against changes in cost that may occur due to the following:

- Actual quantities differing from estimated quantities.
- Variances in design due to refinement or engineering progress
- Variances in pricing due to actual base prices and wages differing from those estimated.
- Actual craft/labor performance versus anticipated productivity.

The contingency allowance does not provide protection against those causes of cost changes that cannot be foreseen or assessed with any degree of certainty. These types of changes are sensitive to external influences, many of which are economic, political or sociological in nature. The cost impact of these scope changes must be added to the estimate if they occur. The contingency analysis does not address any of the following exogenous events:

1. New regulatory, environmental or safety requirements.
2. Change in concept (spent fuel in canal vs. removed)
3. New items not in original concept.
4. Site conditions other than assumed (security access).
5. Accidents, catastrophes.
6. Force Majeure.
7. New work rules (Union or Government).
8. Strikes - Abnormal (those that affect workweek or schedule). The cost of minor strikes experienced on most projects is "built-into" the direct cost of an estimate by the use of the reported workhour and cost data from completed projects.
9. Weather - abnormal.
10. Changes in workweek from that originally estimated.
11. Changes in schedule.
12. Rework and retrofitting backchargeable to others.

Raytheon uses two methods for calculation of contingency - manual and computerized - as outlined below:

1. Manual

   Each of the " Areas of Variance" is analyzed for both material and installation, and appropriate amounts of contingency are assigned to each individual category of cost, depending upon the estimator's judgement of risk for that item of cost. The total contingency amount is the sum of all the individual allowances.

2. Computerized

   Raytheon utilizes a computerized program to augment the manual approach described above. The estimator examines the elements of the estimate. He assesses the critical items in the estimate and establishes potential minimum and maximum values for each. He also expresses, for each critical item, a confidence level (expressed as a percentage, based on the validity of the information used in develcping the cost of that item) for the amount used in the estimate. These determinations are then fed into the computer, and the numerous possibilities are considered in a multitude of combinations. In effect, the computer constructs the project a thousand or more times, randomly selecting for each critical item values between the minimum and maximum values specified by the estimator. This methodology provides management with a statistical analysis giving:

   - Probability of overrunning the estimate.
   - Level of confidence in the estimate.
   - Ranking of the potential critical items.

This program provides a means of statistically measuring the uncertainties. Furthermore, the program permits the selection of an appropriate contingency amount and brings the chance of overrunning the estimate to an acceptable risk level. This methodology will be performed during the review period of the Conceptual Design Report. A manual analysis was performed for this conceptual design estimate.

5.7.3.5 Cost Estimate Exceptions

Activities which will be performed by the BNL staff have been noted and are not included within the cost estimate. Examples of BNL activities and support include:

a. Remove and ship spent fuel, spent control rod blades, and other irradiated material.

b. Temporary canal water storage facilities and/or canal water disposal.

c. Remove canal internal structures and appurtenances. Store those to be re-used and dispose of those to be replaced.

d. Draining, vacuuming, cleaning and decontaminating the canal.

e. Refilling the canal.

f. Alternation or replacement of affected canal internals and appurtenances.

g. Return those canal internals and appurtenances which were stored for re-use.

h. BNL project management and support.

i. Health Physics services for monitoring of personnel. They will perform radiological surveillance and required decontamination of equipment for release back to the contractor.

j. Support services such as security administration

k. Other support services such as operation of the hot laundry for the contractor.

l. Provide utility services such as water and electricity.

6.0 RISK ANALYSIS AND CONTINGENCY PLANS

6.0 RISK ANALYSIS AND CONTINGENCY PLANS

A preliminary risk analysis of the recommended Option E has been performed in order to identify and assess technical, environmental, installation and cost/schedule risk factors.

All the risk elements identified have mitigation measures and/or contingency plans that will reduce the likelihood and consequences of the risk elements. As noted in Section 5, mitigation measures and cost/schedules contingencies have been factored into the Conceptual Design Approach.

Table 6-1 presents the preliminary risk analysis. The overall conclusion is that the Liner System installation is considered to have a moderate to low risk. This conclusion is similar to that arrived at in the preconceptual design feasibility study (Ref. 11). The earlier risk was dominated by elements resulting from the possibility of having to install the liner assembly in sections while spent fuel remained in the pool. One third of the risk elements were the result of an approach requiring the use of watertight gates and drysuit divers.

The present approach has all fuel removed before work begins and therefore the current analyses shows that the greatest risk factor is the condition of the concrete and construction joints under or behind steel plates and tiles. The main risk is in terms of cost and schedule impact of extensive decontamination, concrete repair and/or engineering evaluations are found to be required. Overall the risk is considered to be low since the canal water chemistry has been well controlled.

One of the benefits of the alternatives evaluation described in Section 4.0, is that it identifies potential contingency plans. For example, if the existing concrete is found to be in extremely poor condition, then a variation of Option B with two steel liner plates, could be implemented.

The main risk issue for the Leak Detection and Recovery System is the chance that some leak collection channels do not drain completely. The impact of this is likely to be minor since it would be trapped in stainless steel channels and unavailable for leakage to the ground. Preventive measures will include a high percentage of shop welding, non-destructive examination and field inspection of slopes during installation.

The dominant environmental risk remains the transfer and storage of the tritiated canal water during the installation phase. The risk of minor spillage is considered to be moderate but mitigation measures such as spillways, pans, recirculation lines, procedures and surveillance training can be readily implemented.

As a contingency, if fuel removal from the canal is extensively delayed, (i.e., more than 6 months), then a watertight temporary gate similar to the cofferdam used for spent fuel pool liner installation at Yankee Rowe Nuclear Power Plant can be employed. SK-A-11 (in Appendix B) shows a diagram of a typical keyway. Installing the keyway for the gate is the most critical part of this contingency approach. The temporary gate would be approximately 20 or 30 ft high and 8 ft wide. The keyway is secured to the wall and floor of the canal with anchor bolts and underwater epoxy grout. Inflatable seals are also installed around the canal gate to prevent leakage from the undrained portion of the canal. One concept for installation of a temporary gate is presented in SK-A-12 (in Appendix B).

The keyway has to be installed underwater by divers in dry suits with the spent fuel stored at the far ends (s) of the canal to reduce diver exposure to an acceptably low level. Underwater screens are needed to constrain the divers within a designated area since the water shielding is very distance-sensitive.

Table 6-1

HFBR Spent Fuel Storage Canal/Liner Installation
Preliminary Risk Analysis

Risk Factors or Hazards	Potential Impact/Likelihood	Mitigation and Control Measures
I. Technical		
1. Existing canal conditions worse than expected	Analysis testing and evaluation required/Low	Experience with engineering evaluations, alternate designs can be employed.
2. Leak Detection System Design	Channels do not drain properly/Moderate	Inspections, NDE, and other design features will mitigate as well as good water quality.
3. Seismic Design Considerations	Delay for reanalysis and fabrication of new supports, racks, etc./Low	All previous liners have been seismically designed. Rack design will be essentially the same.
II. Environmental Health & Safety		
1. No Action or Delay	Situation is not remedied. Potential for environmental damage due to canal leakage continues/Moderate.	Project is underway on an accelerated schedule. Regulatory and design bases are well understood.
2. Fuel Handling Incident	Same as normal operation/Low	Water level and lift restrictions, procedures, design and analysis.
3. Heavy Drop on Fuel	Multiple fuel failures/Low	Restrictions, interlocks procedures, and training.
4. Heavy Object Drop on Canal Area	Canal damage/Moderate	Lift procedures, fully supported bottom and special canal repair procedures.
5. Spill Tritiated Water Outside the Canal Area	Limited spill on equipment level floor or outside/Low	24 hour surveillance, H_2O test, spill pan, recirc. line and other provisions provided.
6. Worker Health and Safety	Worker receives dose above acceptable/Low Worker injured during work/Low	Rad protection procedures and safe work practices; full ALARA and OSHA reviews.
III. Installation		
1. Availability of Skilled Labor	Delay project/Low	Long Island and BNL situation is good.
2. Access and Laydown Area Restrictions	Schedule delay/Low	Plans will be reviewed by BNL and space made available. Modular construction will be employed.
3. Remote Welding needed at Section Connections	Cost/Schedule impact/Low	No new techniques required.

Table 6-1 (Cont'd)

Risk Factors or Hazards	Potential Impact/Likelihood	Mitigation and Control Measures
4. Higher Radiation Levels than anticipated or hot spots	Exposure of personnel, lower productivity/Low	Radiation levels will be defined by the shielding, distance and special shields will be employed as well as procedures and contingency plans.
5. Tile Removal Difficulties	Delay and additional waste produced/Moderate	Schedule allowance, extra shift work if needed, and Waste Minimization Program will be employed.
IV. Cost/Schedule		
1. Delay	Increased cost of project/Moderate	Work started on an accelerated schedule. Construction sequence will be optimized. Contingency plans being developed.
2. Additional Concrete repair required	Extra material cost and schedule impact/Moderate	Schedule contingency, extra shift works. Special repairs products to be evaluated during preliminary design.
3. Delayed Delivery of Liner Material	Liner material is on critical path/Moderate	Schedule allowance, premium payments, expediting, etc.
4. Material Quality	Rework required/Low	Vendor inspections, material certifications/NDE, etc.

7.0 DELIVERABLES DURING LATER TITLES

7.0 DELIVERABLES DURING LATER TITLES

This section describes the deliverables, including required analyses and evaluations planned for each of the major phases of work that follow Conceptual Design. The project objectives for each phase and a summary description of the engineering and construction activities related to the deliverables are also provided.

The activities planned for Titles I, II and III follow the requirements of Department of Energy Acquisition Regulation (DEAR), Part 936-Construction and Architect-Engineer Contracts (936.605).

7.1 Title I (Preliminary Design)

Definition: Architect-Engineer (A/E) services typically include management and integration of preliminary design activities such as: preparation of preliminary cost estimates and schedules for engineering and construction; finalization and documentation of design criteria; preparation of engineering studies and evaluations not completed during the conceptual design phase; regulatory support and preparation of the Title I design report, drawings, calculations, engineering specifications and bill of materials (as applicable to the project scope).

Objective: It is during the preliminary design phase that the Conceptual Design is translated (advanced) into baseline design documents. Preliminary plans covering canal, concrete repair, waste management, liner procurement, fabrication, assembly and installation are prepared.

A/E Services: At the outset of Title I, the project design requirements defined during Conceptual Design (Section 2.0) are updated to ensure proper integration of all technical requirements associated with the preferred design option and comments received during the conceptual design review process (April 7- May 5, 1997) are resolved.

Engineering/Design activities focus on concluding any engineering studies, cost-benefit analysis, trade studies, and other analyses required to *refine* the scope and cost issues for the preferred alternative. During this process potential cost-saving design approaches are developed and evaluated. This effort will focus on assuring quality and safety while achieving schedule and cost savings. In order to minimize changes during the final design phase interfaces and tie-ins to the existing HFBR systems are identified. Preliminary specification for instruments, equipment, annunciators, materials, tritium monitors, level instrumentation, sump ejector, pumps, valves and tubing are also prepared.

These early-on activities will baseline the selected option and will develop the key structural analyses and design calculation(s). Table 7-1 identifies the analyses and evaluations planned for Title I.

Upon completion of Title I, the cost estimate and schedule are updated and significantly more detail is presented. Raytheon will have a much firmer estimate of the cost and schedule of the work scope at this point.

Table 7-1

Evaluations and Analyses - Title I

I. Civil

1. Studies on the option of using cementitious waterproofing or epoxy coating, or both on the concrete surface treatment considering leak-tightness, radiation resistance, ease of decontamination, schedule, and cost.

2. Study to determine compatibility of cementitious waterproofing agent with epoxy coating system. Determine acceptable adhesion test parameters and optimum application. Independent mock-up may be required.

3. Concrete treatment studies: In order to utilize the most appropriate concrete treatments (i.e., repair, sealing and coating), Raytheon will implement the following actions:

    - For each possible type of surface treatment, evaluate the surface preparation requirements, the priming method and the application method;

    - For each possible type of surface treatment, evaluate the material compatibility between the surface treatment and the concrete and determine if there is an optimal treatment regime;

    - For each possible type of surface treatment, conclude a literature search to obtain information on current uses and/or applications of each treatment on similar projects;

    - If successive surface treatments are to be used, determine the compatibility between the successive treatments;

    - If successive surface treatments are to be used, establish the curing time for each treatment and optimize the application schedule for the successive treatments;

    - Prepare detailed specifications and procedures for each treatment and if successive treatments are to be used an overall treatment application specification and procedure; and

    - Evaluate alternatives for the removal methods for the existing tiles considering: ALARA, feasibility, disposal, cost and schedule.

4. Study on the oversized grooves vs. simple grooves for leak collection/detection.

5. Study weld types for liner plate, stiffener, and leak collection channel connections.

Table 7-1 (Cont'd)

6. Preliminary design analyses, including material trade-off studies to finalize types of material (for liner plates, stiffeners, and leak collection channels), thickness of liner plates, size and spacing for stiffeners/channels, etc.

7. Study to determine the best non-destructive examination techniques to be applied to the concrete walls/floors.

8. Mock-up of the canal to study the optimal design for the liner assembly modular construction.

9. Preliminary calculations to determine the following loads:

   - Seismic loads,
   - Hydrodynamic pressures
   - Racks and other attachments interface loads
   - Thermal loads
   - Fuel basket drop loads
   - Cask drop loads

10. Finite element analyses of the final design of the liner assembly.

11. Design calculations for anchorages, connections, penetrations and other local details.

II. Nuclear

1. ***Radiation Protection Plan*** - Establish requirements for radiological controls to minimize worker dose during tile removal and liner installation. The work plan will determine equipment needed to meet BNL radiological controls, DOE's requirements and Raytheon ALARA criteria, e.g., type of Continuous Air Monitors, Protective Clothing, instrumentation for monitoring and any additional equipment to meet guidelines.

2. ***ALARA Procedure and ALARA Checklist*** - Establish guidelines to regulate access, routine surveys, and any other steps to guide day to day operations. The ALARA checklist will outline the radiological requirements which shall be incorporated into the different phases of the design. Each deliverable will have a formal ALARA review done. The ALARA design features have to be incorporated during Title I.

3. ***Decontamination Procedure*** - Procedure to outline the way in which the waste will be disposed of and handled. The procedures will follow RD APM 8.2. These procedures will be needed before work initiation, preferably at the end of the preliminary design.

4. ***Low Level Waste Disposal Procedure*** - This will be done in conjunction with BNL input and their review and approval.

Table 7-1 (Cont'd)

5. ***Preliminary Supporting Calculations*** - To be completed during Title I.

- Energy fluence at the liner and concrete wall
- Thermal loads on liner due to gamma heating
- Integrated doses for qualification of material, components and equipment
- Gamma streaming calculation for air gap and penetrations
- Man-rem estimates and cost-benefit analyses

III. Mechanical/I&C

1. Sump Design
2. Pump Selection
3. Piping/Penetrant Analysis
4. Mock-up of Sealed Channels
5. Set-point Study

IV. Electrical/Corrosion

1. Grounding Study
2. Cathodic Protection Study
3. Protective Coatings Evaluation
4. Additional Materials Compatibility Studies

V. Construction

1. Constructibility Reviews of all design documents and plans
2. Construction Utilities Study
3. Mock-ups to support prefabrication and installation
4. Construction plan including subcontracting strategy, sequencing, logistics, training procurement, resource loading of schedules and cost estimates

VI. General

1. Requirements Document

7.2 Title II (Final Design)

Definition. These A/E services typically include preparation of final "approved for construction" detailed design drawings; vendor engineering interface; preparation of inquiry bid specifications and sketches; assistance in the evaluations of procurement and contract bids; preparation of definitive cost estimates and project schedule.

Objective. Complete all design activities necessary to develop Final Design Baseline.

A/E Services. Upon authorization to proceed with final design, work is focused on carrying forward the preliminary design into the detailed engineering phase. Major activities include the preparation of working drawings, specifications, bid documents, final cost estimates and schedule, and preparation of a Final Design Report. Early in Title II the engineering services will include assistance in evaluating the most productive, cost-effective, innovative and feasible construction methods to be utilized for every phase of construction and installation.

Drawings are completed early in Title II, allowing validation of assembly and installation plans. Material and construction specifications will be finalized with all necessary details for incorporation in bid specifications. Final dose assessment and ALARA reviews are conducted.

Temporary shielding is designed and analyzed, and personal protective equipment, dosimetry and air monitoring requirements will be specified as part of the Radiation Work Permits covering individual work packages.

All analyses listed in Table 7-1 are finalized as detailed vendor information is developed. The analyses will validate the design and confirm that all design and regulatory requirements have been satisfied.

At the conclusion of Title II a Final Design Report will be prepared to include all systems, equipment, and facilities modified for vessel removal and subsequent replacement/installation efforts. The report will include the final cost estimate reflecting the completed engineering activities and will be accompanied by the updated project schedule. All supporting documentation (calculations, studies drawings, etc.) will also be provided to BNL.

During this phase of the work, the construction manager's responsibility will also be expanded to finalize the procurement plans. He will also work closely with the scheduling, procurement and design staffs in finalizing the lead time requirements for equipment acquisition and finalization of subcontracting strategy and develop subcontract plan.

Construction Bid Packages will be developed for the procurement of material, construction, and services including the preparation of bidders lists, and development of request for proposals and contract forms. This will also include the review of technical specifications and drawings for completeness. Construction bid packages will also include requirements for radiation protection, industrial hygiene, shielding, containments and personal protective equipment.

The Waste Management Plan will include a complete strategy for the correct processing, packaging and certifying for transport and disposal of the various generated work materials, and will specifically address and set forth procedures which will guarantee the minimum amount of waste generated.

It will establish the physical, environmental, safety, health and quality assurance activities for planning and integrating, waste classifying, minimizing waste generation, packaging, and work minimization.

The A/E will review all work packages to minimize the generation of radioactive liquid, solid or mixed waste.

A preliminary startup/turnover plan and procedures for the operational and preoperational testing will be prepared.

7.3 Title III (Engineering Support of Construction) and Title IV (Construction Management Services)

Definition. Title III engineering services cover the post-Title II engineering and design activities which occur during construction to support the conversion of the final design into the as-built installation. These services include: inspection; preparation of as-built drawings; assurance of quality construction to design documents; resolution of construction problems as they arise; and preparation of estimates, schedules and prc[illegible] eports.

Objective. Title III/IV includes shop inspections and assisting construction in prompt resolution of any issues through the conclusion of construction testing and turnover.

The construction manager's responsibilities for this phase include: (H&S) assuring site safety; HP and RADPRO supervision; preparation of bid packages, review of bids, subcontractor oversight and inspection. The consolidation under a single management of these functions is an advantage in terms of schedule and cost.

During this phase, construction activities drive the overall project schedule. Accordingly, project administrative, cost/schedule control, procurement, constructibility review, start-up support and QA functions will transition from design to construction support. In other words, the same individuals who initially provided planning and design support services during Titles I and II now personally implement the planning they helped develop.

The " core" design team who were responsible for the detailed design will continue to be available to the project. Their responsibilities will include: engineering support to clarify and revise (if needed) the design documents; supervision of construction activities from an engineering compliance standpoint; ongoing engineering inspection and review of shop drawings; and, preparation of as-built drawings.

During Title III the responsibilities of the A/E will include inspection, QA construction monitoring services and safety monitoring (if requested). For Title IV these responsibilities would include: development of construction bid packages; bid evaluations and preparation of award

recommendations; management and administration of construction contracts; review of contractor schedules and monitoring of progress; interfacing with engineering and procurement to assure material and drawing availability; safety compliance and reporting; and change order management.

At the outset of Title IV, the Construction Manager will issue the following baselined and approved plans:

- Site Management
  - Construction Plan and Schedule
  - Manpower and Shiftwork Plan
  - Construction Techniques Plan
  - Subcontractor Scope, Strategy and Plan
- Procurement
  - Procurement Plan and Schedule
  - Subcontract Award Schedule
- Construction Management
  - Construction Procedures
  - Constructibility Review Plans
  - Construction Equipment Plan

Rigging and lifting of material will receive thorough up-front assessment and a great deal of engineering attention to establish the necessary technical parameters such as weights, rigging configuration and off-center constraints.

On-Site Facilities

- Services (i.e., welding, drilling)
- Hot Tool Room Inventory
- Decontamination - Personal Monitoring
- Crane Utilization (20-ton, 3-ton, 1-ton) with Current Maintenance
- Rigging Materials (i.e., slings, shackles)
- Laydown Areas (Outside/Inside Plant)
- Temporary Power and Lighting

Mobilization

- Access and Egress of Personnel
  - Security Issues
  - Health Physics
- Schedule and Resource Impact
- Training
  - Plant-Specific (General Education Training, Radiation Worker Training)
  - Raytheon Corporate Work Standards
    (1) Safety
    (2) Quality

    - (3) Productivity
  - Mock-Up Training
  - Foreign Material Exclusion
  - Employee Concerns Program
  - Ethics
- Office/Craft Trailers

Installation

- Schedule
  - Single/Multiple Shifts
  - Support Resources
- Modular and Pre-Fabrication Alternatives
  - On Site/Off Site
  - Limiting Factors
    - (1) Pool Size
    - (2) Limited Area to Access - Truck Bay
    - (3) Rigging
- Pool Preparation
  - Health Physics - Engineered Controls
    - (1) Ventilation
    - (2) Solid Waste Management
    - (3) Liquid Waste
    - (4) Storage
- Plant Clearances
  - Tag Outs
  - Temporary Modifications
  - Design Configuration Control
  - Non-Destructive Examination Techniques
    - (1) Visual
    - (2) Liquid Penetrant
    - (3) Vacuum Testing
  - Functional Testing
    - (1) Construction Testing (i.e., continuity checks, megger)
    - (2) Component/System Testing

- Demobilization
  - Restoration to Plant Configuration
  - Decontamination Tools/Equipment
  - Office/Craft Trailers
  - Tool Accountability
  - Cost Control & Contractual Close-out

The work area and surfaces will be kept clean and free of debris. Unnecessary material will be stored outside the work area and radioactive and non-radioactive materials will not be mixed. Wastes will be bagged immediately, as close to the work area as is feasible, and removed as soon as possible.

Trash will be stored in sealed heavy duty plastic bags. Unused tools will be removed or stored. Floors will be cleaned periodically. Dust/debris catchers will be utilized where appropriate. Systems will be drained prior to being cut an liquid spill prevention methods practiced.

A Training Plan will be developed. The plan will encompass worker training required by State, Federal and BNL regulations, as well as training required to conduct a safe and efficient project with radiation doses ALARA.

Training for specific work packages will be performed as required. Each work package will address unique work training requirements as well as the need for mock-ups or practice in "clean" areas. The emphasis on this training is to minimize radiation exposure and contamination.

High level of worker awareness and commitment to safety are the basic tenets of Raytheon's techniques. Involving the trades in productivity reviews, work planning and performance assessment also contributes to a strong sense of accountability. Routine pre-job briefings coupled with thorough training will be *the* significant contributors to achieving no unplanned or appreciable radiation doses to work crews.

8.0 SUMMARY AND RECOMMENDATIONS

8.0 SUMMARY AND RECOMMENDATIONS

This Conceptual Design Report has defined the applicable requirements, identified potential options for satisfying the requirements, evaluated five of the most promising options and developed a description of the recommended option, its installed cost and schedule, as well as uncertainties and contingencies. Technical issues, risk issues and trade studies for the later titles have also been identified.

A final version of this draft report is scheduled for May 5, 1997 and will respond to the comments, inputs and suggestions received during the next two weeks. This will support the DOE's 90 day commitment. Option E is the preferred approach. Options C and D may be feasible but have been eliminated from further consideration based on not satisfying Suffolk County requirements. Options A and B satisfy all technical requirements but have a significant operational impact due to reduced canal width.

Several key decisions and inputs will affect the recommendation in the final report. These include:

- The spent fuel shipping schedule
- The NEPA review schedule for this modification
- The funding profile
- Results of ongoing studies such as epoxy coating qualification, cementitious water proofing curing time, and corrosion studies
- Receipt of additional supplier and fabricator quotations and information
- Review by Suffolk County

Responses to comments and requests for additional information will be provided in an appendix to the Final Conceptual Design Report.

REFERENCES

REFERENCES

1. BNL-60252 (Informal Report), "Modified Floor Response Spectra for the Brookhaven National Laboratory High Flux Beam Reactor (HFBR)," by R. Morante and J. Skonieczny, dated March 1994.

2. US Atomic Energy Commission, TID-7024, "Nuclear Reactors and Earthquakes," by Lockheed Aircraft Corporation and Holmes & Narver, Inc., 1963.

3. ASCE, Journal of the Technical Councils, "Seismic Design of Liquid Storage Tank," 1981.

4. EPRI NP 5228-SL, "Seismic Verification of Nuclear Plant Equipment Anchorage, Guidelines on Tanks and Heat Exchanger," 1991.

5. BNL-52361, "Seismic Design and Evaluation Guidelines for the Department of Energy High Level Waste Storage Tanks and Appurtenances," by K. Bandyopadhyay, etc. dated January 1993.

6. DOE-STD-1020-94 "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities," by US Department of Energy, dated April 1994.

7. C. Czajkowski, J.R. Weeks and S.R. Protter (Brookhaven National Laboratory) "Corrosion of Structural and Poison Materials in Spent Fuel Storage Pools," International Corrosion Forum, April, 1981.

8. Ebasco Services Incorporated, "Water Chemistry Manual," Department of Energy Heavy Water Reactor Facility, HWRF-FPT-SP-002-R1, August 1992.

9. Ann Gibbs (Savannah River Site), Personal Communication, March 17, 1997.

10. J. P. Howell (Westinghouse Savannah River Company) "Durability of Aluminum-Clad Spent Fuels in Wet Basin Storage," NACE Corrosion/96, 1996.

11. Feasibility of Adding an Impervious Liner to the HFBR Spent Fuel Storage Canal, Raytheon HFBR-3-E.1 dated February 18, 1997.

APPENDICES

A. Scope of Work

ATTACHMENT 1

SCOPE OF WORK DESCRIPTION

CONCEPTUAL DESIGN OF AN IMPERVIOUS LINER FOR THE HFBR SPENT FUEL STORAGE CANAL

1.0 PURPOSE

1.1 To have Raytheon Engineers & Constructors (Raytheon) provide the necessary expertise to investigate various options for installing an impervious liner in the existing spent fuel storage canal (canal) of the BNL High Flux beam Reactor (HFBR) and to develop a conceptual design.

2.0 BACKGROUND

2.1 Recently, tritium concentrations, in excess of drinking water standards, were found in a sample taken from a groundwater monitoring well located in close proximity to the HFBR confinement building. While the source of the tritium has not yet been identified, the BNL Reactor Division is initiating the design of, and obtaining costs associated with, the installation of an impervious liner in the HFBR canal.

2.2 In 1993 the DOE commissioned a study of the storage of irradiated materials at all of its nuclear facilities. The report from this study, "Spent Fuel Working Group Report on Inventory and Storage of the Department's Spent Nuclear Fuel and Other Reactor Irradiated Nuclear Materials and Their Environmental, Safety and Health Vulnerabilities," did not identify a need for addition of a spent fuel pool liner and leak detection system for the HFBR. However, regardless of the outcome of the recently initiated investigation of tritium levels in groundwater samples, BNL is considering the addition of a liner as it would be useful for facilitating fuel canal cleanup activities, eliminate the potential for future problems from continued concrete sloughing and pool debris, and prevent the actual or potential leakage of water from the HFBR canal to the environment.

3.0 SCOPE OF WORK

3.1 This task assignment involves providing an initial assessment of various alternatives (materials of construction, method of attachment, installation processes, etc.) for the installation of an impervious liner in the HFBR canal; selection of a "most suitable" alternative based on factors such as material availability, constructability, and cost; and providing a conceptual design for this "most suitable" alternative.

3.2 Also to be included with the conceptual design are a preliminary cost estimate and projected schedule for the design, fabrication, and installation of the recommended alternative. The cost estimate and schedule shall consider the case of having all remaining spent fuel present (see paragraph 5.7.1) and also having all remaining spent fuel absent.

3.3 Included in the scope of this task is the determination of a "pre-conceptual" cost estimate and schedule for the design, fabrication, and installation of the liner system. This "pre-conceptual" cost estimate and schedule shall be prepared and submitted at time agreed to by the BNL Reactor Division and Raytheon during the initial stages of conceptual design, and shall consider the design, fabrication and installation work as being performed on an "accelerated" basis. Both schedule cases, as described in paragraph 3.2 above, shall be presented.

4.0 REFERENCE DOCUMENTS

In order to facilitate the work to be performed via this Task Order, copies of the following reference documents will be provided.

4.1 Drawings

4.1.1 General Canal Layout and Construction

(a) ME-107-372-5G, "HFBR Canal Layout," dated 12/12/96.

(b) D4653-101-8, "Architectural Plan-Equipment Level," dated 08/23/91.

(c) D4653-105-8, "Architectural Cross Section (North-South)," dated 06/17/88.

(d) D4653-106-6, "Architectural Cross Section (East-West)," dated 12/12/62.

(e) E4653-121-5, "Core Structure Foundation Plan," dated 02/12/62.

(f) E4653-121A-4, "Core Structure Foundation - Bottom Reinforcement," dated 12/22/61.

(g) E4653-121B-5, "Core Structure Foundation - Top Reinforcing, Sections and Details," dated 02/12/62.

(h) E4653-121C-5, "Core Structure Foundation - Sections and Details," dated 02/12/62.

(i) E4653-121D-6, "Pits for Passenger Elevator and Tank FA-101," dated 03/25/65.

(j) E4653-174-5, "Canal Bridge, Platform, and Gamma Facility Cover," dated 01/19/62.

(k) D4653-100A-3, "Boring Log Data," dated 08/24/61.

4.1.2 Shipping Cask/Canal Strike Plate Assembly

(a) HFBR-M-135-5A, "HFBR Canal Strike Plate Assembly," dated 09/26/83.

4.1.3 Canal Circulating Water Piping

(a) E4653-301-15, "Plan, Piping - Equipment Level Filters and Water Purification Area," dated 06/27/89.

(b) E4653-303-21, "Plan, Piping - Equipment Level Shutdown and Thermal Shield Area," dated 07/22/92.

(c) E4653-322-19, "Sections, Piping - Equipment Level, Sheet 2 of 2," dated 06/12/92.

4.1.4 **Canal Water Level Instrumentation**

(a) HR32-132-01-3D, "Canal Level Channel, LA 307," dated 05/13/96.

4.2 Design Basis Earthquake

4.2.1 BNL-26019 (Informal Report), "Determination of Floor Response Spectra for the Brookhaven HFBR Reactor Building Structure," by M. Subudhi and H. Goradia dated November 1978.

4.2.2 BNL-60252 (Informal Report), "Modified Floor Response Spectra for the Brookhaven National Laboratory High Flux Beam Reactor (HFBR)," by R. Morante and J. Skonieczny, dated March 1994.

4.3 HFBR Descriptive Documents

4.3.1 **HFBR Plant Description Manual (PDM)**

(a) PDM-9.3, "Fuel Discharging, Rotation, and Discharging Procedures," Revision 5.

(b) PDM-10.1, "Principles of Canal Area Operating Procedures," Revision 6.

4.3.2 **HFBR Operating Procedures Manual (OPM)**

(a) OPM-2.3, "Fuel Handling and Storage Safety Rules and Limits," Revision 37 dated 09/18/96.

(b) OPM-3.11, "Corrective and Emergency Procedures During Fuel Discharging Operations," Revision 34 dated 03/06/92.

(c) OPM-10.1, "Canal Health Physics and General Safety Restrictions," Revision 35 dated 03/03/96.

(d) OPM-10.2, "Spent Fuel Handling Instructions," Revision 35 dated 03/03/96.

(e) OPM-10.3, "Canal Abnormal Conditions Procedures," Revision 30 dated 02/22/83.

(f) OPM-10.4, "Canal Water System Operating Procedures," Revision 30 dated 02/22/83.

4.4 Other Documents

4.4.1 Design and Construction Specifications

(a) IA-S101-NY-4653 (Sec. 2), "Excavation and Backfill," Revision 5 dated 04/25/61.

(b) IA-S101-NY-4653 (Sec. 4), "Concrete Work," Revision 5 dated 10/24/61.

(c) IA-S101-NY-4653 (Sec. 12), "Tiling," Revision 5 dated 10/24/61.

(d) IA-S101-NY-4653 (Sec. 13), "Waterproofing, Dampproofing and Caulking," Revision 2 dated 08/24/61.

5.0 TECHNICAL REQUIREMENTS

5.1 General

5.1.1 Work to be performed under this Task Order shall be performed in accordance with the requirements of specification HFBR-9203, "HFBR Technical Support," Revision 1 dated January 1996.

5.1.2 Alternatives Evaluation and Conceptual Design

(a) Several different alternatives for an impervious liner for the HFBR are to be investigated as part of this Task Order. These alternatives shall be sufficiently different in characteristics such as, but not necessarily limited to, materials of construction, methods of installation, and cost so as to offer reasonable choice in selecting the "most suitable" option after considering all of the requirements for the HFBR canal. At least two alternatives shall be provided with the relative assets and liabilities for each and the selection of the "most suitable" option identified and justified.

(b) The "most suitable" alternative shall be conceptually designed with sufficient detail to permit the concept to be presented to personnel outside of the BNL Reactor Division and to facilitate, as part of a future phase of the project, progressing to final design and detailing with limited work by BNL.

(c) It is intended that the existing canal concrete walls and floors serve as a secondary containment boundary for the proposed liner system. The conceptual design shall include provisions for the treatment of the existing canal concrete walls and floors, if necessary, to permit them to fulfill this function. Should treatment of the existing concrete be considered not necessary, suitable justification for this conclusion shall be included in the final report.

5.1.3 The canal liner system shall be conceptually designed in accordance with the requirements of DOE Order 5480.30, "Nuclear Reactor Safety Design Criteria," dated January 19, 1993. Portions of DOE Order 6430.1A, "General Design Criteria," dated April 6, 1989 and ANSI/ANS-57.2-1983, "Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants," may be utilized for additional guidance.

5.2 Canal Construction

5.2.1 The HFBR spent fuel storage canal is located on the Equipment Level (elev. 93 ft-0 in.) of the HFBR Confinement Building. It is nominally 43 feet long by 8 feet wide and 20 feet deep except at the western-most end (called the "deep pit") where the depth is increased to 30 feet under the fuel discharge chute. A small bay (8 feet wide by 10 feet long) is located on the north side of the canal to provide space for fuel cutting operations and, if necessary, additional spent fuel storage. The canal holds 68,000 gallons of water. The deep pit is normally covered with a grating assembly making the working depth 20 feet throughout the canal.

5.2.2 The canal is constructed of three (3) foot thick reinforced concrete bottoms and sides integral with the five (5) foot thick Equipment Level floor slab. the sides of the canal are lined with 3/8-inch thick ceramic glazed tile atop a 1-1/8-inch thick concrete setting bed and the bottom with a 1-inch thick layer of hard finished concrete. The top edges of the canal are fitted with a continuous 6 x 6 inch stainless steel angle. The bottom of the canal, except for the deep pit, is covered with loose AISI type 347 stainless steel plates of ¼ inch thickness. These stainless steel plates were added to provide a wear surface and protect the pool floor concrete from further deterioration from interaction with deionized water.

5.2.3 Concrete used for the construction of the canal walls and sides was proportioned so as to have a minimum compressive strength at twenty-eight (28) days of 3600 psi. (Normal weight concrete proportioned in accordance with Method 2 of ACI 318-63.) Test cylinders, taken at the time of concrete placement, were obtained for all concrete pours and the results showed the strength actually obtained was "well above" the specified minimum compressive strength.

5.2.4 Reinforcing used in the concrete was deformed bars conforming to ASTM A432. This steel has a minimum yield point of 60 ksi and a minimum tensile strength of 90 ksi.

5.2.5 The HFBR confinement building is founded on a soil consisting mainly of sandy material with localized traces of clay and gravel. Lenses of various thickness exist to depths at least as great as the deepest test boring. (See drawing D4653-100A, Reference 4.1.1(k).) There is no uniformity of grain size distribution or density in the soil beneath the building. In design calculations, a conservative value of 75 psi/inch was used for the soil modulus and 35° was used as the angle of repose. The maximum soil loading for this type of soil is 6,000 psf with settlements in the range of .5 to .75 inch. Design calculations showed the soil pressure under the core structure foundation mat to be 4000 psf.

5.2.6 Construction details for the canal are shown on the drawings identified as References 4.1.1(a) through 4.1.1(j).

5.3 Design Loads and Load Combinations

5.3.1 The HFBR canal liner system, and appurtenances, shall be designed to resist the effects of all applicable design loads. Loads, except as defined within this document, and load combinations shall be obtained from ASCE 7-93, "Minimum Design Loads for Buildings and Other Structures."

5.3.2 Dead Loads

(a) Dead loads shall consist of the weight of the canal liner system and all permanently attached fixtures, braces, and appurtenances.

5.3.3 Live Loads

(a) Live loads shall consist of all those loads associated with the use of the spent fuel storage canal. The loads resulting from all of the equipment found in the canal, see drawing ME-107-372 (Ref. 4.1.1(a)), spent fuel, and fuel shipment (except cask drop) shall be considered as live loads.

(b) Dry weights for each of the structures present in the HFBR canal were recently determined as part of a different project and are provided on Table 5.3-1. All of the structures and equipment in the canal, including the stainless steel floor plates, is freestanding and moveable.

(c) Loads associated with the presence of water in the canal shall be considered a live load. Normal water level in the canal is at elevation 92'-0" with a maximum level at elevation 93'-0" and a minimum level at 90'-6". Water levels outside this range do not occur as a result of plant operating evolutions.

5.3.4 Seismic Loads

(a) The Design Basis Earthquake (DBE) for the HFBR confinement building structure is defined in BNL-26019 and BNL-60252 (References 4.2.1 and 4.2.2, respectively). For the purposes of design, the canal liner system shall be considered the equivalent of a Seismic Category I structure found in a commercial nuclear power plant.

5.3.5 Thermal Loads

(a) The design value for canal water temperature was 90°F for a heat load of 510,000 BTU/hr, at 40MW operation. With the increase to 60MW operation, the canal temperature was increased to 115°F with a heat load of only 2.8×10^5 BTU/hr primarily due to difficulties in maintaining the heat exchanger secondary side design flow rate and heat exchanger fouling.

(b) The normal, or typical, operating range for the canal circulating water system is 86 to 122°F (30 to 50°C) as measured at the heat exchanger outlet. The system operational flow rate is 100gpm.

(c) Should all canal circulating water capability be lost, canal water could reach 250°F. This corresponds to the boiling point at the maximum depth of 30 feet.

5.3.6 Cask Drop

(a) The eastern-most portion of the canal must be capable of withstanding the effects of a postulated cask drop accident as this is an event associated with spent fuel shipping activities. The area of concern is identified as the "Shipping Cask Loading Area" on Drawing ME-107-372 (Ref. 4.1.1(a)).

(b) This portion of the canal liner shall be capable of withstanding the effects of a 25,000 pound cask dropped from a height of 25 feet above the existing canal strike plate or 28 ft-9 in. above the canal bottom. The canal strike plate assembly is depicted on drawing HFBR-M-135 (Ref. 4.1.2(a)).

(c) Mitigation of the cask drop can be through reuse of the existing canal strike plate, modified to accommodate a revised canal width as a result of liner installation, or the liner can have design features which allow it to satisfactorily mitigate the effects of the cask drop without the use of the strike plate assembly. (Redesign of the strike plate assembly is not included in the scope of this task.)

5.4 Leak Detection

5.4.1 The proposed canal liner shall have provisions for detecting leakage into the area between the proposed liner and the existing canal concrete walls and floor. The conceptual design presented shall include data on this leakage detection system.

5.5 Canal Water Chemistry

5.5.1 Water chemistry parameters for the canal are listed below. (All values are typical or average values unless otherwise noted.)

(a) Specific Resistivity - 1 megaohm - cm (minimum).
(b) pH - 6.5 to 5.5
(c) Chlorides - less than 1 part per million (ppm).
(d) Aluminum - less than 5 parts per billion (ppb).
(e) Copper - less than 3 ppb.
(f) Iron - less than 1 ppb.

5.5.2 Typical valves for radionuclides present in canal circulating water are as follows (all valves are in microcuries/milliliter):

(a) Tritium - 1.2×10^{-1}

(b) Gross Alpha - 5×10^{-8}

(c) Gross Beta - 10×10^{-7}

(d) Gamma - 10×10^{-7} (Zinc-65)
6×10^{-5} (Chromium-51)
7×10^{-7} (Cobalt-60)

5.6 Radiation

Data on radiation levels to which equipment and structures in the canal are exposed will be provided.

5.7 Operating Restrictions

5.7.1 It is recognized that it may not be possible to ship all of the existing spent fuel elements in the canal offsite prior to actual installation of the proposed liner. Therefore, the conceptual design of the proposed liner shall include provisions for the use of a temporary watertight gate or dam to isolate portions of the canal into a wet section for continued fuel storage and dry section which is emptied of all racks and other structures to permit liner installation. Presently, there are 872 spent fuel elements in the canal. A shipment of an additional 210 elements is currently scheduled for the second quarter of 1997. The defective (leaking) fuel element currently stored in the canal will be part of this shipment.

5.7.2 Operating restrictions associated with spent fuel storage are summarized in the following paragraphs:

(a) The water level in the canal shall be maintained at a level sufficient to keep the fueled portion of all spent fuel elements submerged beneath at least ten (10) feet of water. In addition, there is an administrative limit for canal water level to be not more than thirty (30) inches below the top of the canal wall. (The ten foot water level limit does apply to fuel being moved in the canal as an administrative limit.)

(b) Not more than five spent fuel elements shall be stored outside of critically safe containers.

(c) Existing canal water level instrumentation provides both high and low water level alarms in the HFBR control room. This alarm capability shall be maintained whenever spent fuel elements are present in the canal.

(d) No spent fuel elements shall be placed or stored cioser to the tile or concrete surfaces of the canal than the equivalent of twelve (12) inches of water.

(e) All four (4) and six (6) cell movable boron stainless steel storage baskets containing cut spent fuel elements shall be stored in racks which maintain the required minimum spacing. The twenty-one (21) and forty-nine (49) cell stationary boron stainless steel storage bins shall not be lifted or moved while they contain spent fuel.

(f) Heavy objects shall not be moved or suspended over fuel storage racks or any portion of the canal floor that is not protected by the canal strike plate assembly. When placed in the canal, they shall be kept in the strike plate assembly located at the east end of the canal. Heavy objects are defined as any object that is heavier than a six element moveable basket filled with cut fuel elements. During liner construction, should it be necessary to move heavy objects over stored spent fuel, protective measures shall be required and subject to approval by BNL.

(g) No items of appreciable mass are to be stored along the canal edges unless such items are secured in such a manner as to prevent them from inadvertently falling into the canal and striking stored fuel elements. Any equipment extraneous to procedural operations or liner installation shall not be suspended over the canal spent fuel and storage racks.

5.7.3 The temporary dam or gate shall also include provisions for additional shielding so that personnel working on the dry side of the dam or gate receive protection equivalent to having a minimum of ten (10) feet of water separating them from any stored spent fuel.

5.8 Canal Circulating Water System

5.8.1 The existing suction and return piping for the canal circulating water system are shown on drawings E4653-301, -303, and -322 [References 4.1.3(a), 4.1.3(b), and 4.1.3(e)]. The proposed canal liner shall be conceptually designed so as to properly interface with this piping.

5.9 Canal Water Level Instrumentation

5.9.1 Details on the existing canal water level instrumentation are provided on drawing HR32-132-01 (Ref. 4.1.4(a)). Should the conceptual design presented require the retention of damming of portions of the canal, the final report shall also contain provisions for keeping this instrumentation, or some sort of temporary replacement system, operable in that portion of the canal in which the spent fuel is located. Additionally, the proposed canal liner shall be conceptually designed so as to properly interface with this instrumentation or BNL approved replacement instrumentation.

5.10 Laydown Areas and Building Access

5.10.1 Building access for material and equipment to be used in the installation of the canal liner system will be through the East Truck Lock as shown on drawing D4653-101. Data on the truck lock, such as ceiling heights, door sizes and swing limits, crane/hoist capacities and travel limits, etc., will be provided to Raytheon.

5.10.2 Space available within the HFBR confinement building for equipment and material laydown during installation of the liner system is very limited. Only the area immediately south of the canal, in the vicinity of the East Truck Lock, can be practically used. (See drawing D4653-101, Ref. 4.1.1(b).) Use of this space is also restricted by the need to provide vehicle access to/from the truck lock. For the purposes of preparing an estimate it is anticipated that the existing parking area on the south east side of the HFBR confinement will be available for equipment and material laydown to support efforts associated with canal liner installation. Data on parking lot size, access points, etc. will be provided.

5.11 Codes and Standards

5.11.1 The conceptual design for the proposed liner shall include discussion of the specific codes and standards recommended for the design, fabrication, installation, and testing of the HFBR canal liner and leak detection system.

6.0 DOCUMENTATION AND REPORTS

6.1 Upon issuance of a Task Order by the BNL Division of Contracts and Procurement (DCP) for the scope of work contained herein, Raytheon shall submit a milestone schedule for the completion of the task. This schedule shall contain an allotted time period for the review of the draft report described below and give approximate dates for any interface meetings with BNL personnel that may be required.

6.2 The results of all work associated with this Task Order shall be submitted to BNL in report format. This report shall describe the conceptual design process and results in sufficiently detailed narrative so as to permit presentation to personnel outside the BNL Reactor Division and also include, as attachments or appendices, all drawings, sketches, or diagrams necessary to adequately depict the proposed design.

6.3 Two (2) draft copies of the report shall be submitted for BNL review. A minimum of two weeks (10 working days) shall be allotted for the BNL review. All comments resulting from the review shall be resolved prior to the submittal of the final report.

6.4 Twenty (20) copies of each complete (final) report, with all attachments and appendices, shall be required at the completion of the work. In addition to these 20 copies, an additional copy of all drawings, sketches, or diagrams shall be provided on floppy diskette (3-1/2 inch) in such format as to permit their use with AUTOCAD Release 12. The floppy diskette shall also include any custom font, linetype, external references, or similar feature used on the drawings, sketches, or diagrams which are not part of the standard AUTOCAD package.

6.5 With the submittal of the final report the conceptual design including any associated drawings, sketches, diagrams, and analyses, becomes the property of BNL. Raytheon shall not place any restrictions, explicit or implied, on the use of the conceptual design, or any portion thereof in any future phase of this project or the operation, maintenance, or modification of the HFBR.

7.0 KEY PERSONNEL

7.1 BNL Contract

The BNL Reactor Division coordinator for this effort is:

Thomas F. Joos, Project Engineer
Brookhaven National Laboratory
81 Cornell Ave. - Bldg. 120
P.O. Box 5000
Upton, New York 11973-5000
Telephone - (516) 344-7707
FAX - (516) 344-2619
e-mail - joos@zodiac.nov.hfbr.bnl.gov

7.2 Raytheon Contact

The principal contact at Raytheon Engineers and Constructors is:

Joseph Costello
Raytheon Engineers and Constructors
2 World Trade Center, 89th Floor
New York, NY 10048-0752
Telephone - (212) 839-2632
FAX - (212) 839-3316

7.3 Other key or lead personnel shall be identified in the Raytheon proposal and are subject to BNL approval. The proposal shall include resumes or experience summaries for all key or lead personnel identified in the proposal.

8.0 ALLOTTED DURATION

8.1 The allotted duration for the work described in this document shall be four (4) months.

TABLE 5.3-1

Weights of Structures in the Spent Fuel Storage Canal

Structure/Component	Drawing	Quantity	Weight Each (lbs)
1) Spent Fuel Element (Uncut)	N/A	Varies	13
2) Spent Fuel Element (Cut)	N/A	Varies	10
3) Main Control Rod Blade (Stored Portion)	N/A	Varies	27
4) Auxiliary Control Rod Blade (Stored Portion)	N/A	Varies	14
5) 6 Cell Deep Pit Spent Fuel Storage Basket	HFBR-M-194	27	50
6) Deep Pit Storage Rack	HFBR-M-196	1	170
7) Deep Pit Seismic Restraint (w/control rod storage fixture)	HFBR-M-196 & 454	1	300
8) Defective Fuel Element Storage Rack	BR65-0202-4	1	910
9) Defective Fuel Element Storage Can	BR65-0202-3	4	40
10) Heavy Cover	N/A	1	1250
11) Heavy Cover Support Structure	6977-S4, -S5 & -S7	1	500
12) Uncut Element Rack Guard	ME-107-286	1	140
13) 30 Cell Uncut Fuel Element Storage Rack	ME-107-285	1	2650
14) Canal Wall Shield	HFBR-M-388	1	185
15) 49 Cell Fuel Storage Basket	HR30-004-01	3	320
16) 49 Cell Basket Storage Rack	HFBR-M-749 & 750	1	380

TABLE 5.3-1

Weights of Structures in the Spent Fuel Storage Canal

17)	4 Cell Fuel Storage Basket	HFBR-M-138 or -193	56	34
18)	6 Cell Fuel Storage Basket	HFBR-M-137 or -192	28	48
19)	21 Cell Fuel Storage Basket	74702-01-15	21	143
20)	Long Term Fuel Storage Rack	BR62-0101-0	7	140
21)	Canal Strike Plate Assembly	HFBR-M-135	1	4580
22)	Fuel Cut Off Saw	**(LATER)**	1	1000
23)	Retard Chute	ME-107-345	1	640

ATTACHMENT I

CHANGES TO TECHNICAL REQUIREMENTS AND SCHEDULE

A. Add the following new references to paragraph 4.1.1.

(e) E4653-55B-14, "Electrical Power - Equipment Level, in Floor Slab," dated 07/24/96.

(f) E4653-56B, "Electrical Power - Details, Sheet 2 of 5," dated 07/24/96.

B. Add new paragraphs 4.1.4 and 4.1.5 as follows:

4.1.4 Heavy Cover, Heavy Cover Support Structure and Alarm

(a) 6977-S1, "Heavy Cover - General Arrangement Plan and Elevations," Revision 1 dated September 2, 1987.

(b) 6977-S2, "Heavy Cover - Plan, Sections," Revision 1 dated September 2, 1987.

(c) 6977-S3, "Heavy Cover - Plan, Section, Detail," Revision 1 dated September 2, 1987.

(d) 6977-S4, "Heavy Cover Support - Plan, Section and Detail," Revision 1 dated September 2, 1987.

(e) 6977-S5, "Heavy Cover Support - Section, Details, and Bill of Material," Revision 1 dated September 2, 1987.

(f) 6977-S6, "Heavy Cover Panels - Plans, Details," Revision 1 dated September 2, 1997.

(g) 6977-S7, "Heavy Cover Support - Plan, Sections and Details," Revision 0 dated September 1, 1987.

(h) 6977A-S10, "Heavy Cover Alarm - General Arrangements," Revision 0 dated April 13, 1987.

(i) 6977A-S11, "Heavy Cover Alarm - General Arrangement Plan, Details and Sections," Revision 0 dated April 13, 1987.

(j) 6977A-S12, "Heavy Cover Alarm - Details, Views and Sections," Revision 0 dated April 13, 1987.

(k) 6977A-S13, "Heavy Cover Alarm - Details, Views and Sections," Revision 0 dated April 13, 1987.

(l) 6977A-S14, "Heavy Cover Alarm - Details, Views and Sections," Revision 0 dated April 13, 1987.

(m) 6977A-S15, "Heavy Cover Alarm - Section, Detail, General Notes and Bill of Material," Revision 0 dated April 13, 1987.

4.1.5 Spent Fuel Storage Racks

(a) BR62-0101-0-4C, "Spent Fuel Element Storage Cell," dated March 23, 1994.

(b) HFBR-M-350-4B, "Spent Fuel Storage Rack - Increased Capacity," March 23, 1994.

(c) HFBR-M-749-5A, "49 Element Basket Long Term Spent Fuel Storage Rack, Sheet 1 of 2," dated December 12, 1996.

(d) HFBR-M-750-5A, "49 Element Basket Long Term Spent Fuel Storage Rack, Sheet 2 of 2," dated December 12, 1996.

(e) HFBR-M-196-5D, "Spent Fuel Canal, Deep Pool Storage Racks," dated December 1995.

C. Change subsection 4.4, "Other Documents" to read "Other HFBR Documents."

D. Add new subsection 4.5 as follows:

4.5 **<u>Regulatory Documents</u>**

4.5.1 Department of Energy Orders/Standards

(a) DOE Order 5480.30, "Nuclear Reactor Safety Design Criteria," dated January 19, 1993.

(b) DOE Order 6430.1A, "General Design Criteria," dated April 6, 1989.

4.5.2 **Suffolk County Sanitary Code**

(a) "Agreement Between Brookhaven National Laboratory and County of Suffolk," dated September 23, 1987.

(b) Article 12, "Toxic and Hazardous Materials Storage and Handling Controls," as amended December 16, 1992.

4.5.3 **Other Standards**

(a) ANSI/ANS-57.2-1983, "Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants."

E. Delete the existing paragraph 5.1.3 and replace it with a new paragraph 5.1.3 as follows:

5.1.3 The canal liner and leak detection system(s) shall be conceptually designed in accordance with the requirements of DOE Order 5480.30 [Reference 4.5.1(a)] and shall satisfy the intent of the technical requirements of Suffolk County Sanitary Code, Article 12 [Reference 4.5.2(b)] as delineated in the 1987 BNL - Suffolk County Agreement [Reference 4.5.2(a)]. Portions of DOE Order 6430.1A [Reference 4.5.1(b)] and ANSI/ANS-57.2-1983 [Reference 4.5.3(a)] may be utilized for additional guidance.

F. Following paragraph 5.1.3, add the following new paragraphs 5.1.4 and 5.1.5.

5.1.4 The canal liner a 1 leak detection system(s) shall be conceptually designed so as to properly interface with canal internal structures without requiring significant changes to current spent fuel handling, storage and shipping practices. Specifically, but not necessarily limited to, the following shall be considered in the development of the conceptual design:

(a) Interior free space in the liner canal shall not result in the loss of (nor require the reduction of) the interior free space within the Canal Strike Plate Assembly [Reference 4.1.2(a)] for shipping cask placement and reduction of the space(s) available for spent fuel element placement in Spent Fuel Storage Racks [References 4.1.5(a) through 4.1.5(e)]. (**Note:** It is recognized that the existing Canal Strike Plate Assembly and Spent Fuel storage Racks will require some modification or alteration as a result of the installation of the canal liner system. For the purpose of this task Order, the redesign of these structures is **not** within the scope of work.)

(b) Provisions shall be included to permit proper interfaces with the existing canal piping penetrations associated with the Canal Circulating Water System Piping [References 4.1.3(a) through 4.1.3(c)], electric power for the canal lighting [References 4.1.1(e) and 4.1.1(m)], and the Spent Fuel Transfer Chute [Reference 4.1.1(e)].

(c) The canal liner and leak detection systems shall not interfere with the capability of receiving a straight rigid assembly of 185 inches in length into the canal from the Spent Fuel Discharge Chute [Reference 4.1.1(e)] and recovering same from the canal deep pit.

(d) The capability of the existing Canal Bridge [Reference 4.1.1(j)] to travel the entire length of the canal shall not be impaired.

5.1.5 The design life of the canal liner and leakage detection system(s) shall be 30 years.

G. Change the last sentence of existing subparagraph 5.3.3(c) to read as follows:

Water levels outside this range do not occur as a result of plant operating evaluations except as described in subparagraph 5.3.3(d) below.

H. Following the existing subparagraph 5.3.3(c), add the following new subparagraph:

(d) As a result of ongoing Tritium Plume Remediation efforts, BNL is considering implementing a "bleed and feed" maintenance activity to reduce canal water tritium levels. It is anticipated that this may become a regular occurrence during the life of the canal liner system. Therefore, the effects of a water level lowering to elevation 84 ft-0 in. shall also be considered.

I. Delete the existing subparagraph 5.3.5(c) in its entirety and replace it with the following new subparagraph:

(c) Should all canal circulating water capability be lost, canal water could reach 250°F in close proximity to stored spent fuel elements. (This corresponds to the boiling point at the maximum canal depth of 30 feet.) However, due to the fact that only a small portion of the canal is at this maximum depth and that there is significant room in the canal between structures (which are primarily open-bottomed) to permit the natural circulation of spent fuel heated water, it is not anticipated that bulk canal water temperature would be increased above 212°F.

J. After the existing subparagraph 5.3.6(c), add the following new subparagraph:

(a) It may also be necessary to consider other heavy load drops in the conceptual design of the canal liner. Drop of the Heavy Cover [References 4.1.4(a) through 4.1.4(g)], either on to the Heavy Cover Support Structure or the canal bottom in the area reserved for Heavy Cover Laydown. [Reference 4.1.1(a)], should be considered. Also, the drop of a six-element spent fuel storage basket loaded with six (6) cutoff spent fuel elements from a height not greater than 10 feet below the normal canal water level should be considered.

K. Delete the existing subsection 6.3 and replace it with a new subsection as follows:

6.3 Raytheon shall provide a sufficient number of draft copies of the report for BNL and other agency review. It is anticipated that the number of copies required will be approximately twenty-five (25). A minimum of two (2) weeks (10 working days) shall be allotted for the BNL and other agency reviews. All comments resulting from the reviews shall be addressed prior to the submittal of the final report.

L. Delete the existing subsection 8.1 and replace it with the following new subsection:

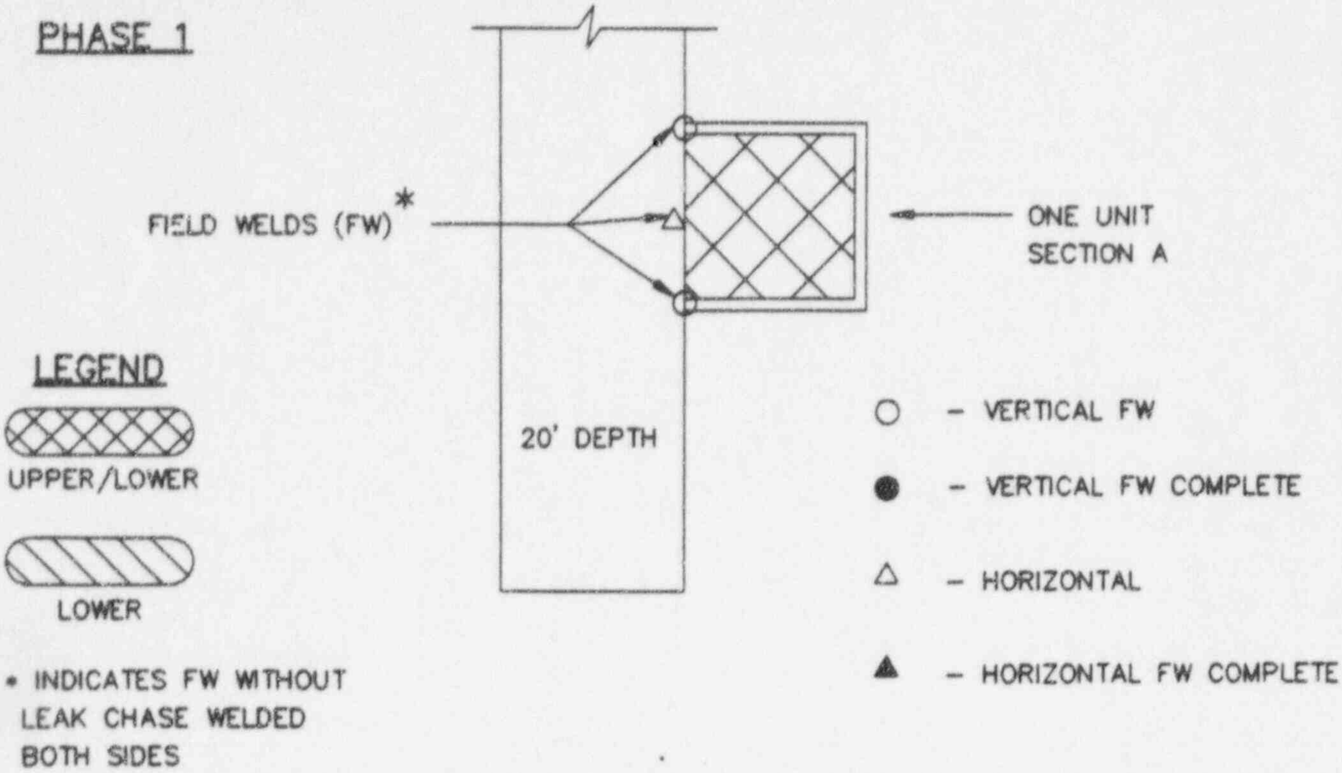
8.1 Allotted duration for this task shall be limited by the following critical milestones:

(a) The draft Conceptual Design Report shall be delivered to BNL no later than April 4, 1997.

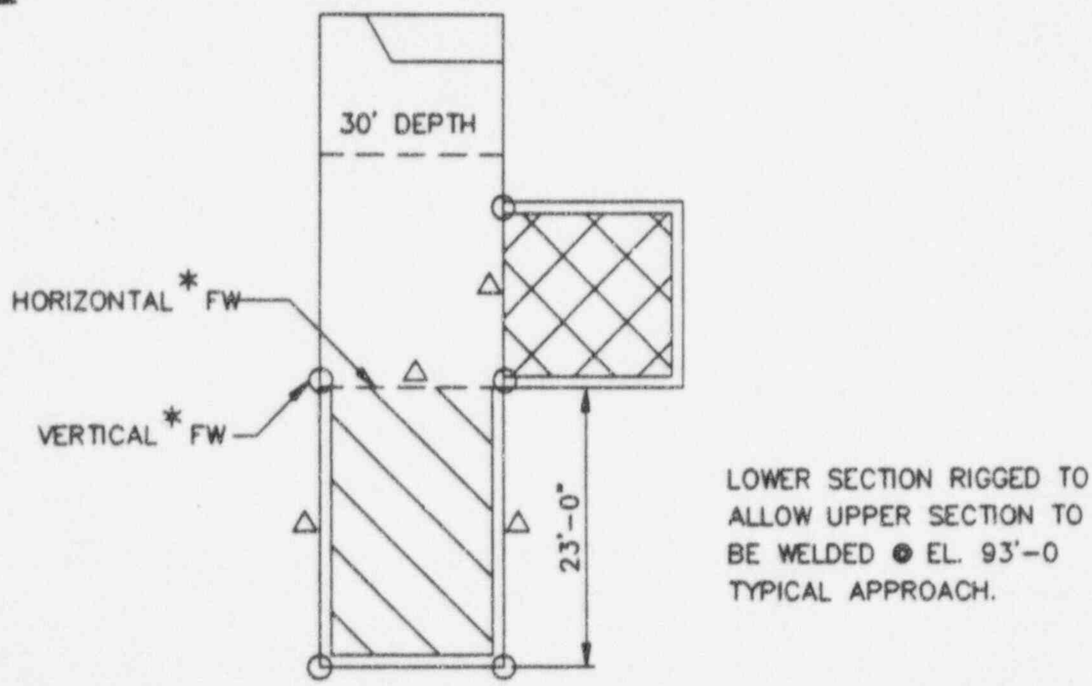
(b) The final Conceptual Design Report (after addressing all revision comments) shall be delivered to BNL no later than May 16, 1997.

B. Sketches

PHASE 1



PHASE 2

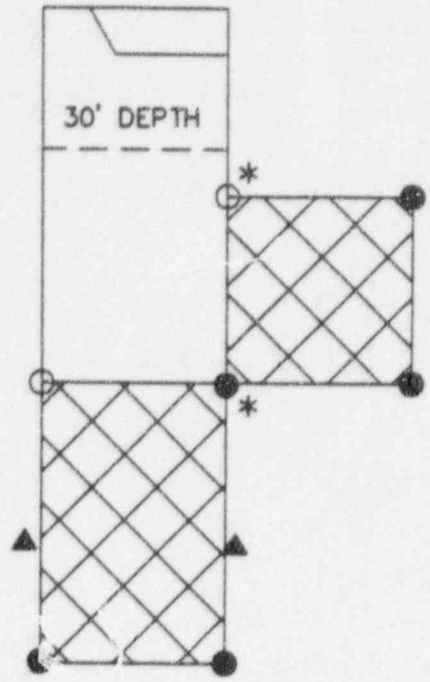


BROOKHAVEN NATIONAL LABORATORY
HIGH FLUX BEAM REACTOR
SPENT FUEL CANAL LINER
CONSTRUCTION SEQUENCE SH. 1

Raytheon ENGINEERS & CONSTRUCTORS

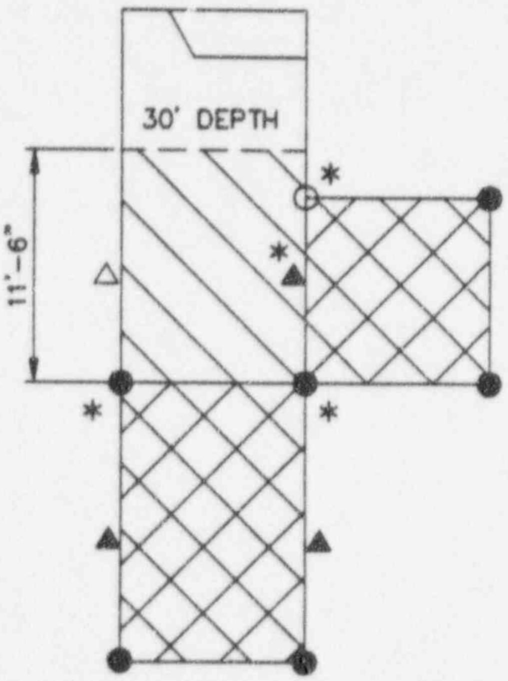
DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
S.M.G.	C. SHIH	03-31-97	AS NOTED	SK-A-08

PHASE 3



UPPER/LOWER SECTION
WELDED HORIZONTAL

PHASE 4

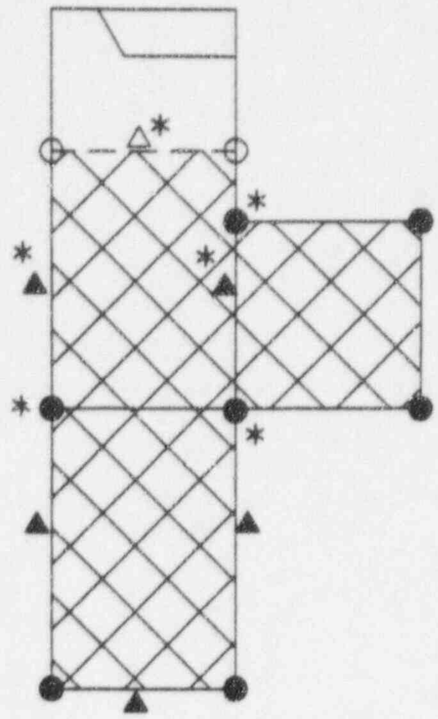


BROOKHAVEN NATIONAL LABORATORY
HIGH FLUX BEAM REACTOR
SPENT FUEL CANAL LINER
CONSTRUCTION SEQUENCE SH. 2

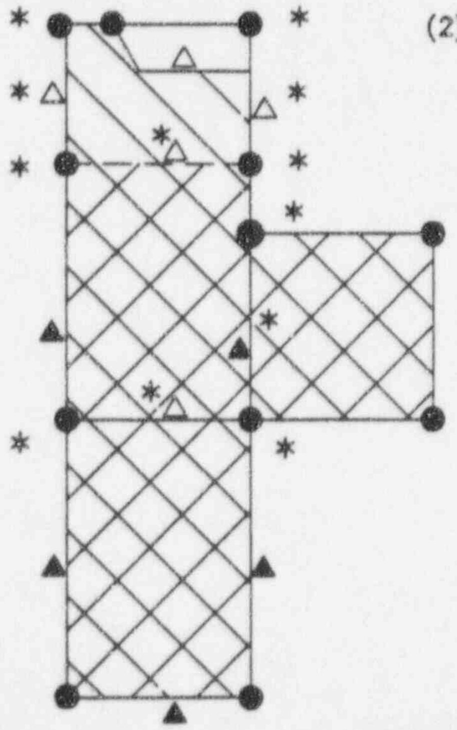
Raytheon ENGINEERS & CONSTRUCTORS

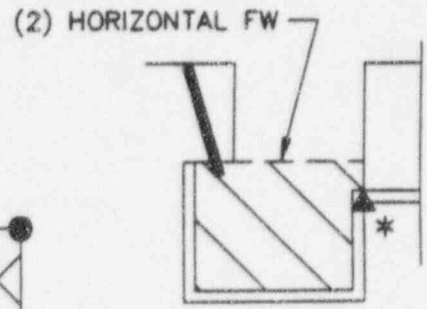
DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
S.M.G.	C. SHIH	03-31-97	AS NOTED	SK-A-09

PHASE 5



PHASE 6

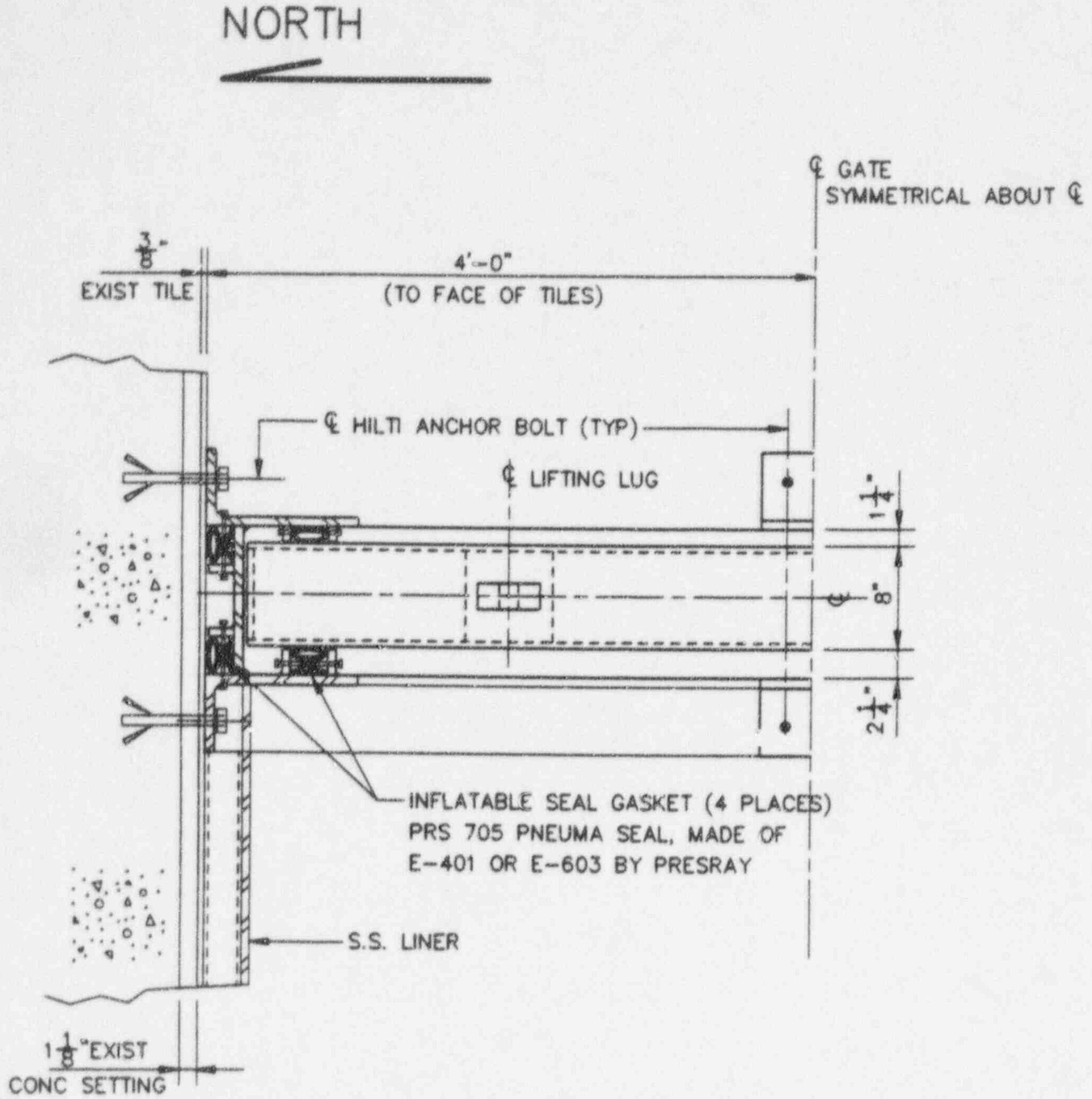




INSTALL LOWER SECTION OF
30 FT DEPTH SECTION

NOTE : PHASE 6 MAY BE FEASIBLE TO OCCUR AFTER PHASE 1 IF A 21 FT LENGTH COULD BE POSITIONED IN THE CANAL. CRITICAL MEASUREMENTS PRIOR TO FABRICATION TO ACCOMMODATE OVERHANG ARE NECESSARY.

BROOKHAVEN NATIONAL LABORATORY HIGH FLUX BEAM REACTOR SPENT FUEL CANAL LINER CONSTRUCTION SEQUENCE SH. 3				
Raytheon ENGINEERS & CONSTRUCTORS				
DRAWN: S.M.G.	CHKD: C. SHIH	DATE: 03-31-97	SCALE: AS NOTED	DWG NO. SK-A-10



TEMPORARY GATE PLAN VIEW

BROOKHAVEN NATIONAL LABORATORY
HIGH FLUX BEAM REACTOR
SPENT FUEL CANAL LINER
TEMPORARY GATE

Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
B.S.RANA	C. SHIH	04-01-97	1"=1'-0"	SK-A-11

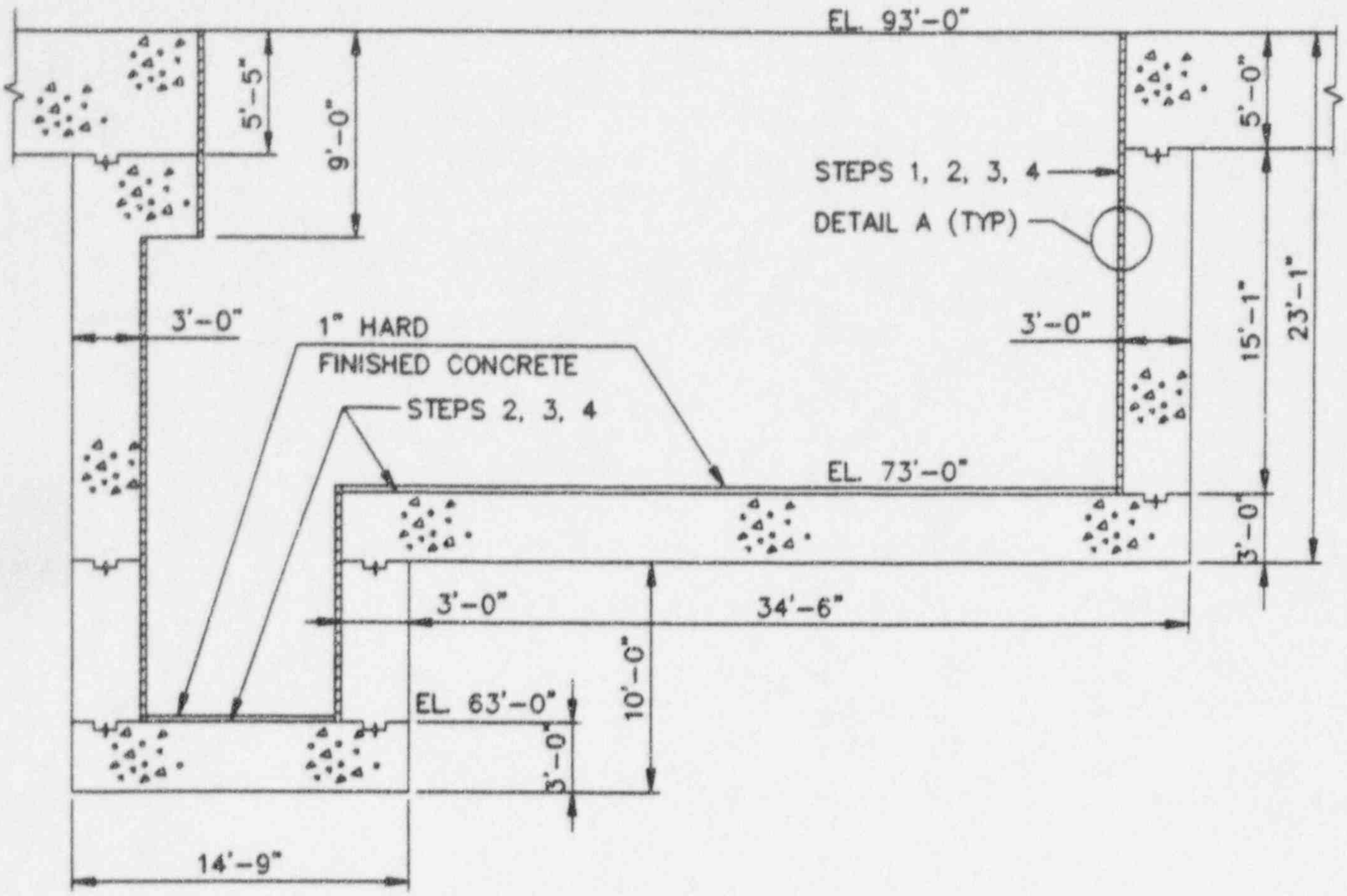
STEPS TO INSTALL TEMPORARY GATE : (CONTINGENCY PLAN)

1. LIFT STRIKE PLATE ASSEMBLY AND MOVE IT TO LAYDOWN ARE : ON THE FLOOR AT EL. 93 FT.
2. SHUFFLE FUEL AND RACKS TO THE EAST END OF THE CANAL AND CLEAR THE AREA NEAR THE GATE, WHICH IS LOCATED AT 22 FT. FROM THE EAST OF THE CANAL.
3. INSTALL HILTI ANCHORS FOR GATE FRAME IN POOL FLOOR AND POOL WALL AS SHOWN IN DETAIL A.
4. DROP GATE FRAME AND FASTEN THE FRAME WITH HILTI BOLT NUTS TO THE FLOOR.
5. INSTALL HILTI BOLTS ON THE WALL AND FASTEN THE FRAME TO THE WALL. THE GATE FRAME WILL BE LEFT IN THE CANAL PERMANENTLY.
6. DROP THE LOWER GATE INTO THE GATE FRAME.
7. DROP THE UPPER GATE INTO THE GATE FRAME (COMPRESSIVE SEALS BETWEEN THE UPPER AND LOWER GATES ARE PROVIDED.
8. INFLAT FOUR INFLATABLE SEALS (SEE DETAIL A).
9. DRAIN WATER IN THE POOL WEST OF THE GATE.
10. INSTALL LINER IN THE WEST POOL AND WELD IT TO THE GATE FRAME.
11. PUMP IN WATER INTO WEST POOL.
12. REMOVE TEMPORARY GATE.
13. MOVE FUEL/RACKS TO THE WEST POOL.
14. SAME AS STEP 6.
15. SAME AS STEP 7.
16. SAME AS STEP 8.
17. DRAIN WATER IN THE EAST POOL.
18. INSTALL LINER IN THE EAST POOL AND WELD IT TO THE GATE FRAME.
19. PUMP IN WATER IN THE EAST POOL.
20. REMOVE TEMPORARY GATE.
21. MOVE FUEL/RACKS TO THE DESIRED LOCATION.

BROOKHAVEN NATIONAL LABORATORY
HIGH FLUX BEAM REACTOR
SPENT FUEL CANAL LINER
STEPS FOR TEMPORARY GATE – SH. 2

Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
S.M.G.	C. SHIH	04-01-97	AS NOTED	SK-A-12



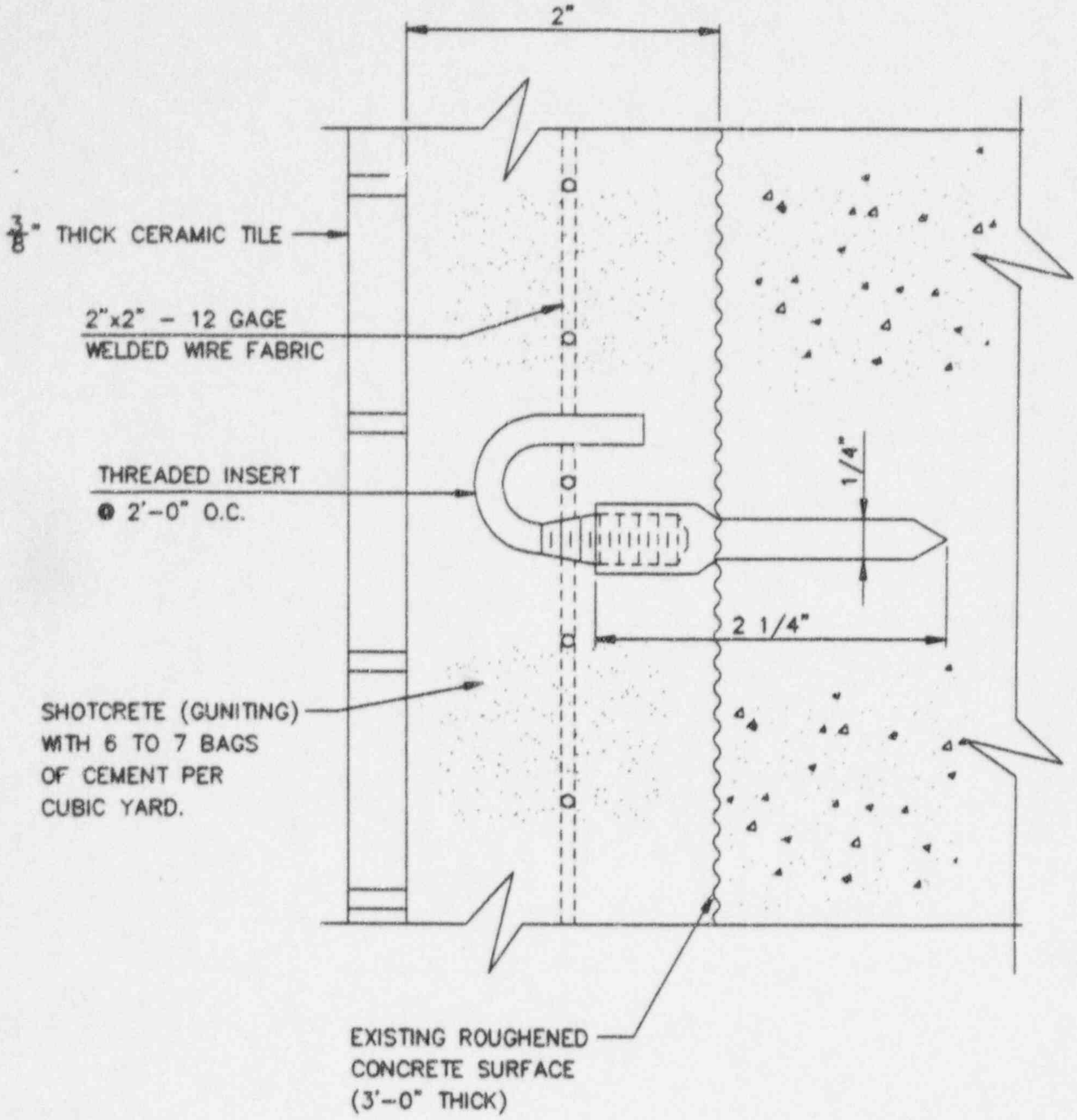
EXISTING SPENT FUEL STORAGE CANAL SECTION

$\frac{1}{8}$"=1'-0"

SEQUENCE FOR CONCRETE TREATMENT

1. REMOVE CERAMIC TILES, SHOTCRETE INCLUDING WELDED WIRE FABRIC (DET. A).
2. REPAIR DEFECTS – CRACKS, CONSTRUCTION/EXPANSION JOINTS AND HONEYCOMBS IN EXISTING CONCRETE.
3. APPLY CEMENTITIOUS WATERPROOFING (IMPERVIOUS COATING).
4. APPLY EPOXY COATING (NUCLEAR COATING).

BROOKHAVEN NATIONAL LABORATORY HIGH FLUX BEAM REACTOR SPENT FUEL STORAGE CANAL SEQUENCE FOR CONC TREATMENT – SH.1				
Raytheon ENGINEERS & CONSTRUCTORS				
DRAWN: S.M.G.	CHKD: C. SHIH	DATE: 04-01-97	SCALE: AS NOTED	DWG NO. SK-A-14

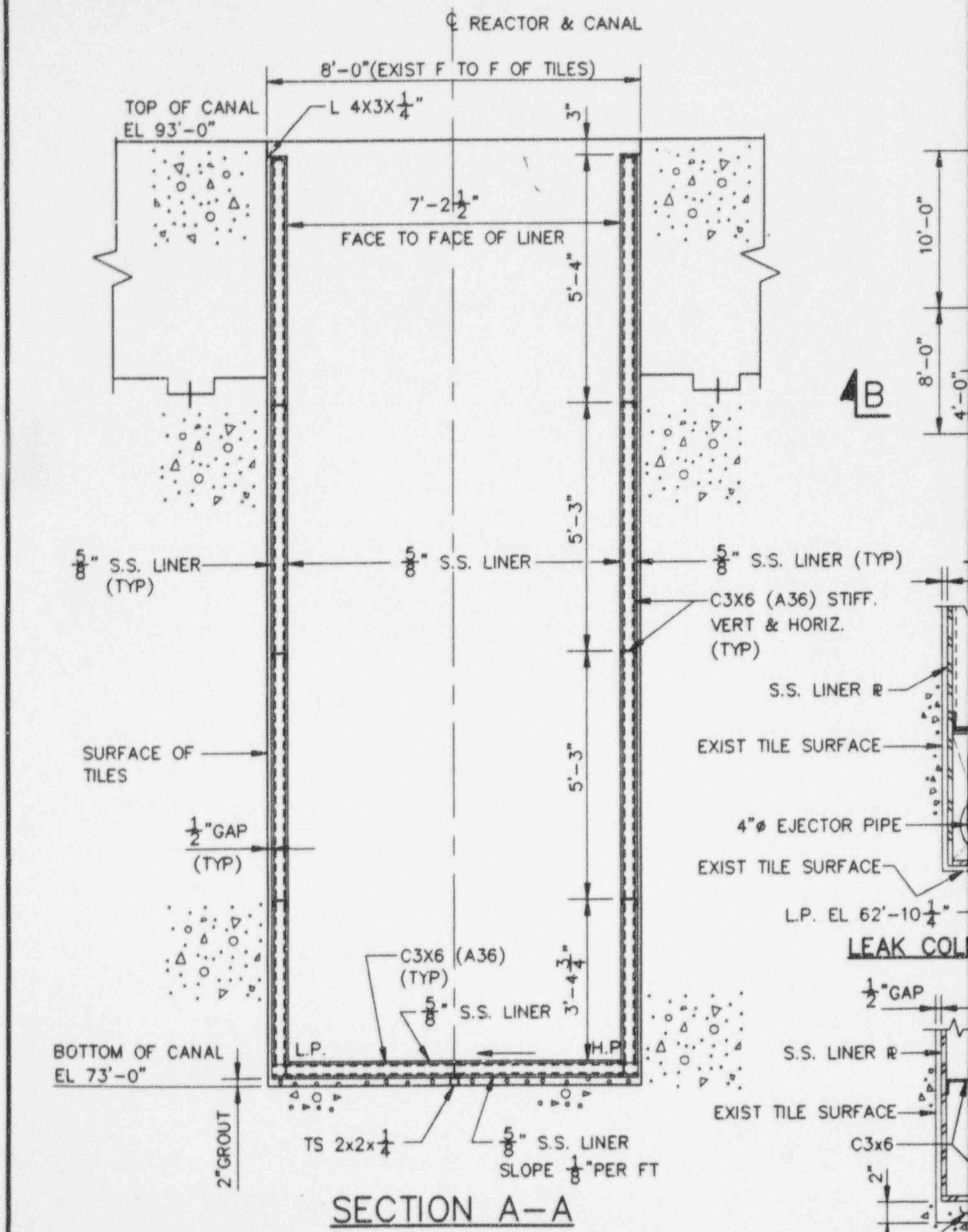


DETAIL A (EXISTING CONDITION)

BROOKHAVEN NATIONAL LABORATORY
HIGH FLUX BEAM REACTOR
SPENT FUEL STORAGE CANAL
SEQUENCE FOR CONC TREATMENT - SH.2

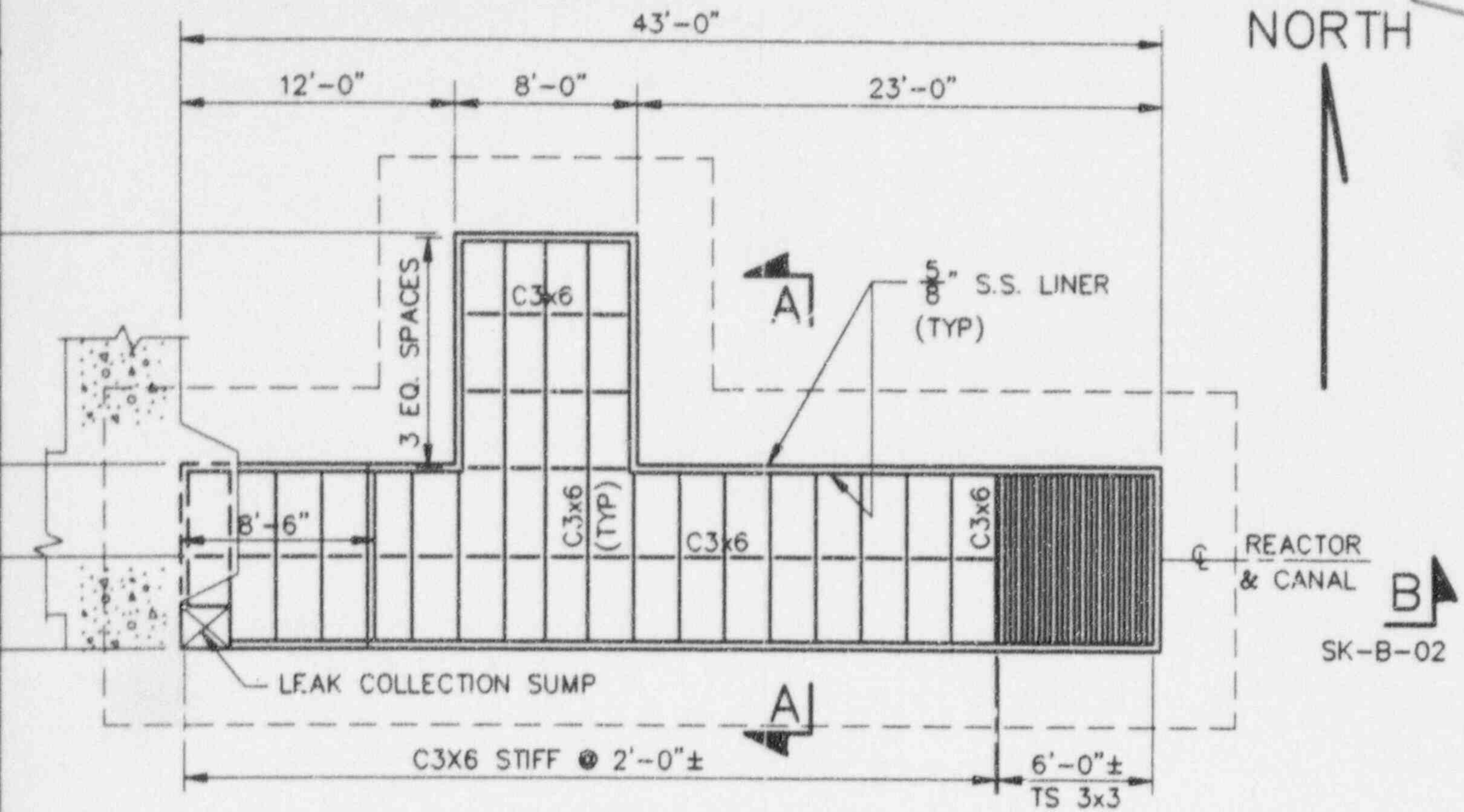
Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
S.M.G.	C. SHIH	04-01-97	AS NOTED	SK-A-15



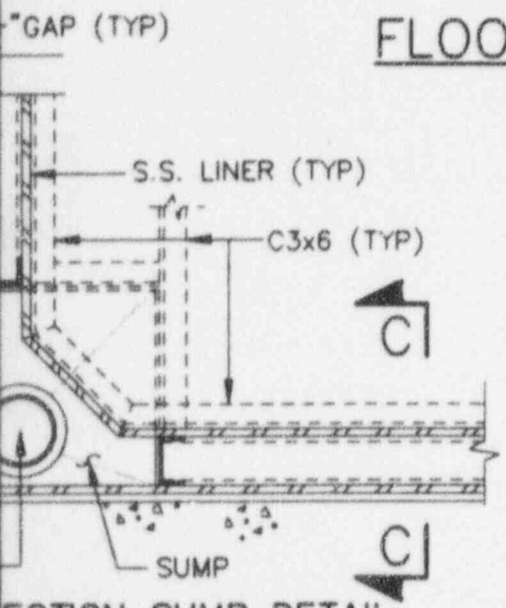
SECTION A-A

3/8"=1'-0"



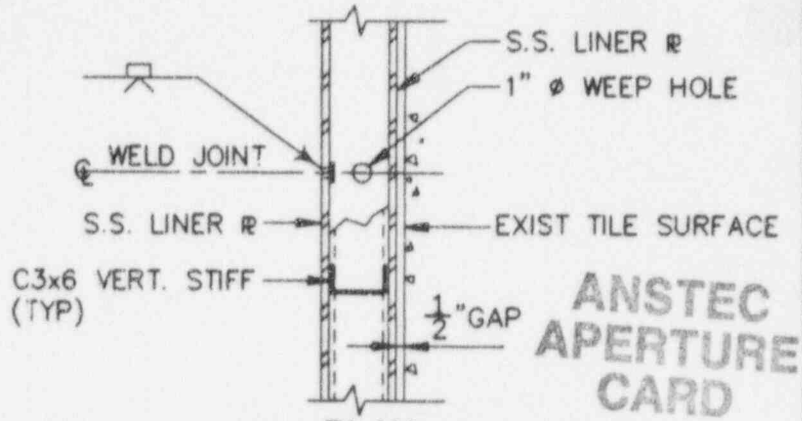
FLOOR STIFFENERS PLAN

1/8"=1'-0"



ECTION SUMP DETAIL

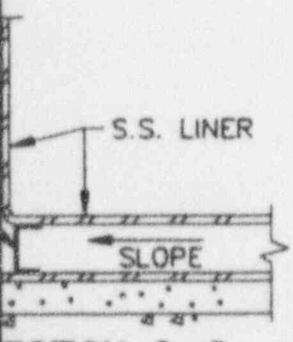
NTS



PLAN

TYP WALL DETAIL

NTS

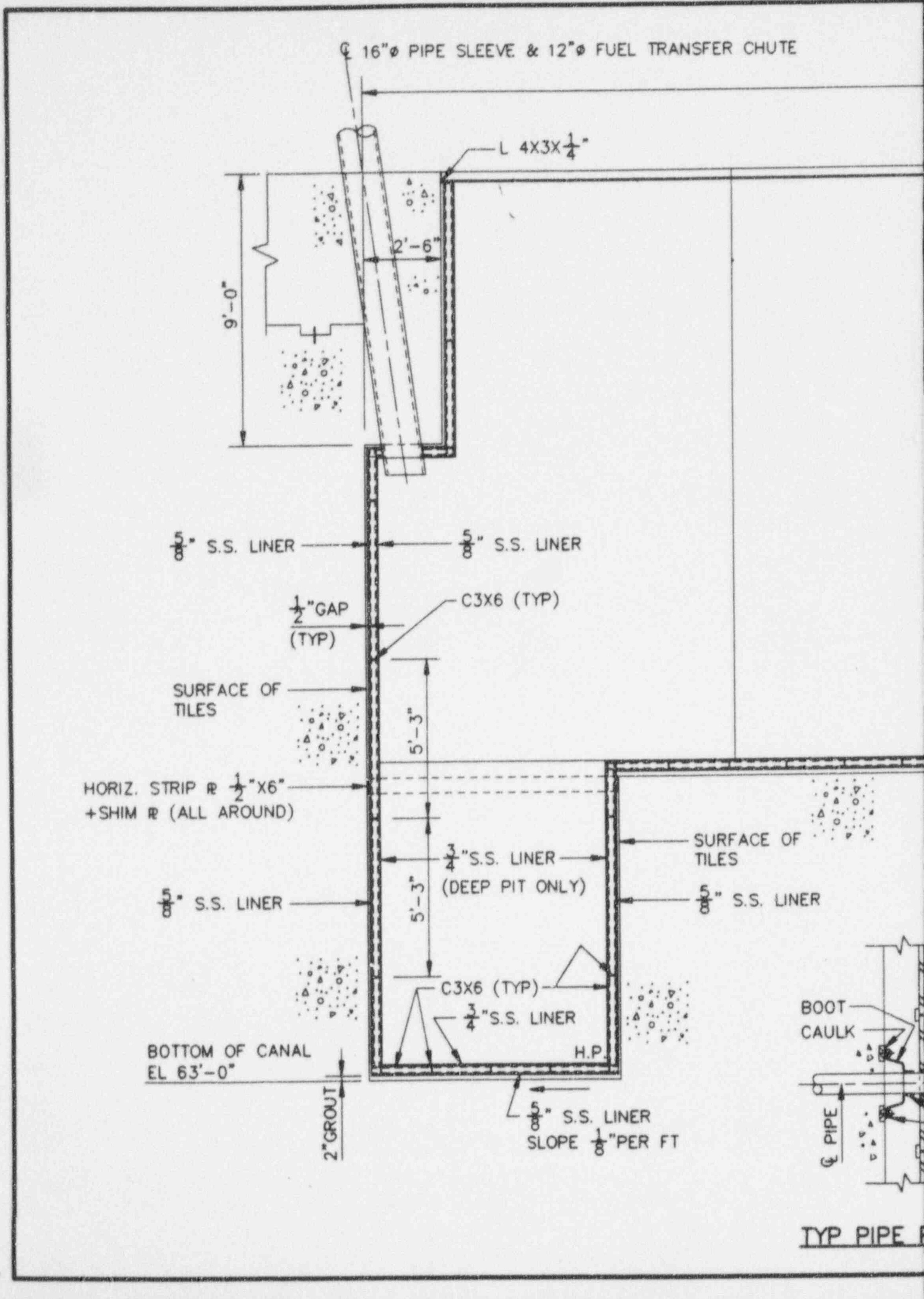


ECTION C-C

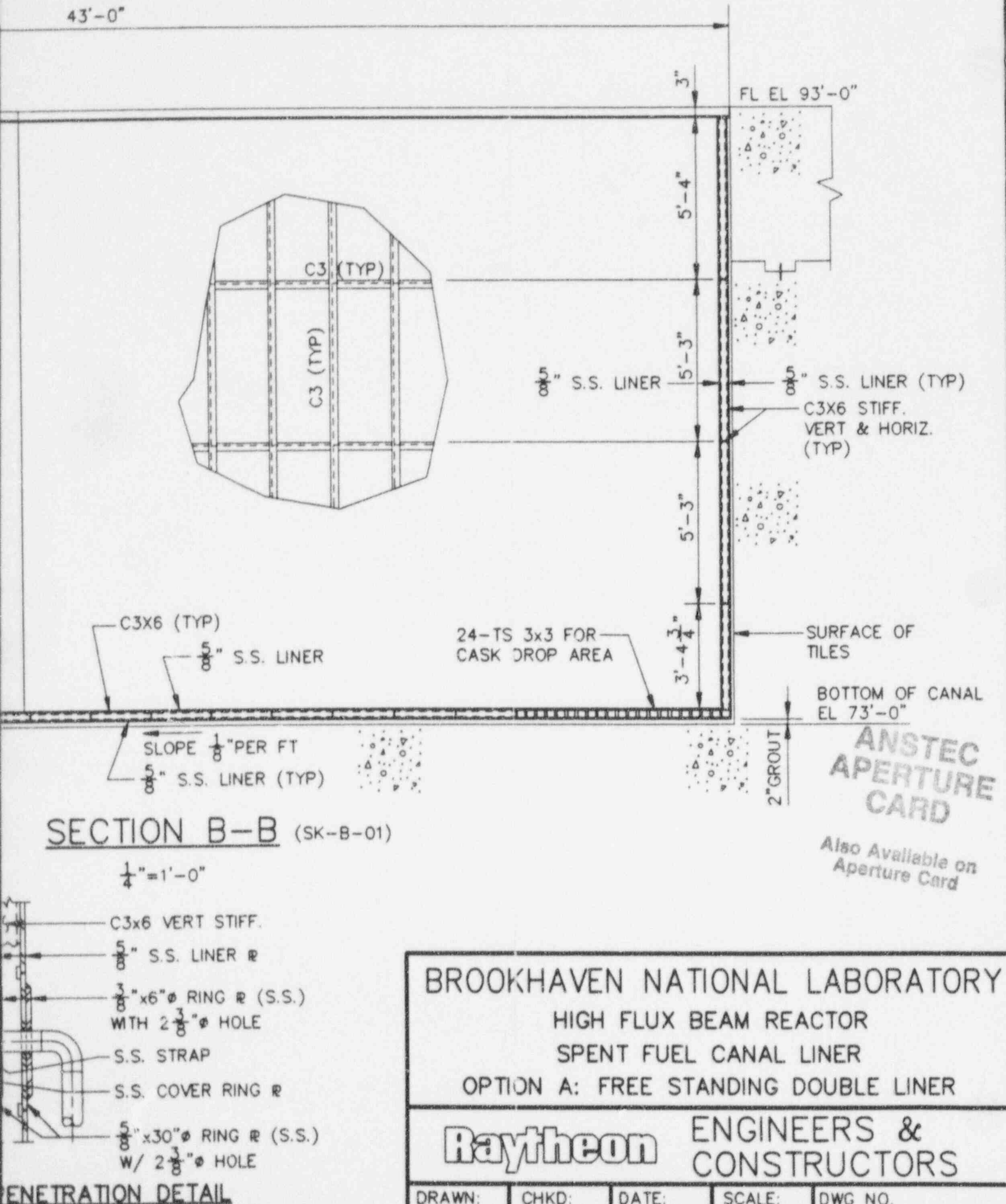
NTS

BROOKHAVEN NATIONAL LABORATORY				
HIGH FLUX BEAM REACTOR SPENT FUEL CANAL LINER OPTION A: FREE STANDING DOUBLE LINER				
Raytheon ENGINEERS & CONSTRUCTORS				
DRAWN: B.S.RANA	CHKD: C. SHIH	DATE: 03-29-97	SCALE: AS NOTED	DWG NO. SK-B-01

9704080218-02



℄ 16"ø PIPE SLEEVE & 12"ø FUEL TRANSFER CHUTE
L 4X3X1/4"
2'-6"
9'-0"
5/8" S.S. LINER
5/8" S.S. LINER
1/2"GAP (TYP)
C3X6 (TYP)
SURFACE OF TILES
5'-3"
HORIZ. STRIP ℞ 1/2"X6" +SHIM ℞ (ALL AROUND)
3/4"S.S. LINER (DEEP PIT ONLY)
5'-3"
SURFACE OF TILES
5/8" S.S. LINER
5/8" S.S. LINER
C3X6 (TYP)
3/4"S.S. LINER
BOTTOM OF CANAL EL 63'-0"
H.P.
2"GROUT
5/8" S.S. LINER SLOPE 1/8"PER FT
BOOT
CAULK
℄ PIPE
TYP PIPE P



BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

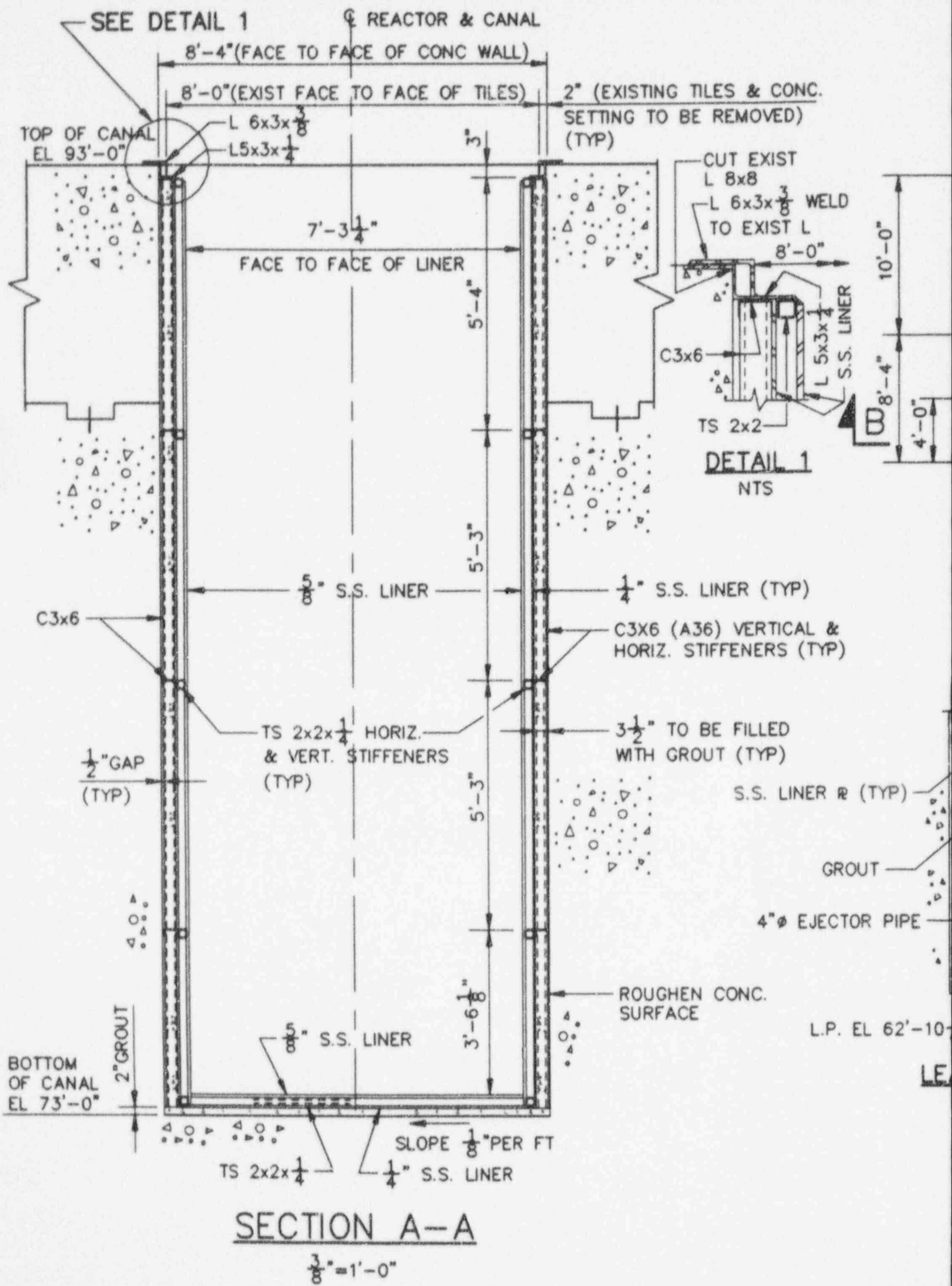
SPENT FUEL CANAL LINER

OPTION A: FREE STANDING DOUBLE LINER

Raytheon ENGINEERS & CONSTRUCTORS

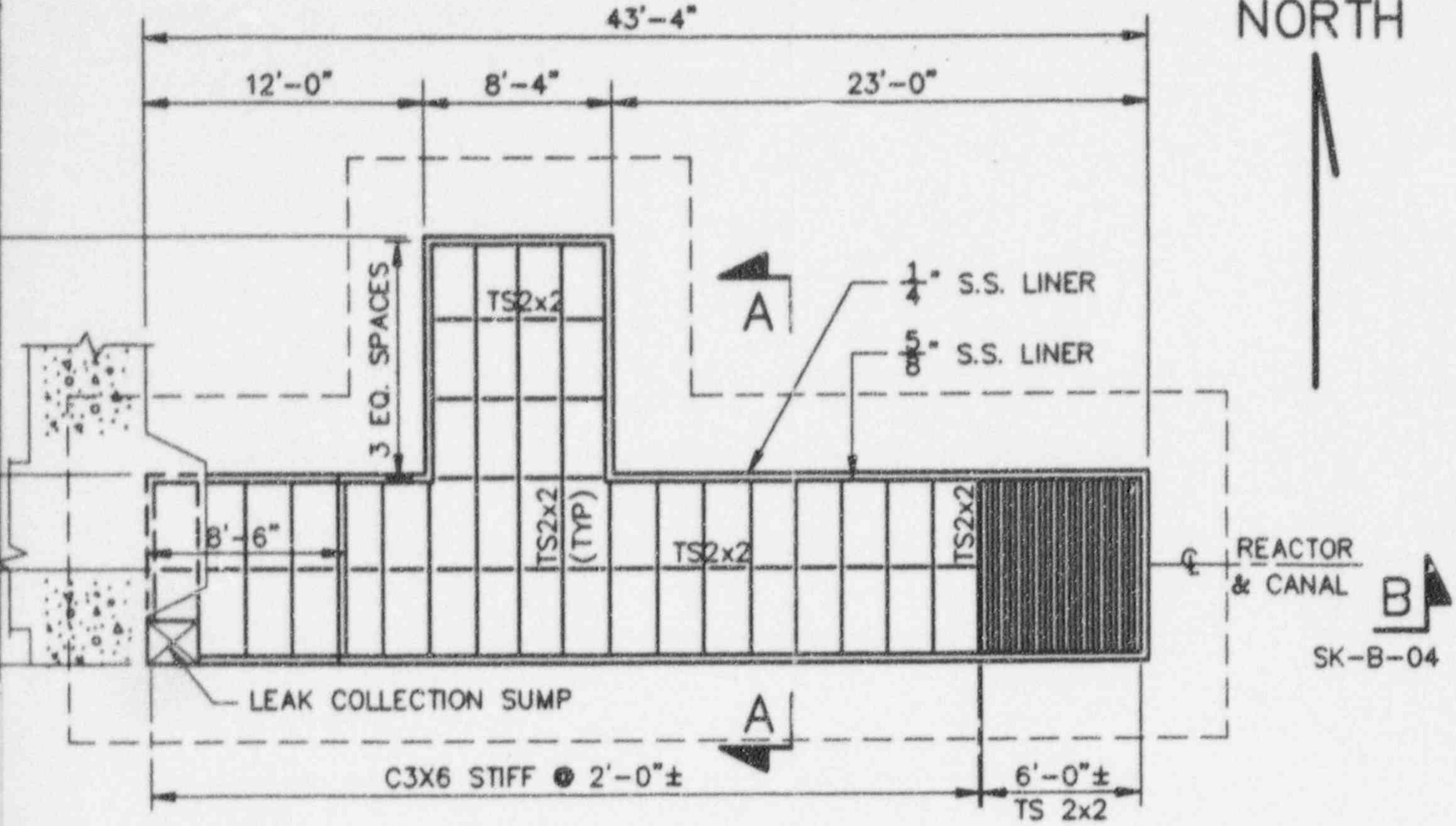
DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
B.S.RANA	C. SHIH	04-03-97	AS NOTED	SK-B-02

9704080218-03



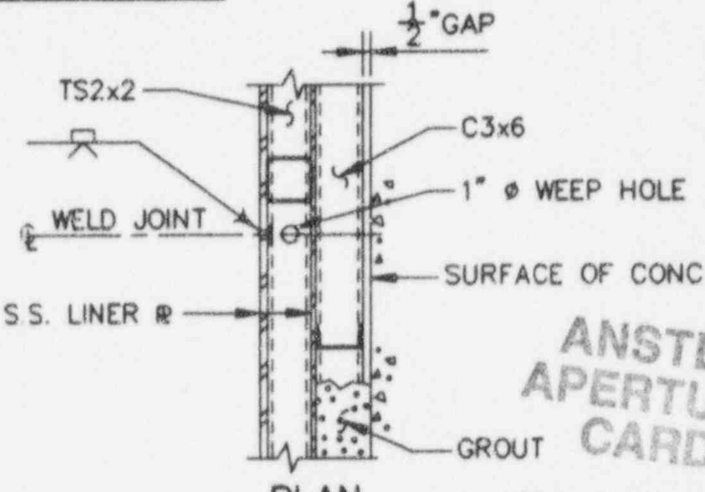
SECTION A-A

3/8"=1'-0"



FLOOR STIFFENERS PLAN

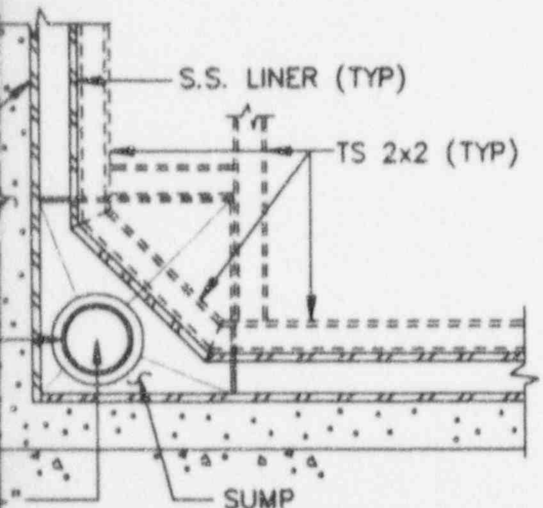
1/8"=1'-0"



PLAN

TYP WALL DETAIL

NTS



AK COLLECTION SUMP DETAIL

NTS

BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

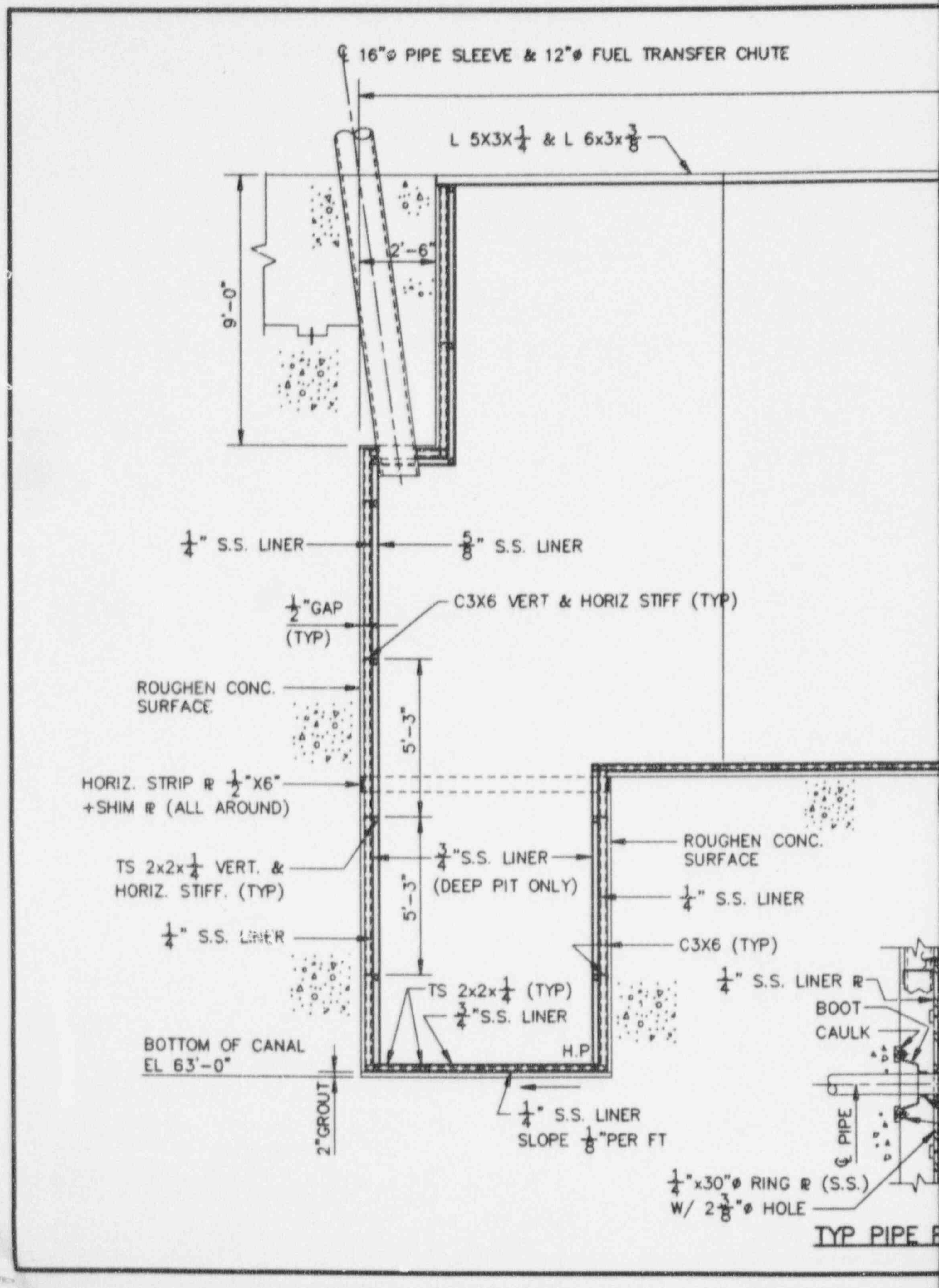
SPENT FUEL CANAL LINER

OPTION B: GROUT BACKED DOUBLE LINER

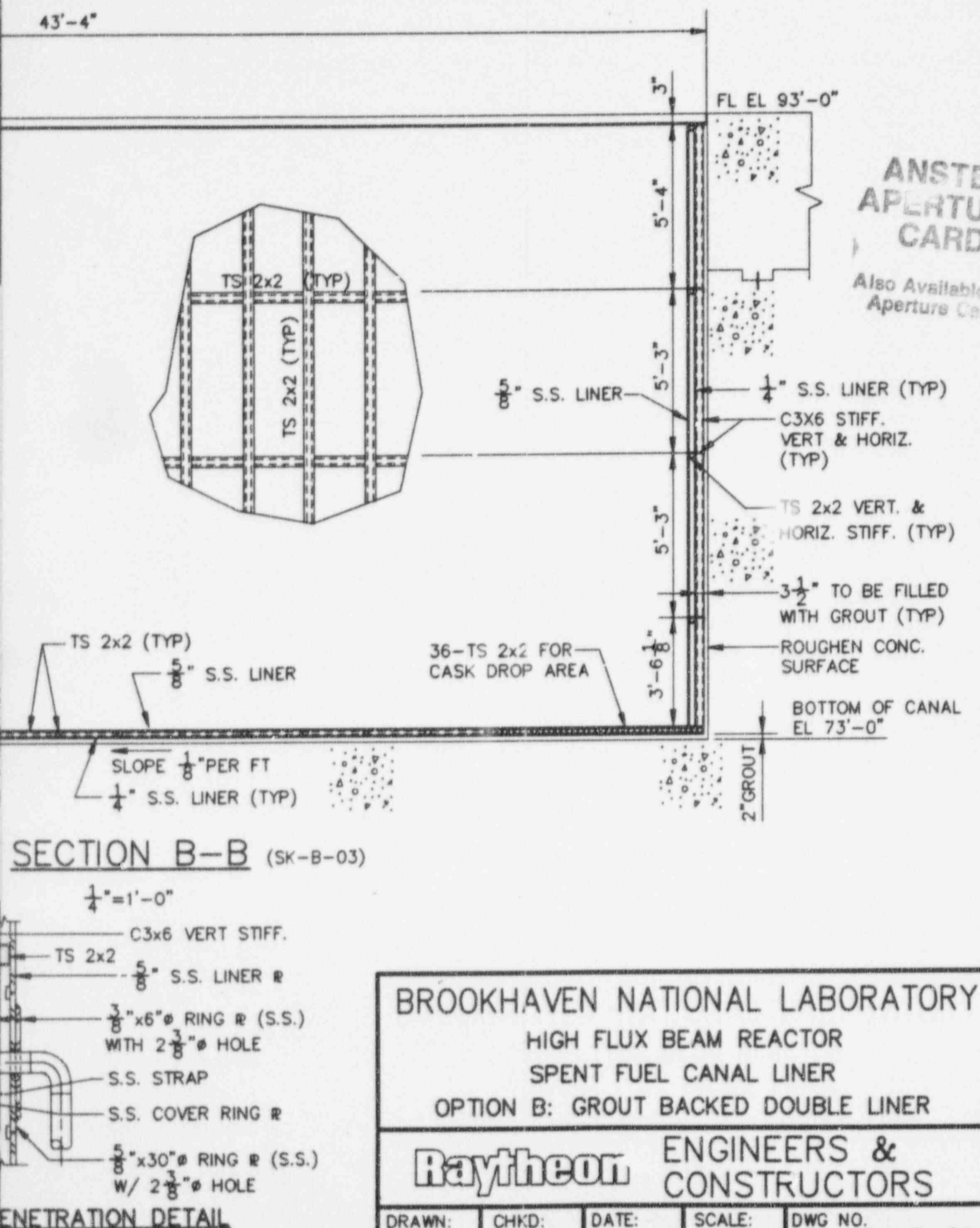
Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
B.S.RANA	C. SHIH	04-04-97	AS NOTED	SK-B-03

9704080218-04



℄ 16"ø PIPE SLEEVE & 12"ø FUEL TRANSFER CHUTE
L 5X3X1/4 & L 6x3x3/8
2'-6"
9'-0"
1/4" S.S. LINER
5/8" S.S. LINER
1/2"GAP (TYP)
C3X6 VERT & HORIZ STIFF (TYP)
ROUGHEN CONC. SURFACE
5'-3"
HORIZ. STRIP ℙ 1/2"X6" +SHIM ℙ (ALL AROUND)
TS 2x2x1/4 VERT. & HORIZ. STIFF. (TYP)
3/4"S.S. LINER (DEEP PIT ONLY)
5'-3"
1/4" S.S. LINER
ROUGHEN CONC. SURFACE
1/4" S.S. LINER
C3X6 (TYP)
TS 2x2x1/4 (TYP)
3/4"S.S. LINER
H.P
BOTTOM OF CANAL EL 63'-0"
2"GROUT
1/4" S.S. LINER SLOPE 1/8"PER FT
1/4" S.S. LINER ℙ
BOOT
CAULK
℄ PIPE
1/4"x30"ø RING ℙ (S.S.) W/ 2 3/8"ø HOLE
TYP PIPE P



BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

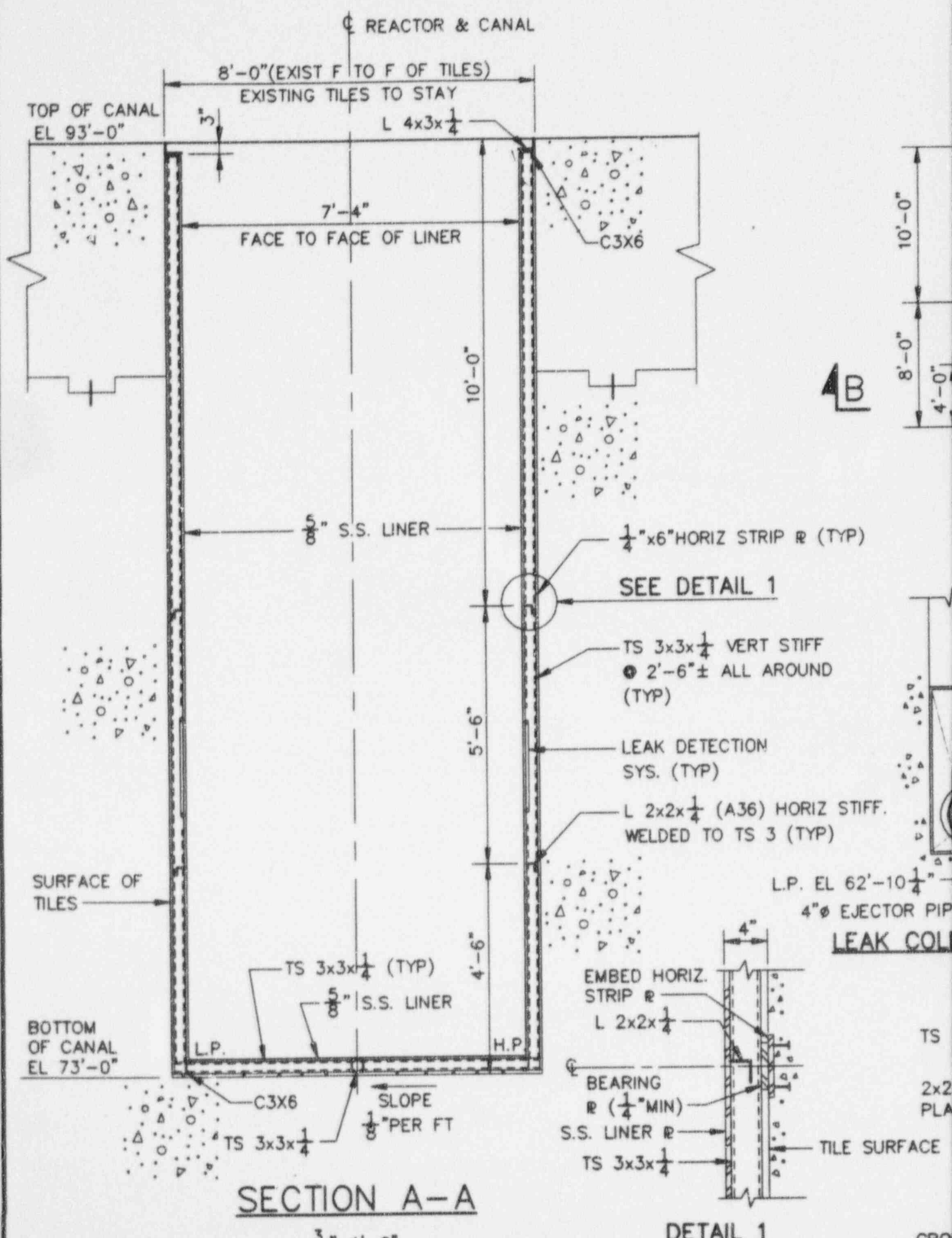
SPENT FUEL CANAL LINER

OPTION B: GROUT BACKED DOUBLE LINER

Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
B.S.RANA	C. SHIH	04-04-97	AS NOTED	SK-B-04

9704080218-05

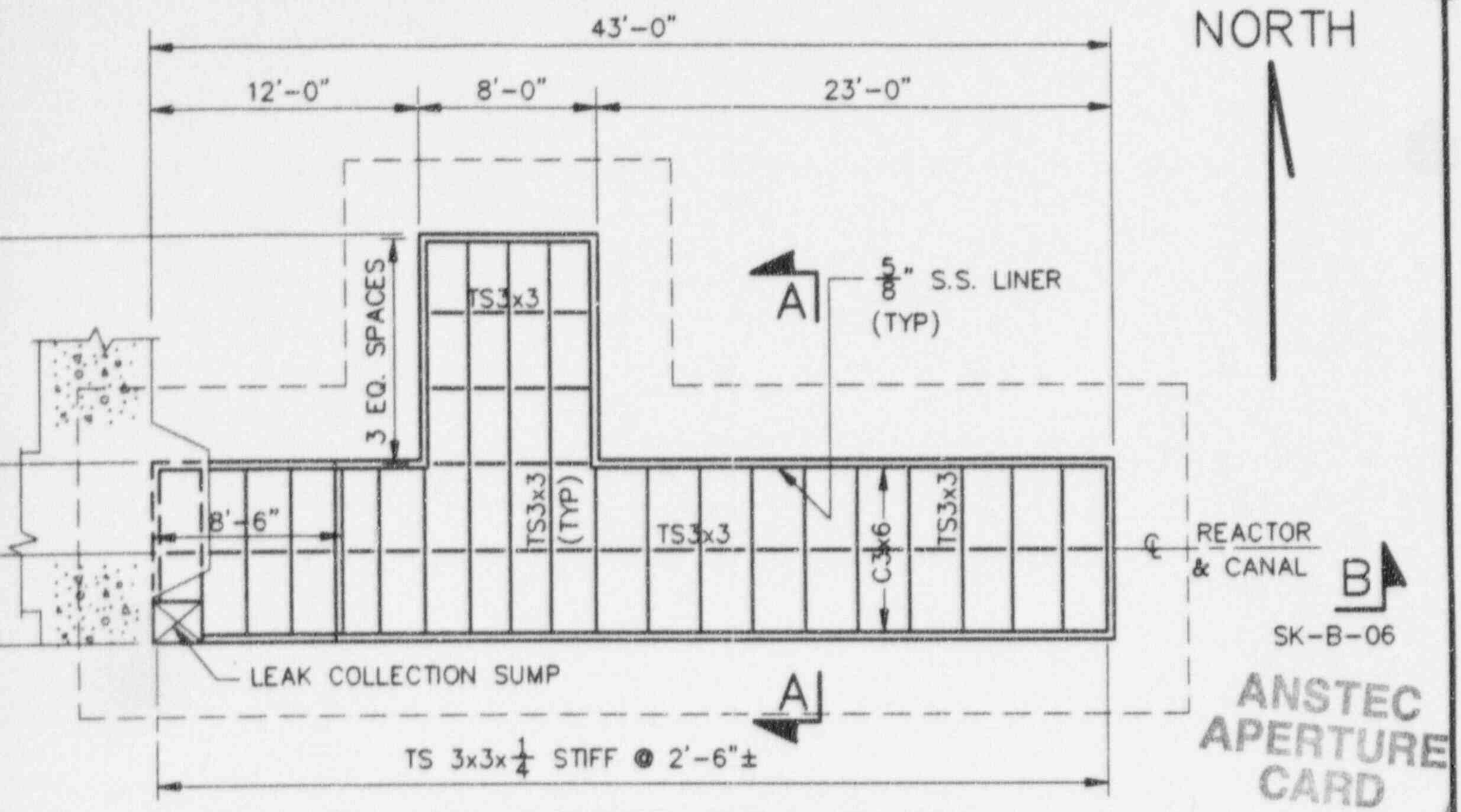


SECTION A–A

3/8"=1'-0"

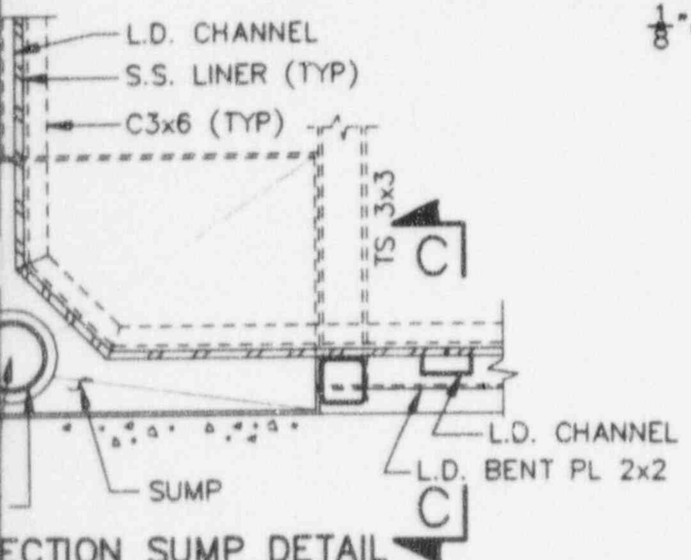
DETAIL 1

NTS



FLOOR STIFFENERS PLAN

1/8"=1'-0"



ECTION SUMP DETAIL

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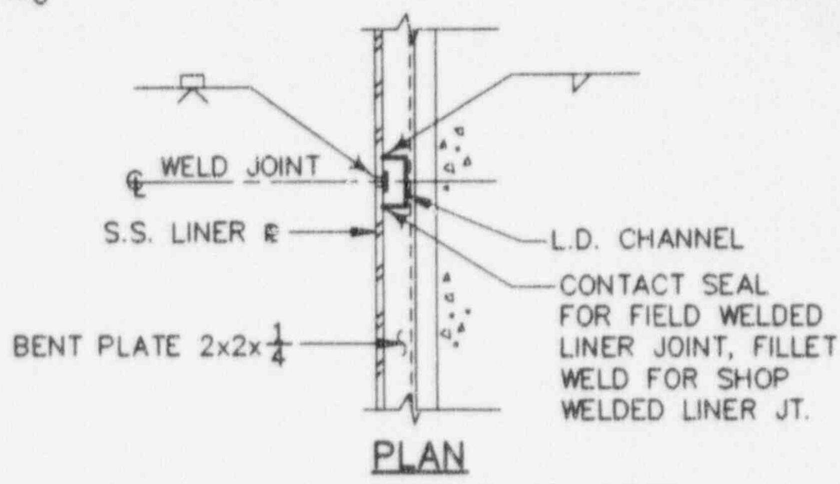
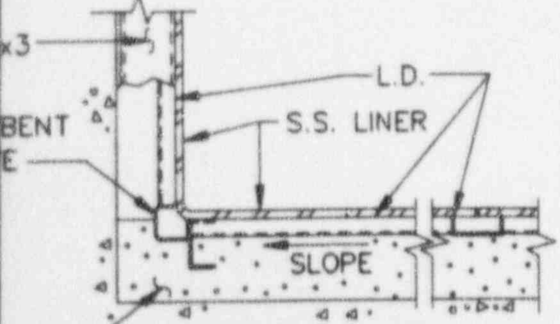


TYP L.D. ON WALL TO FL DETAIL

NTS



SECTION C–C

NTS

BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

SPENT FUEL CANAL LINER

OPTION C: FREE STANDING LINER WITH L.D. SYS.

Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
B.S.RANA	C. SHIH	04-01-97	AS NOTED	SK-B-05

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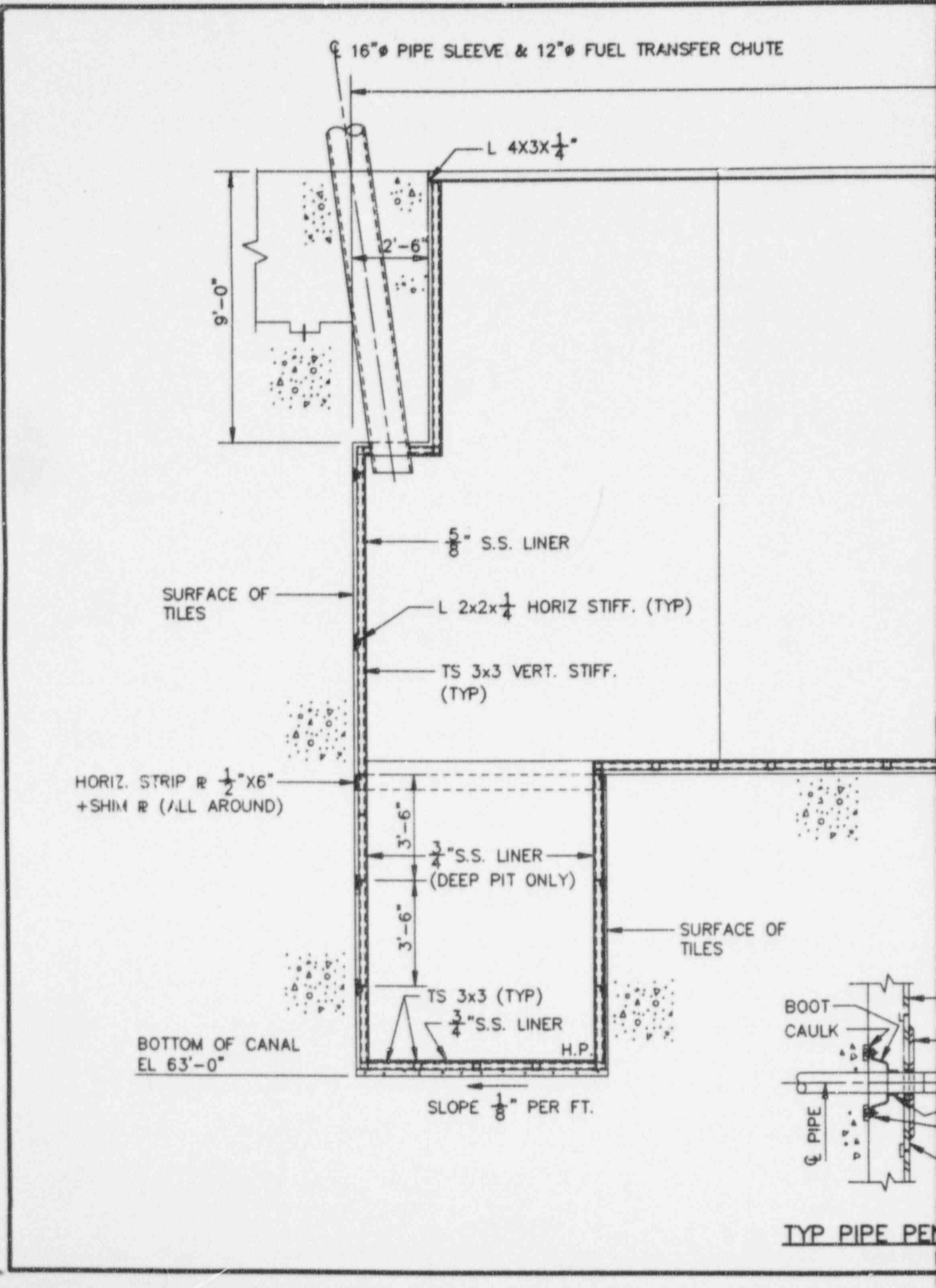
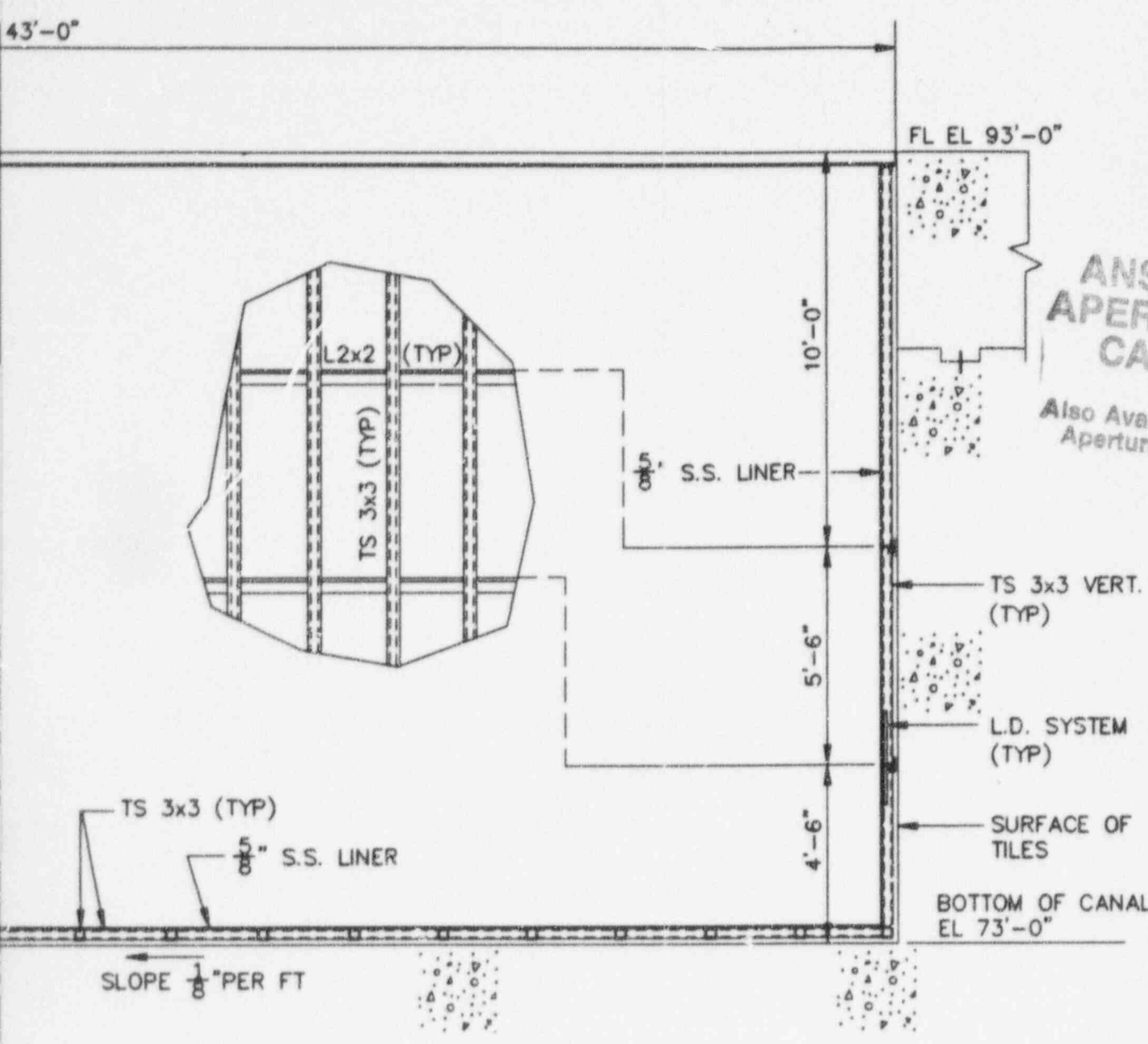
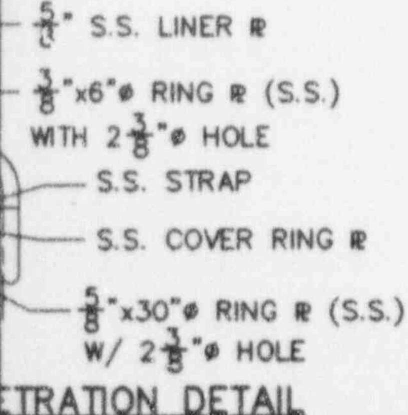


℄ 16"φ PIPE SLEEVE & 12"φ FUEL TRANSFER CHUTE
L 4X3X$\frac{1}{4}$"
9'-0"
2'-6"
$\frac{5}{8}$" S.S. LINER
SURFACE OF TILES
L 2x2x$\frac{1}{4}$ HORIZ STIFF. (TYP)
TS 3x3 VERT. STIFF. (TYP)
HORIZ. STRIP ℞ $\frac{1}{2}$"X6" +SHIM ℞ (ALL AROUND)
3'-6"
$\frac{3}{4}$"S.S. LINER (DEEP PIT ONLY)
3'-6"
SURFACE OF TILES
TS 3x3 (TYP)
$\frac{3}{4}$"S.S. LINER
BOTTOM OF CANAL EL 63'-0"
H.P.
SLOPE $\frac{1}{8}$" PER FT.
BOOT
CAULK
℄ PIPE
TYP PIPE PE



SECTION B-B (SK-B-01)

1/4"=1'-0"



...ETRATION DETAIL

...TS

BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

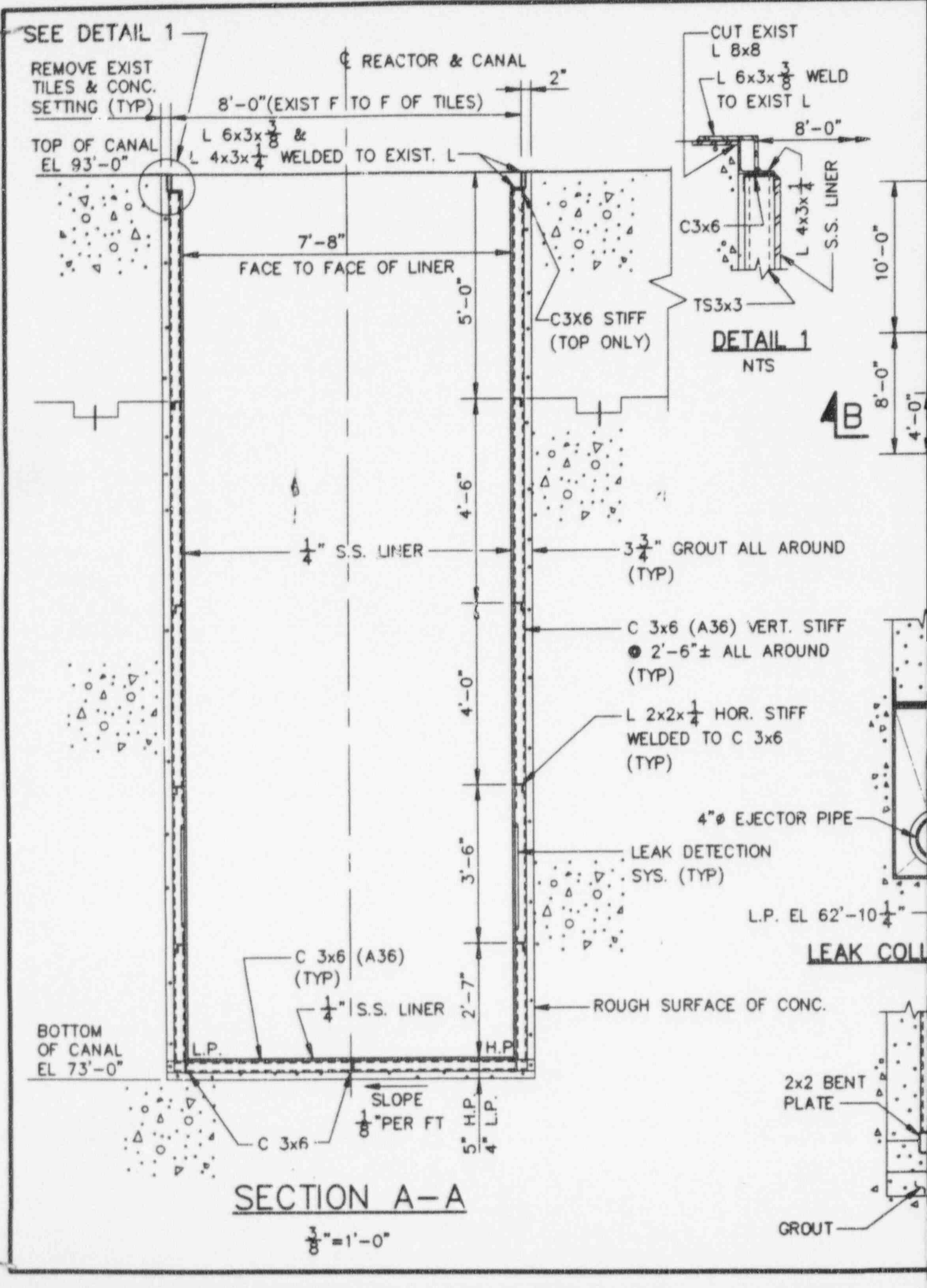
SPENT FUEL CANAL LINER

OPTION C: FREE STANDING LINER WITH L.D. SYS.

Raytheon ENGINEERS & CONSTRUCTORS

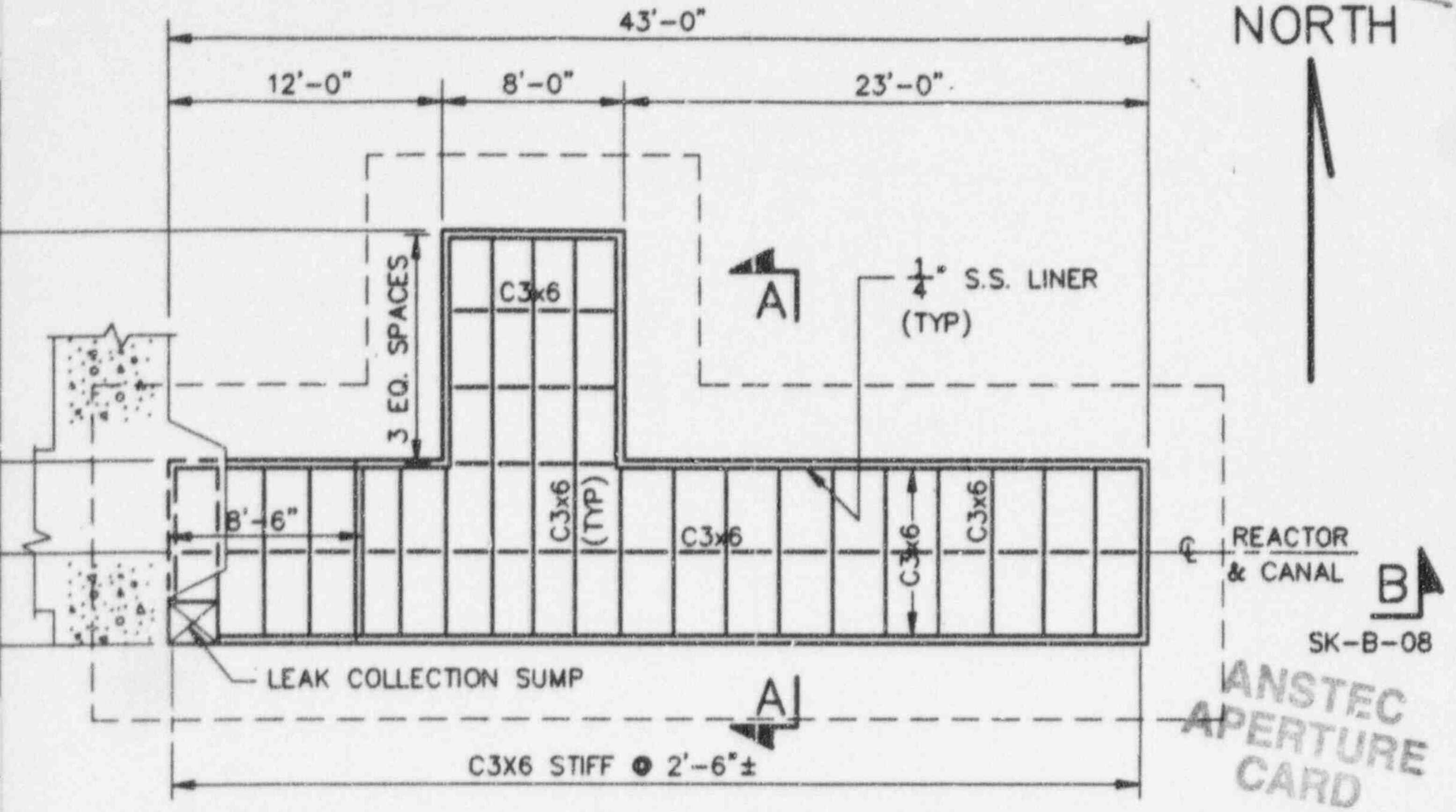
DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
B.S.RANA	C. SHIH	04-04-97	AS NOTED	SK-B-06

9704080218-07



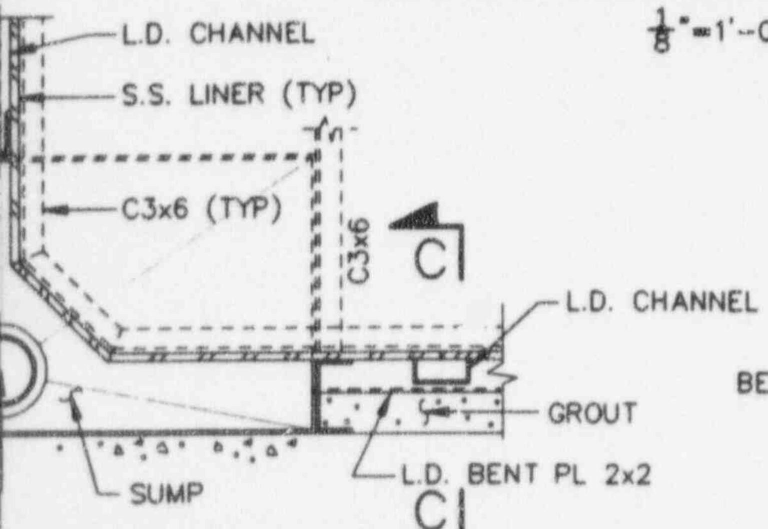
SECTION A-A

3/8"=1'-0"



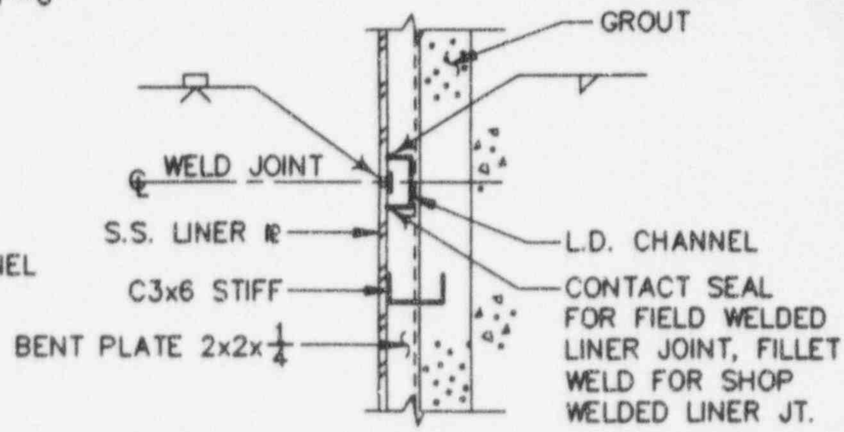
FLOOR STIFFENERS PLAN

1/8"=1'-0"



ECTION SUMP DETAIL

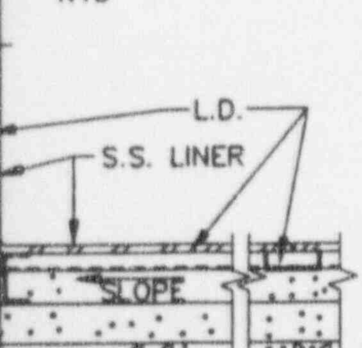
NTS



PLAN

TYP L.D. ON WALL TO FL DETAIL

NTS



ECTION C-C

NTS

BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

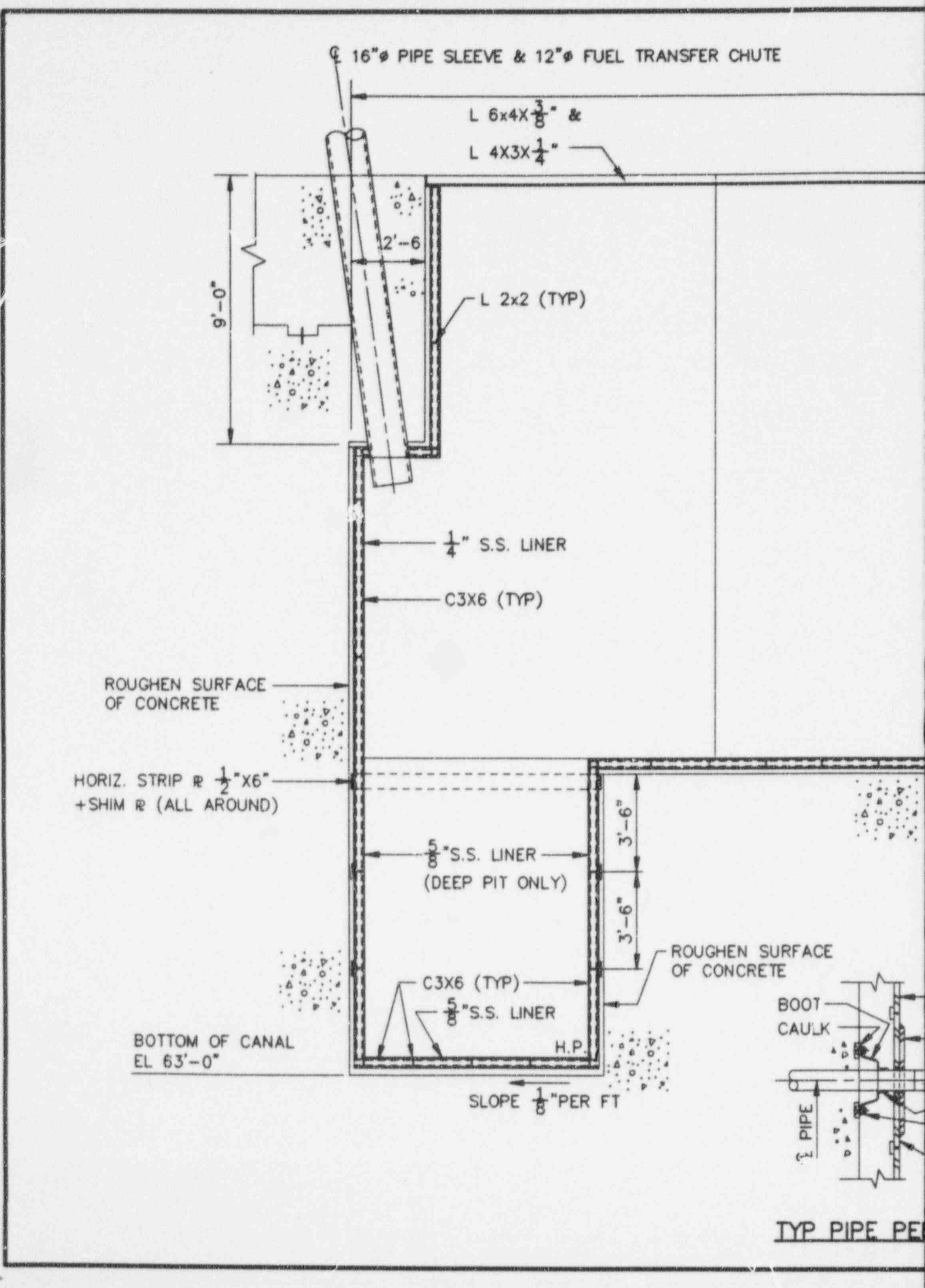
SPENT FUEL CANAL LINER

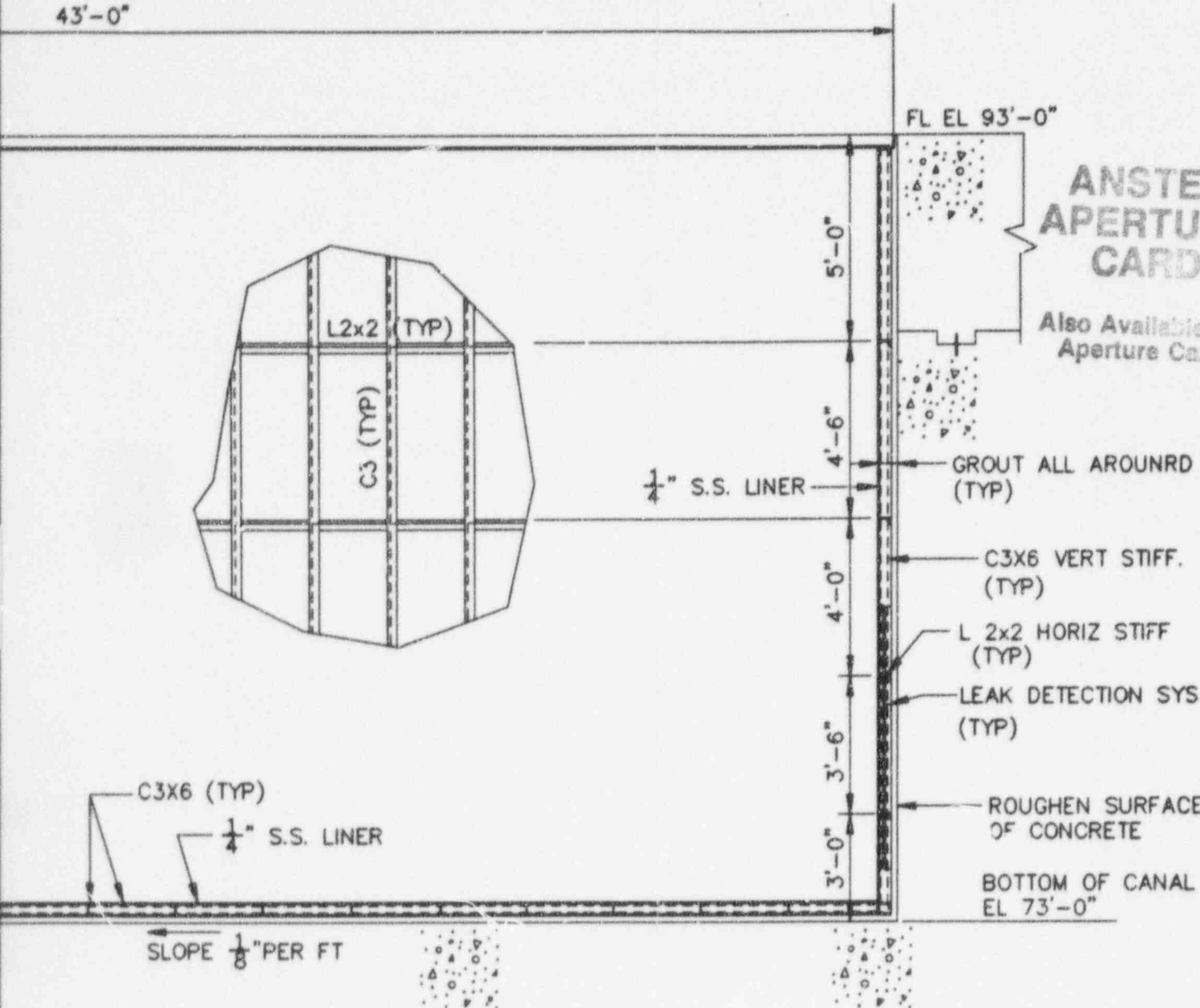
OPTION D: GROUT BACKED LINER WITH L.D. SYS.

Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
B.S.RANA	C. SHIH	04-01-97	AS NOTED	SK-B-07

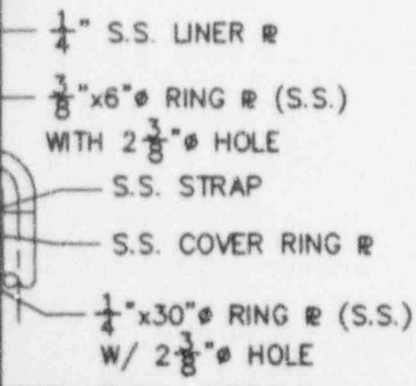
9704080218-08


℄ 16"ø PIPE SLEEVE & 12"ø FUEL TRANSFER CHUTE
L 6x4X3/8" &
L 4X3X1/4"
9'-0"
2'-6
L 2x2 (TYP)
1/4" S.S. LINER
C3X6 (TYP)
ROUGHEN SURFACE OF CONCRETE
HORIZ. STRIP ℞ 1/2"X6" +SHIM ℞ (ALL AROUND)
5/8"S.S. LINER (DEEP PIT ONLY)
3'-6"
3'-6"
ROUGHEN SURFACE OF CONCRETE
C3X6 (TYP)
5/8"S.S. LINER
BOTTOM OF CANAL EL 63'-0"
H.P.
SLOPE 1/8"PER FT
BOOT
CAULK
℄ PIPE
TYP PIPE PE



SECTION B-B (SK-B-07)

1/4"=1'-0"



ETRATION DETAIL

TS

BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

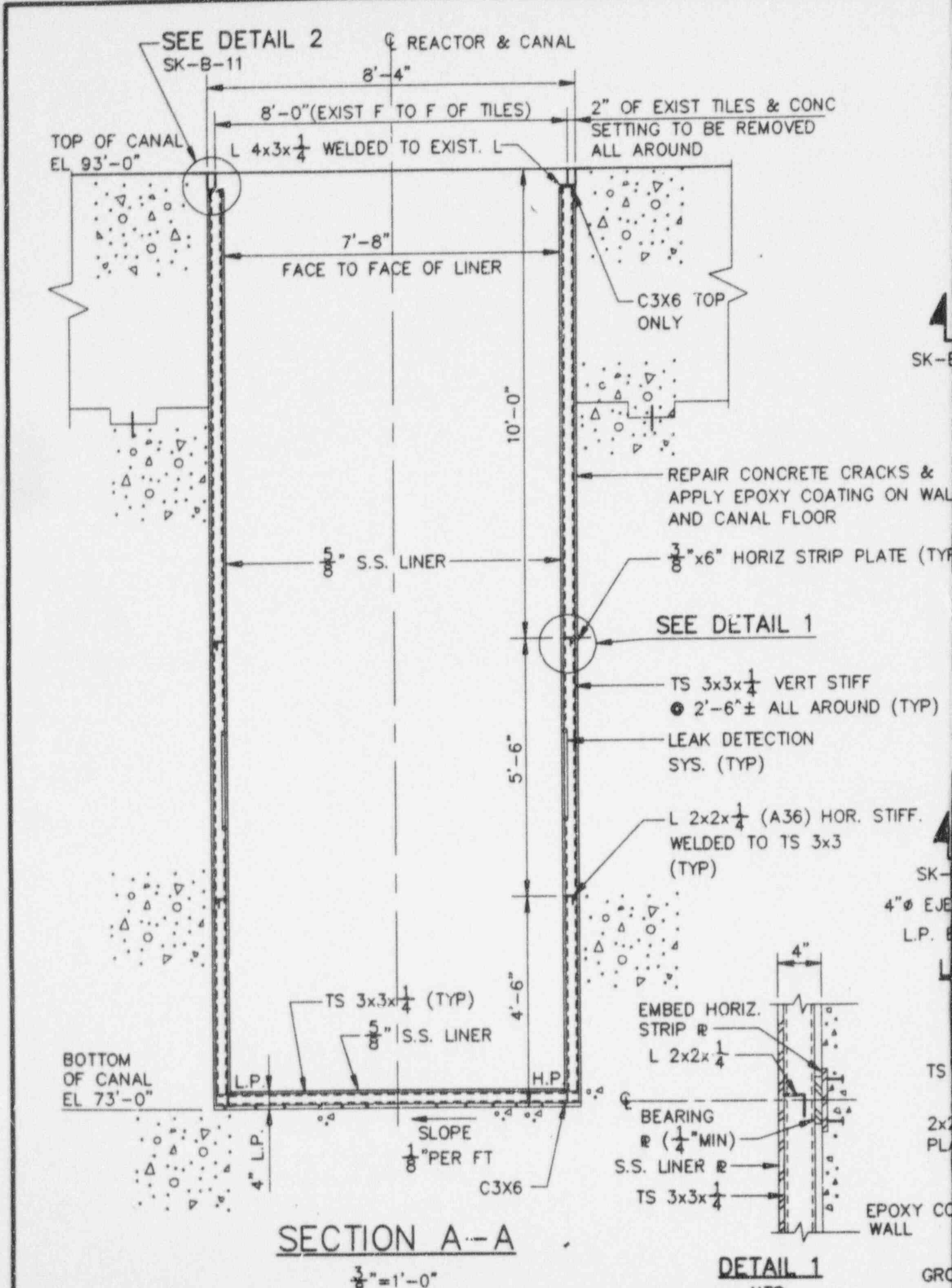
SPENT FUEL CANAL LINER

OPTION D: GROUT BACKED LINER WITH L.D. SYS.

Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
P.S.RANA	C. SHIH	04-04-97	AS NOTED	SK-B-08

9704080218-09

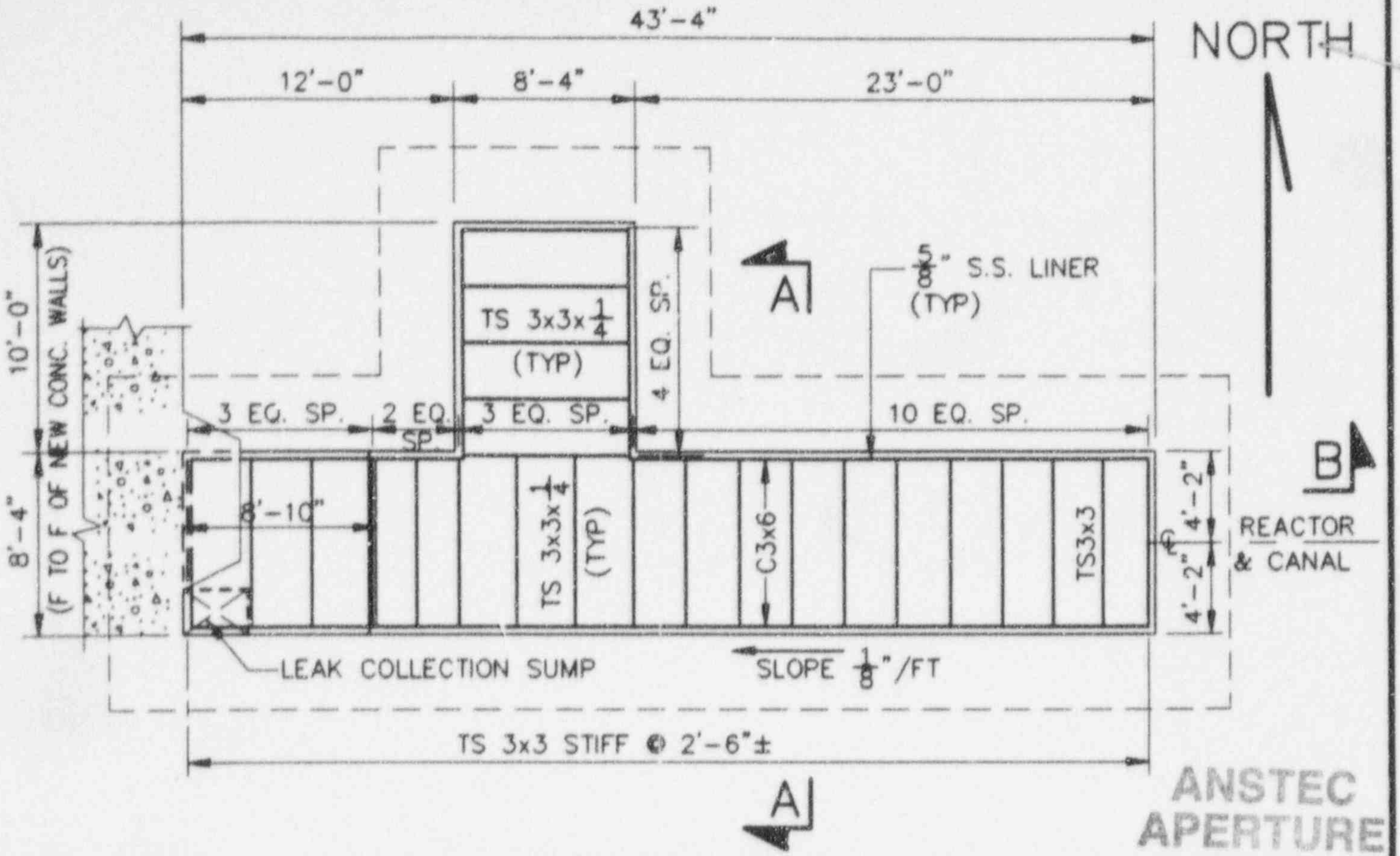


SECTION A-A

3/8"=1'-0"

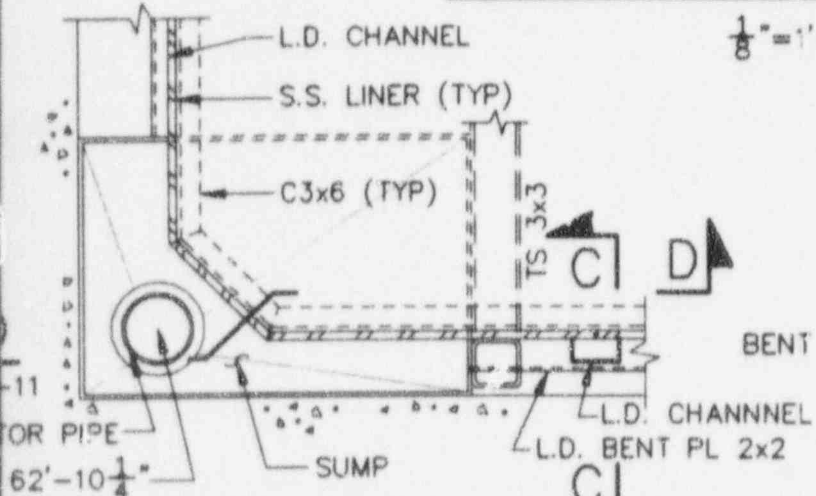
DETAIL 1

NTS



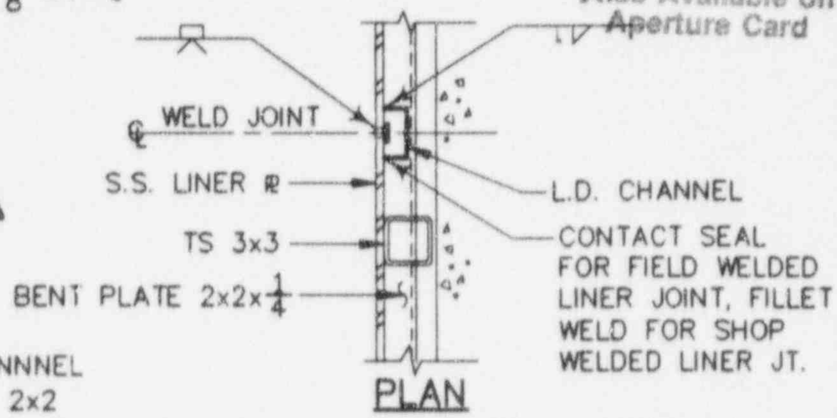
FLOOR STIFFENERS PLAN

$\frac{1}{8}$"=1'-0"



AK COLLECTION SUMP DETAIL

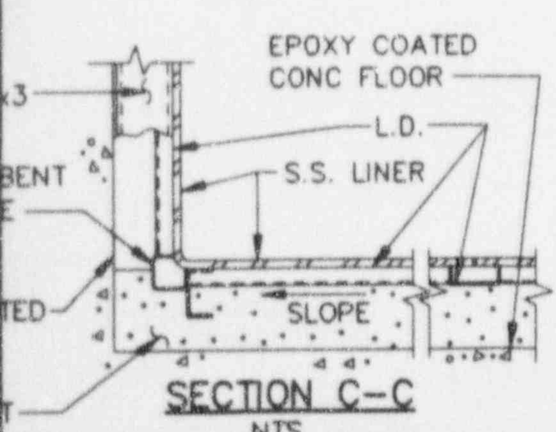
NTS



PLAN

TYP L.D. ON WALL TO FL DETAIL

NTS



SECTION C-C

NTS

BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

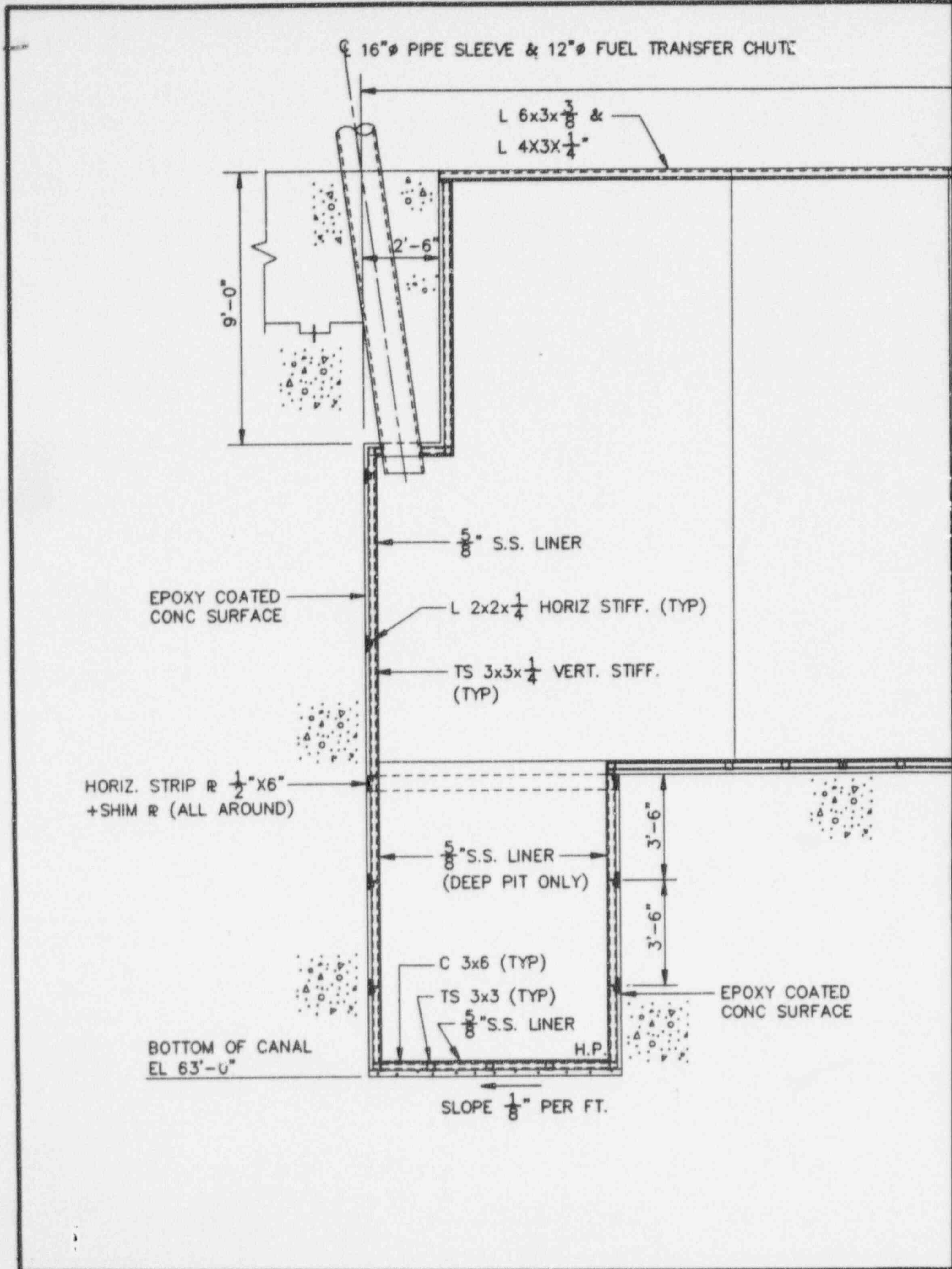
SPENT FUEL CANAL LINER

OPTION E: FREE STANDING LINER WITH L.D. SYS. & CONC COATING ON CANAL FL & WALLS

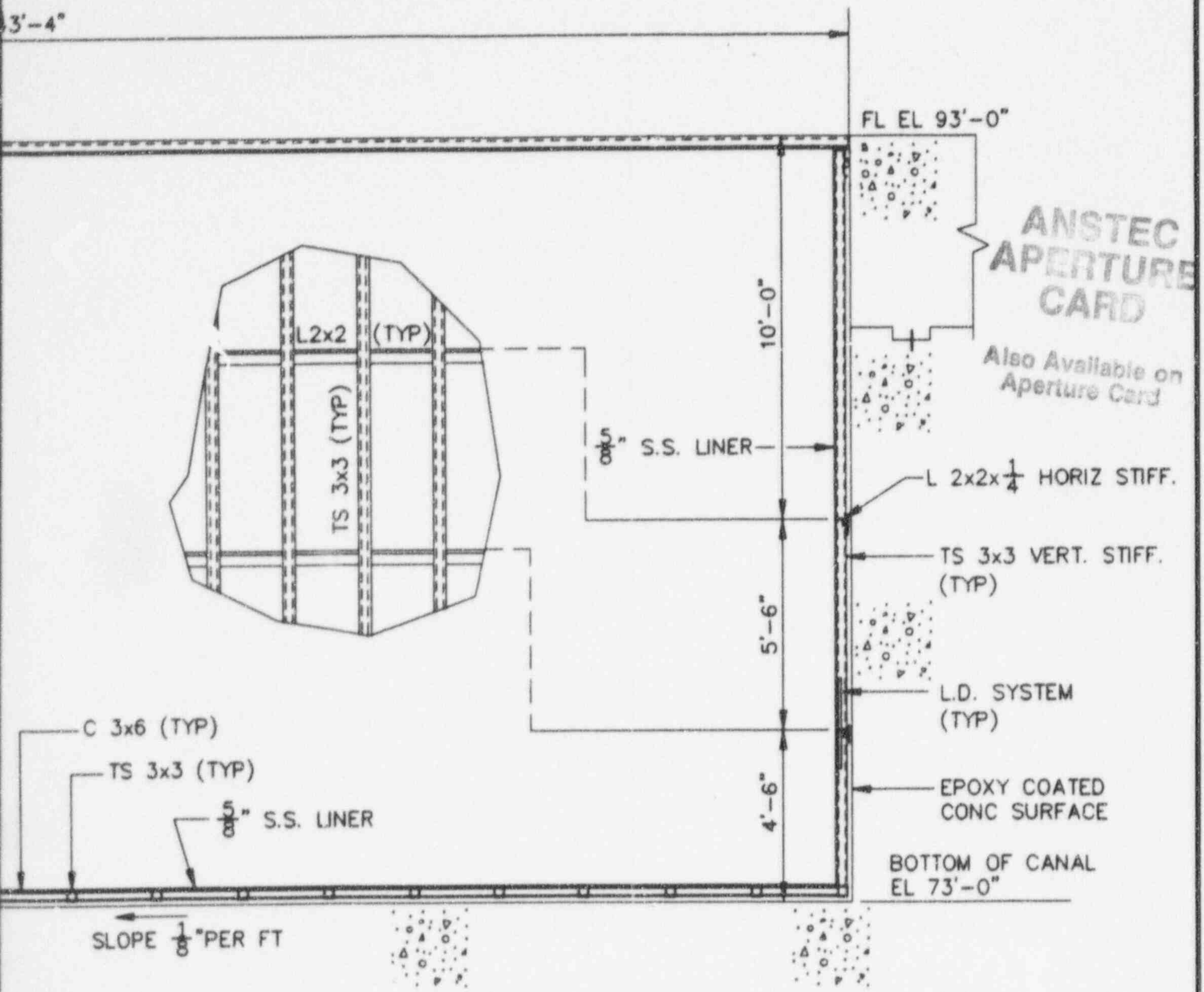
Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
B.S.RANA	C. SHIH	04-01-97	AS NOTED	SK-B-09

9704080218-10



℄ 16"ø PIPE SLEEVE & 12"ø FUEL TRANSFER CHUTE
L 6x3x3/8 &
L 4X3X1/4"
2'-6"
9'-0"
5/8" S.S. LINER
EPOXY COATED
CONC SURFACE
L 2x2x1/4 HORIZ STIFF. (TYP)
TS 3x3x1/4 VERT. STIFF.
(TYP)
HORIZ. STRIP ℞ 1/2"X6"
+SHIM ℞ (ALL AROUND)
5/8"S.S. LINER
(DEEP PIT ONLY)
3'-6"
3'-6"
C 3x6 (TYP)
TS 3x3 (TYP)
5/8"S.S. LINER
EPOXY COATED
CONC SURFACE
BOTTOM OF CANAL
EL 63'-0"
H.P.
SLOPE 1/8" PER FT.



SECTION B–B (SK-B-09)

1/4"=1'-0"

BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

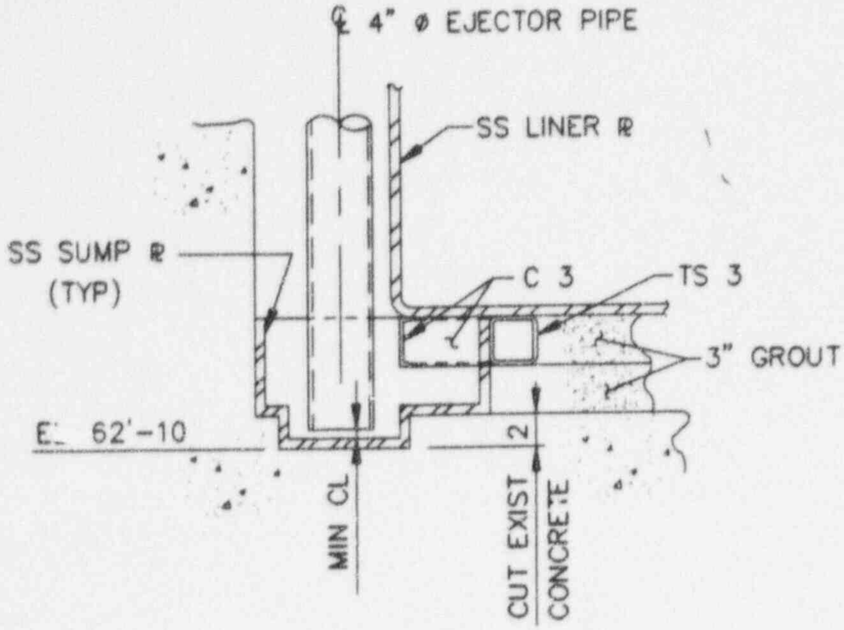
SPENT FUEL CANAL LINER

OPTION E: FREE STANDING LINER WITH L.D. SYS. & CONC COATING ON CANAL FL & WALLS

Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
B.S.RANA	C. SHIH	04-04-97	AS NOTED	SK-B-10

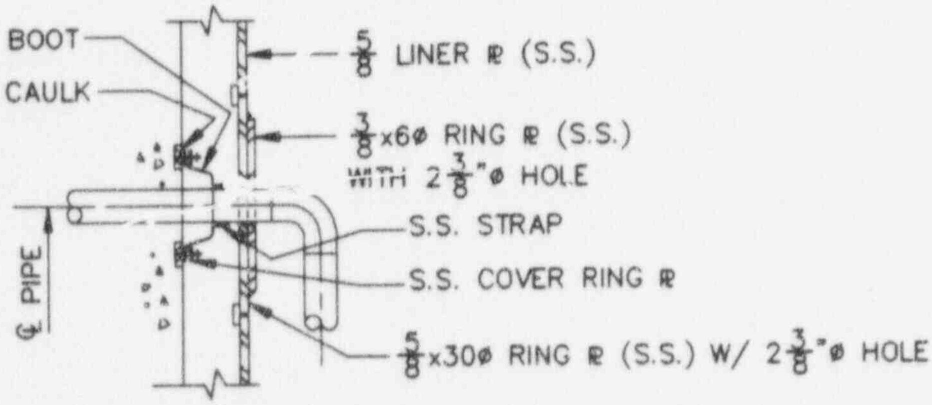
9704080218-11



SECTION D-D

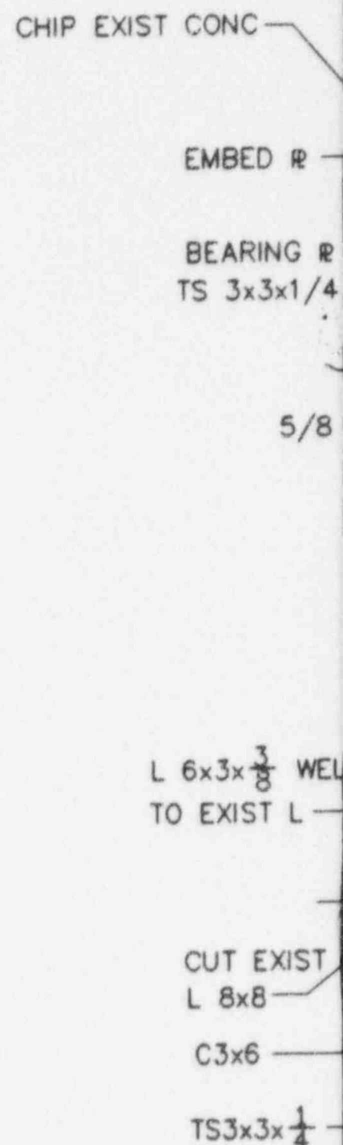
LEAK COLLECTION SUMP

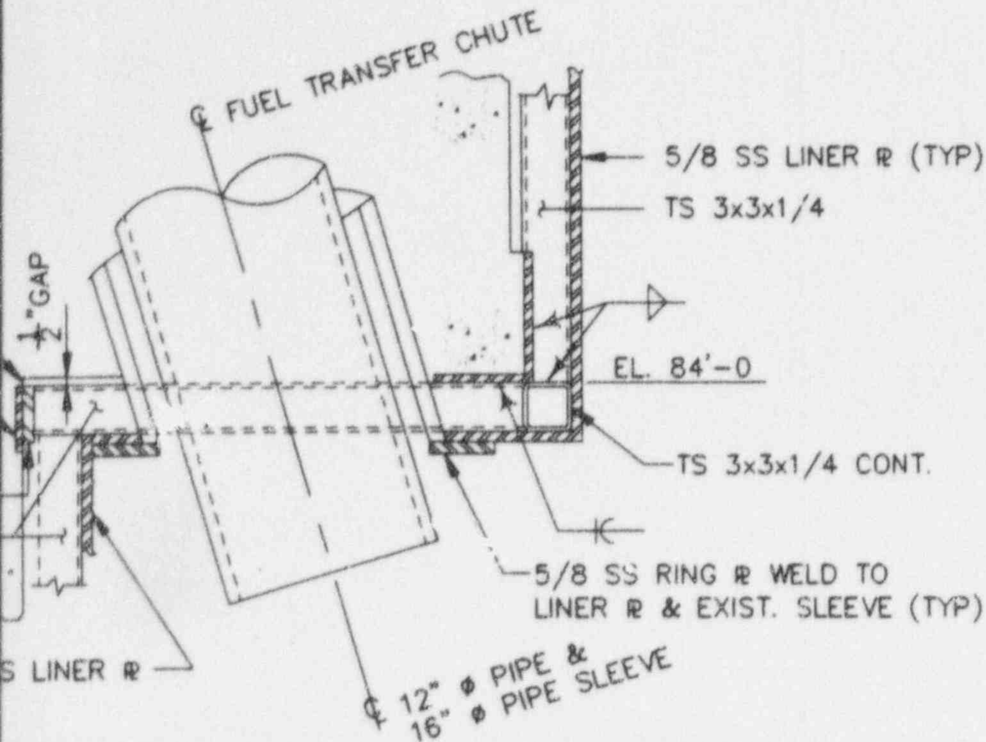
1" = 1'-0



TYP PIPE PENETRATION DETAIL

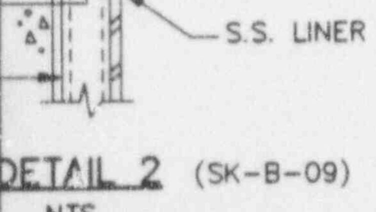
NTS





FUEL TRANSFER CHUTE PENETRATION AND SUPPORT DETAIL

1" = 1'-0



DETAIL 2 (SK-B-09)

NTS

ANSTEC APERTURE CARD

Also Available on Aperture Card

BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

SPENT FUEL CANAL LINER

OPTION E: MISCELLANEOUS DETAILS

Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
S.M.G.	C. SHIH	03-26-97	AS NOTED	SK-B-11

9704080218-12

BILL OF MATER

OPTION A		OPTION B		OPT
$\frac{5}{8}$" S.S. LINER ⅊	7029 SF	$\frac{5}{8}$" S.S. LINER ⅊	3076 SF	$\frac{5}{8}$" S.S. LINER
$\frac{1}{2}$ S.S. ⅊	19 SF	$\frac{3}{4}$" S.S. LINER ⅊	438 SF	C 3x6
C 3x6	2340 LF	$\frac{1}{4}$" S.S. LINER ⅊	3514 SF	TS 3x3x$\frac{1}{4}$
TS 3x3x$\frac{1}{4}$	192 LF	C 3x6	2141 LF	L 2x2x$\frac{1}{4}$
TS 2x2x$\frac{1}{4}$	74 LF	TS 2x2x$\frac{1}{4}$	1302 LF	L 4x3x$\frac{1}{4}$
L 4x3x$\frac{1}{4}$	134 LF	L 5x3x$\frac{1}{4}$	134 LF	C 1$\frac{1}{2}$x$\frac{3}{4}$x$\frac{1}{8}$
GROUT	3.5 CY	L 6x3x$\frac{3}{8}$	134 LF	$\frac{1}{4}$ ⅊ (x6 EMB)
		GROUT	35 CY	$\frac{1}{4}$ ⅊ (BEARING
				GROUT

AL (ESTIMATED)

ON C		OPTION D		OPTION E	
	3514 SF	$\frac{1}{4}$" S.S. LINER ℞	3047 SF	$\frac{5}{8}$" S.S. LINER ℞	3451 SF
	268 LF	C 3x6	1800 LF	C 3x6	277 LF
	1726 LF	L 2x2x$\frac{1}{4}$	609 LF	TS 3x3x$\frac{1}{4}$	1800 LF
	270 LF	L 4x3x$\frac{1}{4}$	134 LF	L 2x2x$\frac{1}{4}$	304 LF
	134 LF	L 6x3x$\frac{3}{8}$	134 LF	L 4x3x$\frac{1}{4}$	134 LF
	330 LF	C 1$\frac{1}{2}$x$\frac{3}{4}$x$\frac{1}{8}$	330 LF	L 6x3x$\frac{3}{8}$	134 LF
	403 LF	$\frac{1}{4}$ ℞ (BENT)	32 SF	C 1$\frac{1}{2}$x$\frac{3}{4}$x$\frac{1}{8}$	330 LF
	128 SF	GROUT	58 CY	$\frac{1}{4}$ ℞ (x6 EMB)	403 LF
	8 CY			$\frac{1}{4}$ ℞ (BEARING)	128 SF
				$\frac{1}{4}$ ℞ (BENT)	32 SF
				GROUT	9 CY

BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

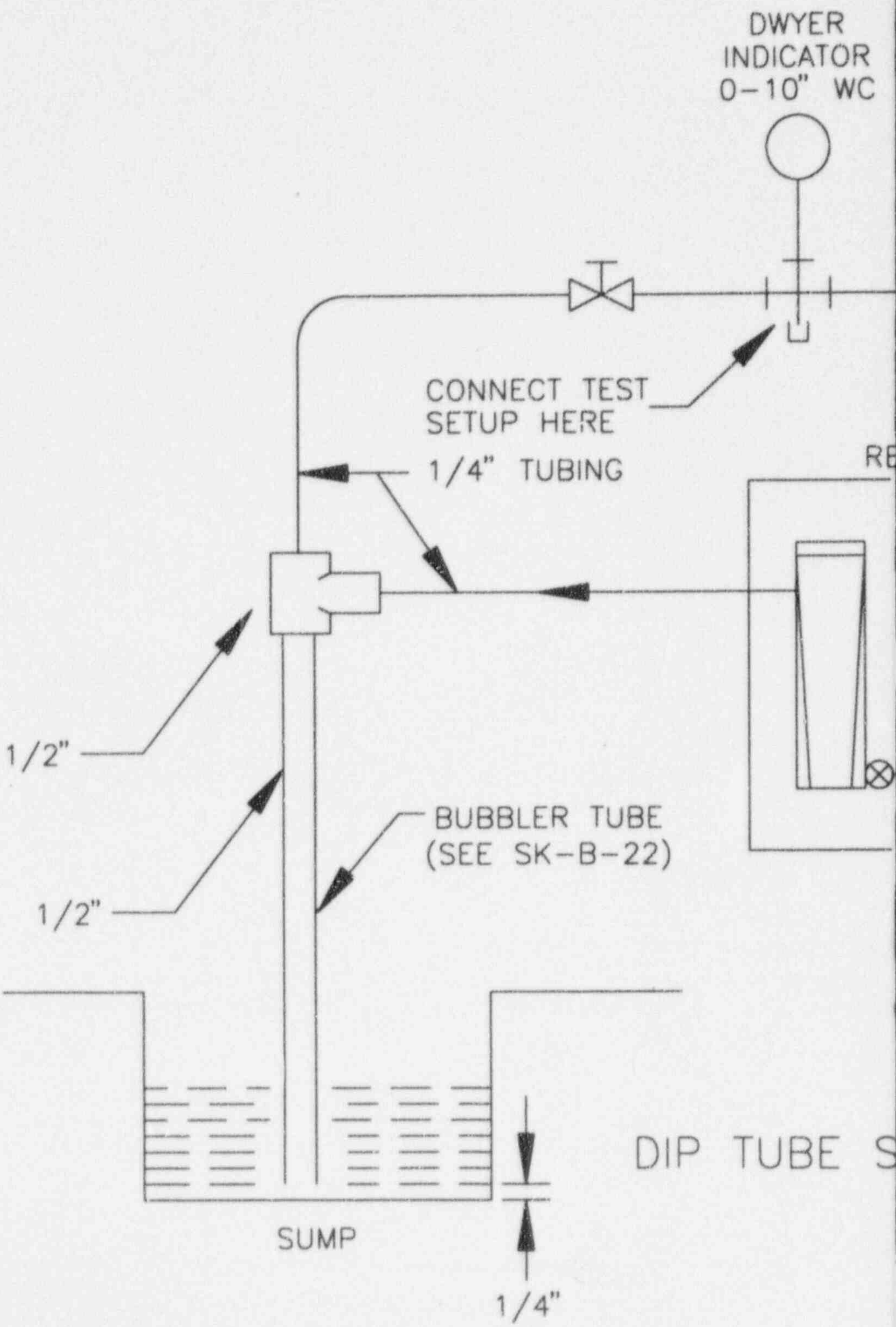
SPENT FUEL CANAL LINER

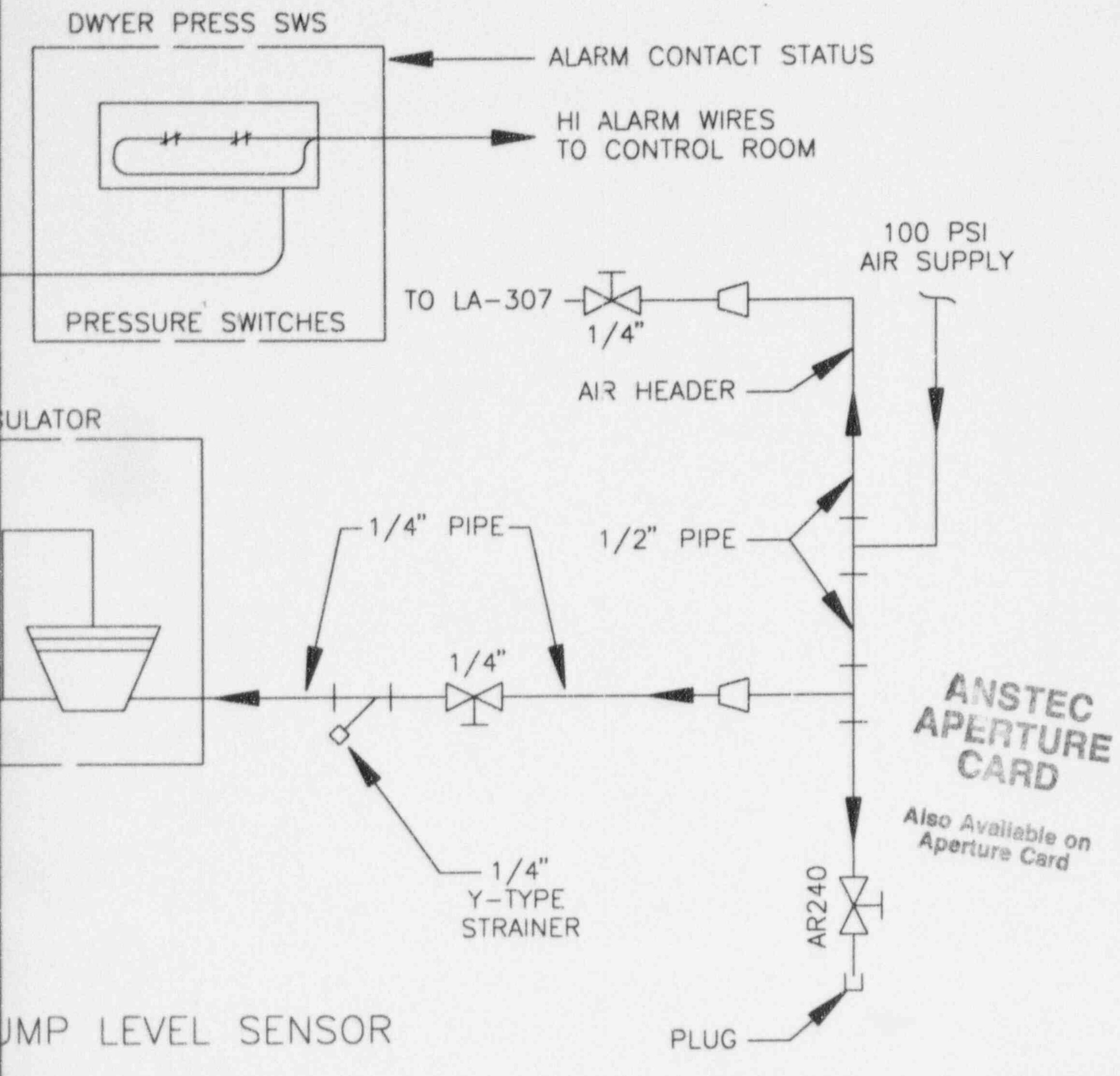
OPTION A THRU E: BILL OF MATERIAL (ESTIMATED)

Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
B.S.RANA	C. SHIH	04-04-97	NONE	SK-B-12

9704080218-13


DWYER
INDICATOR
0-10" WC
CONNECT TEST
SETUP HERE
1/4" TUBING
RE
1/2"
1/2"
BUBBLER TUBE
(SEE SK-B-22)
SUMP
1/4"
DIP TUBE S



BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

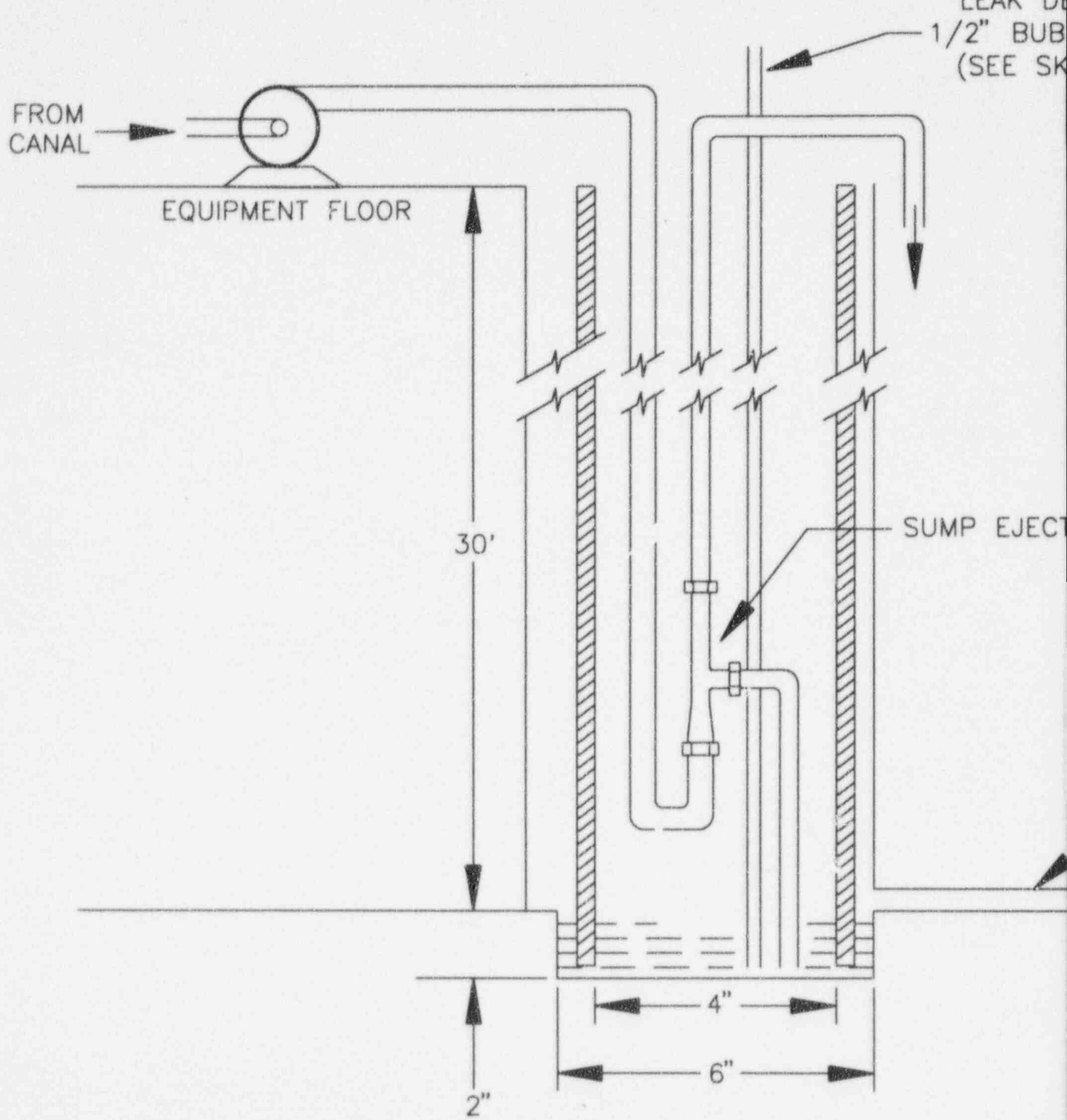
SPENT FUEL CANAL LINER

LEAK DETECTOR

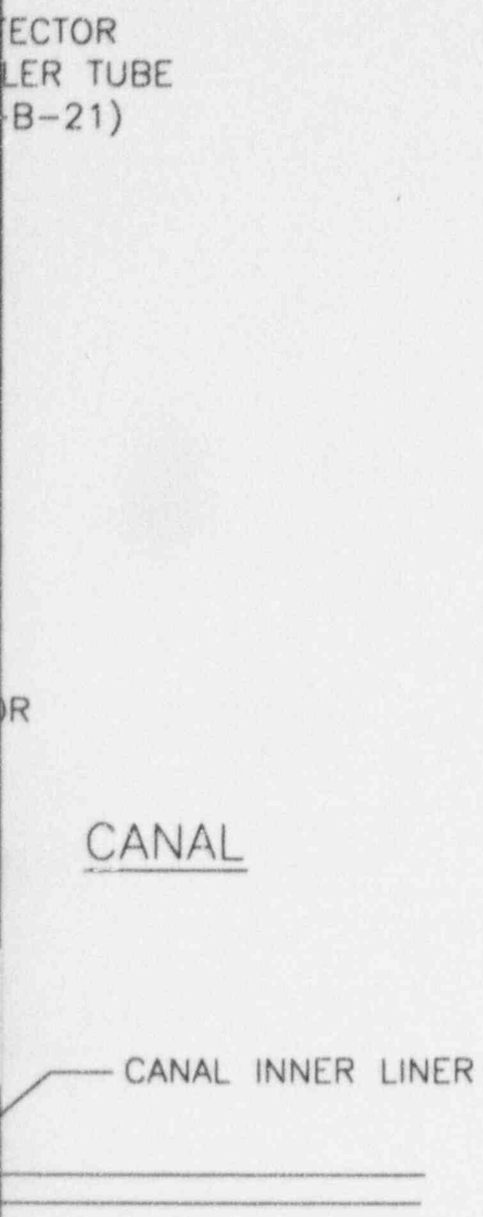
Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
TROMBETTA	J.STEVENS	03-24-97	AS NOTED	SK-B-21

9704080218-14


LEAK DE
1/2" BUB
(SEE SK
FROM
CANAL
EQUIPMENT FLOOR
30'
SUMP EJECT
4"
6"
2"

SUMP



BROOKHAVEN NATIONAL LABORATORY

HIGH FLUX BEAM REACTOR

SPENT FUEL CANAL LINER

SUMP JET PUMP & LEAK DETECTION TUBE

Raytheon ENGINEERS & CONSTRUCTORS

DRAWN:	CHKD:	DATE:	SCALE:	DWG NO.
TROMBETTA	J.STEVENS	03-24-97	AS NOTED	SK-B-22

9704080218-15

C. Schedules for Options A, B, C, D and E

APPENDIX C

C.1 CDR ACCELERATED OPTION COMPARISON (OPTIONS A-E)

EARLY START	EARLY FINISH	ORIG DUR	Activity
			OPTION A: 2 - 5/8"S LINERS, TILED, NO GROUT BACK
21FEB97A	31OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
20MAY97	15AUG97	88	PRELIMINARY ENGINEERING (TITLE I)
1AUG97	8NOV97	100	DETAILED ENGINEERING DESIGN (TITLE II)
16AUG97	17NOV97	94	PROCUREMENT / MATERIAL DELIVERY
30AUG97	13MAR98	196	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
9NOV97	20MAR98	132	LINER/PERIPHERALS CONSTRUCTION
			OPTION B: 5/8 & 1/4 LINER, NO TILES, GROUT BACK
21FEB97A	31OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
20MAY97	15AUG97	88	PRELIMINARY ENGINEERING (TITLE I)
1AUG97	1NOV97	93	DETAILED ENGINEERING DESIGN (TITLE II)
16AUG97	17NOV97	94	PROCUREMENT / MATERIAL DELIVERY
30AUG97	6APR98	220	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
2NOV97	13APR98	163	LINER/PERIPHERALS CONSTRUCTION
			OPTION C: 3/8 LINER, TILED, NO GROUT BACK
21FEB97A	31OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
20MAY97	15AUG97	88	PRELIMINARY ENGINEERING (TITLE I)
1AUG97	25OCT97	86	DETAILED ENGINEERING DESIGN (TITLE II)
16AUG97	17NOV97	94	PROCUREMENT / MATERIAL DELIVERY
30AUG97	7MAR98	190	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
26OCT97	14MAR98	140	LINER/PERIPHERALS CONSTRUCTION
			OPTION D: 1/4 LINER, NO TILES, GROUT BACKED
21FEB97A	31OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
20MAY97	15AUG97	88	PRELIMINARY ENGINEERING (TITLE I)
1AUG97	18OCT97	79	DETAILED ENGINEERING DESIGN (TITLE II)
16AUG97	17NOV97	94	PROCUREMENT / MATERIAL DELIVERY
30AUG97	16MAR98	199	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
19OCT97	23MAR98	156	LINER/PERIPHERALS CONSTRUCTION
			OPTION E: 5/8 LINER, NO TILES, EPOXY COATED CONC
21FEB97A	31OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
20MAY97	15AUG97	88	PRELIMINARY ENGINEERING (TITLE I)
1AUG97	1NOV97	93	DETAILED ENGINEERING DESIGN (TITLE II)
16AUG97	17NOV97	94	PROCUREMENT / MATERIAL DELIVERY
30AUG97	22MAR98	205	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
2NOV97	29MAR98	148	LINER/PERIPHERALS CONSTRUCTION

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL
CDR ACCELERATED OPTION COMPARISON

C.1.1 OPTION A

EARLY START	EARLY FINISH	ORIG DUR	1997: MAY – DEC / 1998: JAN – MAY
OPTION A: 6/10's, TWO SHIFT DESIGN/ENGINEERING SERVICES			
19MAY97		0	DOE ISSUES NOTICE TO PROCEED
20MAY97	15AUG97	88	PRELIMINARY ENGINEERING (TITLE I)
1AUG97		0	ISSUE TITLE I DESIGN REPORT
	15AUG97	0	DOE/BNL REVIEW/ APPROVE - TITLE I DESIGN REPORT
1AUG97	6NOV97	100	DETAILED ENGINEERING DESIGN (TITLE II)
26OCT97		0	ISSUE FINAL DESIGN REPORT (TITLE II)
	8NOV97	0	DOE/BNL REVIEW/APPROVE TITLE II DESIGN REPORT
30AUG97	13MAR98	196	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
PROCUREMENT			
16AUG97	17NOV97	94	PROCUREMENT / MATERIAL DELIVERY
ENVIRONMENTAL			
	15AUG97	0	ENVIRONMENTAL ASSESSMENT
CONSTRUCTION			
21FEB97A	31OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
31OCT97		0	FUEL REMOVED FROM SPENT FUEL STORAGE CANAL
31OCT97	6NOV97	7	REMOVE ITEMS FROM SPENT FUEL STORAGE CANAL
7NOV97	17NOV97	11	DECON SPENT FUEL STORAGE CANAL
9NOV97		0	START PRE-FAB LINER 1ST SECTION/ PERIPHERALS
9NOV97	19JAN98	72	PRE-FAB LINER SECTIONS
18NOV97	1DEC97	14	REPAIR CONCRETE
20DEC97	13MAR98	84	INSTALL MECH./ I&C DETECTION SYSTEM
2DEC97	23FEB98	84	INSTALL LINER SECTIONS

Plot Date 4APR97
Data Date 1MAY97
Project Start 7JAN97
Project Finish 6JUN98

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

CPT1 Sheet 1 of 10

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCHEDULE

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

EARLY START	EARLY FINISH	ORIG DUR	1997 MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	1998 JAN	FEB	MAR	APR	MAY
OPTION A: 6/10's, TWO SHIFT PACKAGE CLOSEOUT															
14MAR98	20MAR98	7											PACKAGE CLOSEOUT		
	20MAR98	0											TURNOVER TO BNL		

Plot Date	4APR97
Data Date	1MAY97
Project Start	7JAN97
Project Finish	6JUN98 *

(c) Primavera Systems, Inc.

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

CPT1

Sheet 2 of 10

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCHEDULE

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

C.1.2 OPTION B

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCHEDULE

CONCEPTUAL DESIGN - BY DISCIPLINE

Timescale: 1997 (MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC) – 1998 (JAN, FEB, MAR, APR, MAY)

EARLY START	EARLY FINISH	ORIG DUR	ACTIVITY
OPTION B: 6/10's, TWO SHIFT DESIGN/ENGINEERING SERVICES			
19MAY97		0	DOE ISSUES NOTICE TO PROCEED
20MAY97	15AUG97	88	PRELIMINARY ENGINEERING (TITLE I)
1AUG97		0	ISSUE TITLE I DESIGN REPORT
	15AUG97	0	DOE/BNL REVIEW/ APPROVE - TITLE I DESIGN REPORT
1AUG97	1NOV97	93	DETAILED ENGINEERING DESIGN (TITLE II)
19OCT97		0	ISSUE FINAL DESIGN REPORT (TITLE II)
	1NOV97	0	DOE/BNL REVIEW/ APPROVE TITLE II DESIGN REPORT
30AUG97	6APR98	220	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
PROCUREMENT			
16AUG97	17NOV97	94	PROCUREMENT / MATERIAL DELIVERY
ENVIRONMENTAL			
	15AUG97	0	ENVIRONMENTAL ASSESSMENT
CONSTRUCTION			
21FEB97A	31OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
31OCT97		0	FUEL REMOVED FROM SPENT FUEL STORAGE CANAL
31OCT97	6NOV97	7	REMOVE ITEMS FROM SPENT FUEL STORAGE CANAL
7NOV97	17NOV97	11	DECON SPENT FUEL STORAGE CANAL
18NOV97	15DEC97	28	TILE/GROUT REMOVAL
2NOV97		0	START PRE-FAB LINER 1ST SECTION/ PERIPHERALS
2NOV97	10JAN98	70	PRE-FAB LINER SECTIONS
16DEC97	5JAN98	21	REPAIR CONCRETE
13JAN98	6APR98	84	INSTALL MECH./ I&C DETECTION SYSTEM

Plot Date 4APR97
Data Date 1MAY97
Project Start 7JAN97
Project Finish 6JUN98 *

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

CPT1 Sheet 3 of 10

Date	Revision	Checked	Approved

EARLY START	EARLY FINISH	ORIG DUR	Activity
OPTION B: 6/10's, TWO SHIFT CONSTRUCTION			
6JAN98	30MAR98	84	INSTALL LINER SECTIONS
19MAR98	1APR98	14	INSTALL BACKING GROUT
PACKAGE CLOSEOUT			
7APR98	13APR98	7	PACKAGE CLOSEOUT
	13APR98	0	TURNOVER TO BNL

Timescale: 1997 — MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC; 1998 — JAN, FEB, MAR, APR, MAY

Plot Date	4APR97
Data Date	1MAY97
Project Start	7JAN97
Project Finish	6JUN98 *

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Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

CPT1 Sheet 4 of 10

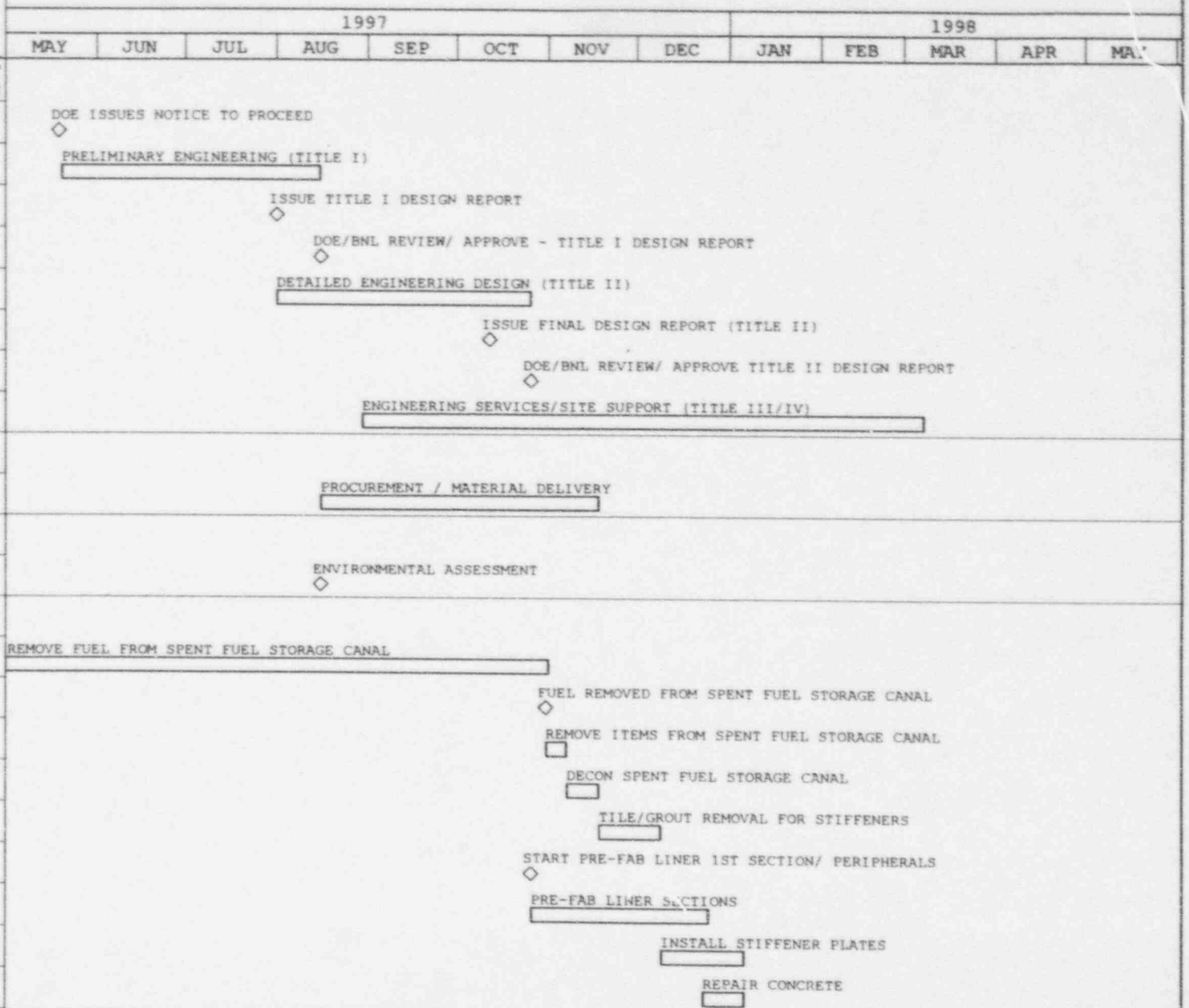
BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCHEDULE

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

C.1.3 OPTION C

EARLY START	EARLY FINISH	ORIG DUR	ACTIVITY
OPTION C: 6/10'S, TWO SHIFT DESIGN/ENGINEERING SERVICES			
19MAY97		0	DOE ISSUES NOTICE TO PROCEED
20MAY97	15AUG97	88	PRELIMINARY ENGINEERING (TITLE I)
1AUG97		0	ISSUE TITLE I DESIGN REPORT
	15AUG97	0	DOE/BNL REVIEW/ APPROVE - TITLE I DESIGN REPORT
1AUG97	25OCT97	86	DETAILED ENGINEERING DESIGN (TITLE II)
12OCT97		0	ISSUE FINAL DESIGN REPORT (TITLE II)
	25OCT97	0	DOE/BNL REVIEW/ APPROVE TITLE II DESIGN REPORT
30AUG97	7MAR98	190	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
PROCUREMENT			
16AUG97	17NOV97	94	PROCUREMENT / MATERIAL DELIVERY
ENVIRONMENTAL			
	15AUG97	0	ENVIRONMENTAL ASSESSMENT
CONSTRUCTION			
21FEB97A	31OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
31OCT97		0	FUEL REMOVED FROM SPENT FUEL STORAGE CANAL
31OCT97	6NOV97	7	REMOVE ITEMS FROM SPENT FUEL STORAGE CANAL
7NOV97	17NOV97	11	DECON SPENT FUEL STORAGE CANAL
18NOV97	8DEC97	21	TILE/GROUT REMOVAL FOR STIFFENERS
26OCT97		0	START PRE-FAB LINER 1ST SECTION/ PERIPHERALS
26OCT97	24DEC97	60	PRE-FAB LINER SECTIONS
9DEC97	5JAN98	28	INSTALL STIFFENER PLATES
23DEC97	5JAN98	14	REPAIR CONCRETE



Plot Date 4APR97
Data Date 1MAY97
Project Start 7JAN97
Project Finish 6JUN98

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

CPT1

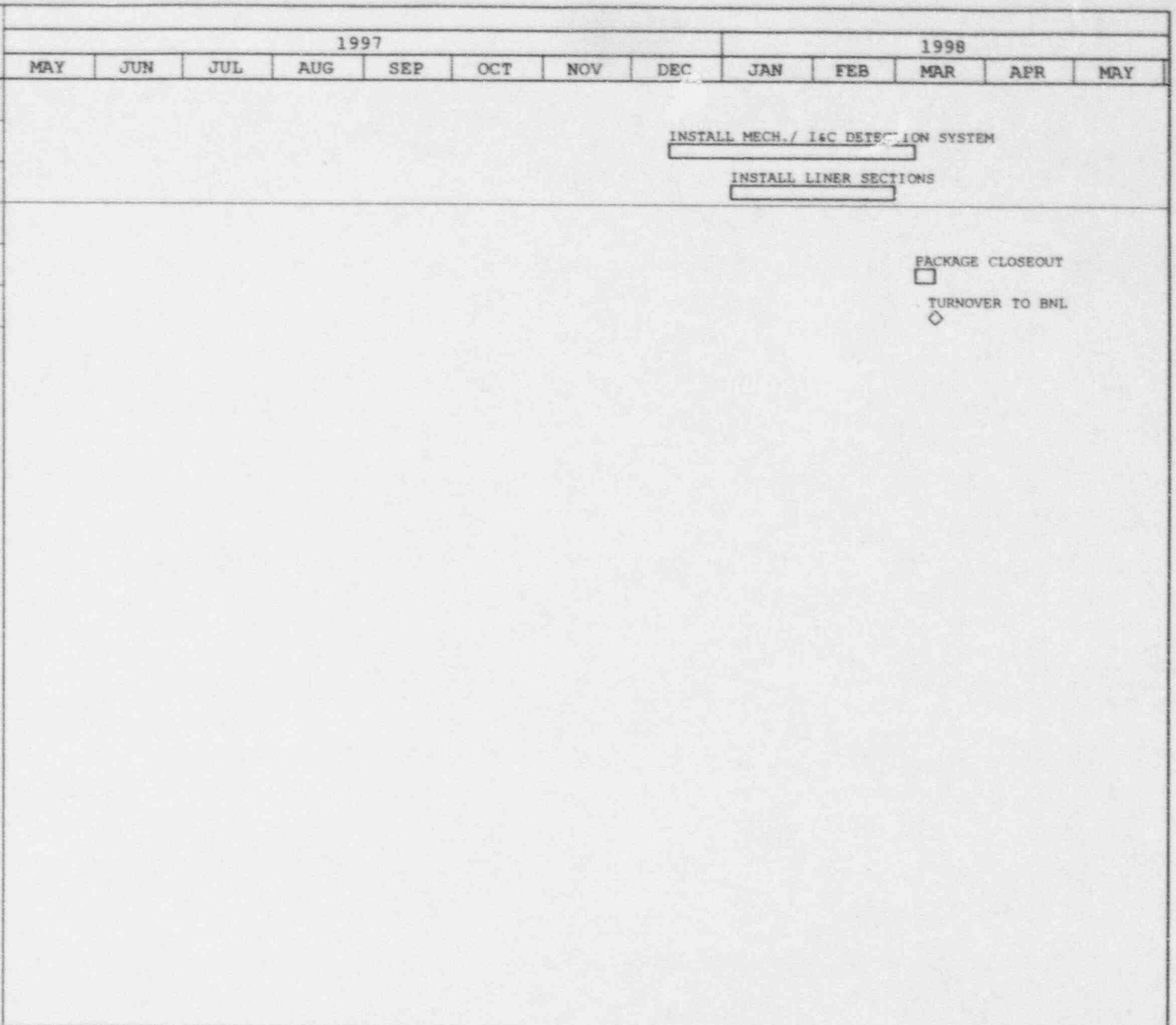
Sheet 5 of 10

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCHEDULE

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

EARLY START	EARLY FINISH	ORIG DUR
OPTION C: 6/10'S, TWO SHIFT CONSTRUCTION		
14DEC97	7MAR98	84
4JAN98	28FEB98	56
PACKAGE CLOSEOUT		
8MAR98	14MAR98	7
	14MAR98	0



Plot Date	4APR97
Data Date	1MAY97
Project Start	7JAN97
Project Finish	6JUN98

(c) Primavera Systems, Inc.

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

CPT1

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BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCHEDULE

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

C.1.4 OPTION D

EARLY START	EARLY FINISH	ORIG DUR	Activity
OPTION D: 6/10's, TWO SHIFT			
DESIGN/ENGINEERING SERVICES			
19MAY97		0	DOE ISSUES NOTICE TO PROCEED
20MAY97	15AUG97	88	PRELIMINARY ENGINEERING (TITLE I)
1AUG97		0	ISSUE TITLE I DESIGN REPORT
	15AUG97	0	DOE/BNL REVIEW/ APPROVE - TITLE I DESIGN REPORT
1AUG97	18OCT97	79	DETAILED ENGINEERING DESIGN (TITLE II)
5OCT97		0	ISSUE FINAL DESIGN REPORT (TITLE II)
	18OCT97	0	DOE/BNL REVIEW/ APPROVE TITLE II DESIGN REPORT
30AUG97	16MAR98	199	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
PROCUREMENT			
16AUG97	17NOV97	94	PROCUREMENT / MATERIAL DELIVERY
ENVIRONMENTAL			
	15AUG97	0	ENVIRONMENTAL ASSESSMENT
CONSTRUCTION			
21FEB97A	31OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
31OCT97		0	FUEL REMOVED FROM SPENT FUEL STORAGE CANAL
31OCT97	6NOV97	7	REMOVE ITEMS FROM SPENT FUEL STORAGE CANAL
7NOV97	17NOV97	11	DECON SPENT FUEL STORAGE CANAL
18NOV97	15DEC97	28	TILE/GROUT REMOVAL
19OCT97		0	START PRE-FAB LINER 1ST SECTION/ PERIPHERALS
19OCT97	10DEC97	53	PRE-FAB LINER SECTIONS
16DEC97	29DEC97	14	INSTALL STIFFENER PLATES
30DEC97	19JAN98	21	REPAIR CONCRETE & APPLY/CURE EPOXY

Timescale: 1997 — MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC; 1998 — JAN, FEB, MAR, APR, MAY

Plot Date 4APR97
Data Date 1MAY97
Project Start 7JAN97
Project Finish 6JUN98 *

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

CPT1

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCHEDULE

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

EARLY START	EARLY FINISH	ORIG DUR	Activity (1997: MAY–DEC; 1998: JAN–MAY)
OPTION D: 6/10's, TWO SHIFT CONSTRUCTION			
23DEC97	16MAR98	84	INSTALL MECH./ I&C DETECTION SYSTEM
13JAN98	9MAR98	56	INSTALL LINER SECTIONS
25FEB98	10MAR98	14	INSTALL BACKING GROUT
PACKAGE CLOSEOUT			
17MAR98	23MAR98	7	PACKAGE CLOSEOUT
	23MAR98	0	TURNOVER TO BNL

Plot Date 4APR97
Data Date 1MAY97
Project Start 7JAN97
Project Finish 6JUN98

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

CPT1

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BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCHEDULE

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

C.1.5 OPTION E

EARLY START	EARLY FINISH	ORIG DUR	Activity
OPTION E: 6/10's, TWO SHIFT			
DESIGN/ENGINEERING SERVICES			
19MAY97		0	DOE ISSUES NOTICE TO PROCEED
20MAY97	15AUG97	88	PRELIMINARY ENGINEERING (TITLE I)
1AUG97		0	ISSUE TITLE I DESIGN REPORT
	15AUG97	0	DOE/BNL REVIEW/ APPROVE - TITLE I DESIGN REPORT
1AUG97	1NOV97	93	DETAILED ENGINEERING DESIGN (TITLE II)
19OCT97		0	ISSUE FINAL DESIGN REPORT (TITLE II)
	1NOV97	0	DOE/BNL REVIEW/ APPROVE TITLE II DESIGN REPORT
30AUG97	22MAR98	205	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
PROCUREMENT			
16AUG97	17NOV97	94	PROCUREMENT / MATERIAL DELIVERY
ENVIRONMENTAL			
	15AUG97	0	ENVIRONMENTAL ASSESSMENT
CONSTRUCTION			
21FEB97A	31OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
31OCT97		0	FUEL REMOVED FROM SPENT FUEL STORAGE CANAL
31OCT97	6NOV97	7	REMOVE ITEMS FROM SPENT FUEL STORAGE CANAL
7NOV97	17NOV97	11	DECON SPENT FUEL STORAGE CANAL
18NOV97	15DEC97	28	TILE/GROUT REMOVAL
2NOV97		0	START PRE-FAB LINER 1ST SECTION/ PERIPHERALS
2NOV97	7JAN98	67	PRE-FAB LINER SECTIONS
16DEC97	23DEC97	8	INSTALL STRIP PLATE SUPPORTS
24DEC97	1FEB98	40	REPAIR CONCRETE & APPLY/CURE EPOXY

Timeline: 1997 (MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC); 1998 (JAN, FEB, MAR, APR, MAY)

Plot Date 4APR97
Data Date 1MAY97
Project Start 7JAN97
Project Finish 6JUN98 *

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

CPT1

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BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCHEDULE

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

EARLY START	EARLY FINISH	ORIG DUR	1997 MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	1998 JAN	FEB	MAR	APR	MAY
OPTION E: 6/10's, TWO SHIFT CONSTRUCTION															
25DEC97	22MAR98	88	INSTALL MECH./ I&C DETECTION SYSTEM												
14JAN98	14MAR98	60	INSTALL LINER SECTIONS												
PACKAGE CLOSEOUT															
23MAR98	29MAR98	7	PACKAGE CLOSEOUT												
	29MAR98	0	TURNOVER TO BNL												

Plot Date 4APR97
Data Date 1MAY97
Project Start 7JAN97
Project Finish 6JUN98

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

CPT1

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BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCHEDULE

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

C.2 CDR NON-ACCELERATED OPTION COMPARISON (OPTIONS A, B & E)

EARLY START	EARLY FINISH	ORIG DUR	ACTIVITY (1997: MAY–DEC; 1998: JAN–OCT)
			OPTION A: 2 - 5/8's LINERS, TILED, NO GROUT BACK
21FEB97 0:00A	3NOV97 14:59	1048	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
20MAY97 7:00	15AUG97 10:59	500	PRELIMINARY ENGINEERING (TITLE I)
1AUG97 7:00	10NOV97 7:59	561	DETAILED ENGINEERING DESIGN (TITLE II)
15AUG97 11:00	17NOV97 10:59	520	PROCUREMENT / MATERIAL DELIVERY
29AUG97 11:00	14JUL98 7:59	1754	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
10NOV97 9:00	21JUL98 7:59	1396	LINER/PERIPHERALS CONSTRUCTION
			OPTION B: 5/8 & 1/4 LINER, NO TILES, GROUT BACK
21FEB97 0:00A	3NOV97 14:59	1048	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
20MAY97 7:00	15AUG97 10:59	500	PRELIMINARY ENGINEERING (TITLE I)
1AUG97 7:00	3NOV97 7:59	521	DETAILED ENGINEERING DESIGN (TITLE II)
15AUG97 11:00	17NOV97 7:59	517	PROCUREMENT / MATERIAL DELIVERY
29AUG97 11:00	2SEP98 7:59	2042	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
3NOV97 8:00	10SEP98 7:59	1725	LINER/PERIPHERALS CONSTRUCTION
			OPTION E: 5/8 LINER, NO TILES, EPOXY COATED CONC
21FEB97 0:00A	3NOV97 14:59	1048	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
20MAY97 7:00	15AUG97 10:59	500	PRELIMINARY ENGINEERING (TITLE I)
1AUG97 7:00	3NOV97 7:59	521	DETAILED ENGINEERING DESIGN (TITLE II)
15AUG97 11:00	17NOV97 7:59	517	PROCUREMENT / MATERIAL DELIVERY
29AUG97 11:00	30JUL98 7:59	1850	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
3NOV97 8:00	6AUG98 7:59	1533	LINER/PERIPHERALS CONSTRUCTION

Plot Date 4APR97 16:23
Data Date 1MAY97 7:00
Project Start 7JAN97 7:00
Project Finish 1OCT98 23:59

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL
CDR NON-ACCELERATED OPT. COMPARISION

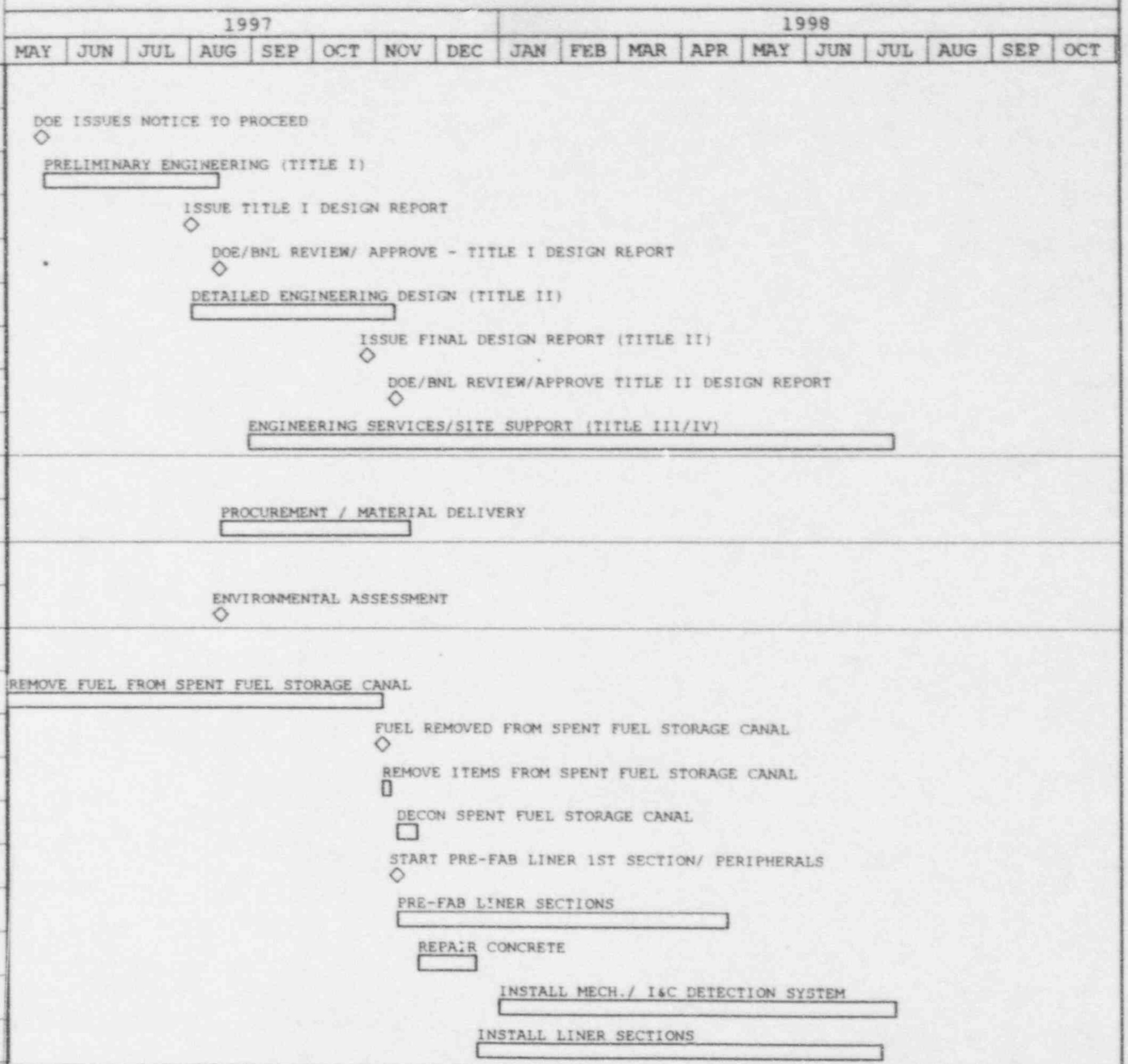
Sheet 1 of 1

CONCEPTUAL DESIGN OPTIONS

Date	Revision	Checked	Approved

C.2.1 OPTION A

EARLY START	EARLY FINISH	ORIG DUR	ACTIVITY
OPTION A - 5/8 SINGLE SHIFT DESIGN/ENGINEERING SERVICES			
19MAY97 7:00		0	DOE ISSUES NOTICE TO PROCEED
20MAY97 7:00	15AUG97 10:59	500	PRELIMINARY ENGINEERING (TITLE I)
1AUG97 11:00		0	ISSUE TITLE I DESIGN REPORT
	15AUG97 10:59	0	DOE/BNL REVIEW/ APPROVE - TITLE I DESIGN REPORT
1AUG97 7:00	10NOV97 7:59	561	DETAILED ENGINEERING DESIGN (TITLE II)
27OCT97 8:00		0	ISSUE FINAL DESIGN REPORT (TITLE II)
	10NOV97 8:59	0	DOE/BNL REVIEW/APPROVE TITLE II DESIGN REPORT
29AUG97 11:00	14JUL98 7:59	1754	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
PROCUREMENT			
15AUG97 11:00	17NOV97 10:59	520	PROCUREMENT / MATERIAL DELIVERY
ENVIRONMENTAL			
	15AUG97 7:59	0	ENVIRONMENTAL ASSESSMENT
CONSTRUCTION			
21FEB97 0:00A	3NOV97 14:59	1048	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
3NOV97 7:00		0	FUEL REMOVED FROM SPENT FUEL STORAGE CANAL
3NOV97 7:00	7NOV97 14:59	40	REMOVE ITEMS FROM SPENT FUEL STORAGE CANAL
10NOV97 7:00	20NOV97 12:59	70	DECON SPENT FUEL STORAGE CANAL
10NOV97 9:00		0	START PRE-FAB LINER 1ST SECTION/ PERIPHERALS
10NOV97 9:00	22APR98 11:59	904	PRE-FAB LINER SECTIONS
20NOV97 13:00	19DEC97 12:59	160	REPAIR CONCRETE
30DEC97 8:00	14JUL98 7:59	1088	INSTALL MECH./ I&C DETECTION SYSTEM
19DEC97 13:00	7JUL98 7:59	1088	INSTALL LINER SECTIONS



Plot Date	4APR97 18:25
Data Date	1MAY97 7:00
Project Start	7JAN97 7:00
Project Finish	1OCT98 23:59

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

Sheet 1 of 6

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR NON-ACCELERATED OPT. COMPARISION

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

EARLY START	EARLY FINISH	ORIG DUR	Activity
OPTION A - 5/8 SINGLE SHIFT PACKAGE CLOSEOUT			
14JUL98 8:00	21JUL98 7:59	40	PACKAGE CLOSEOUT
	21JUL98 7:59	0	TURNOVER TO BNL

Timescale: 1997 — MAY JUN JUL AUG SEP OCT NOV DEC; 1998 — JAN FEB MAR APR MAY JUN JUL AUG SEP OCT

Plot Date 4APR97 18:25
Data Date 1MAY97 7:00
Project Start 7JAN97 7:00
Project Finish 1OCT98 23:59

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

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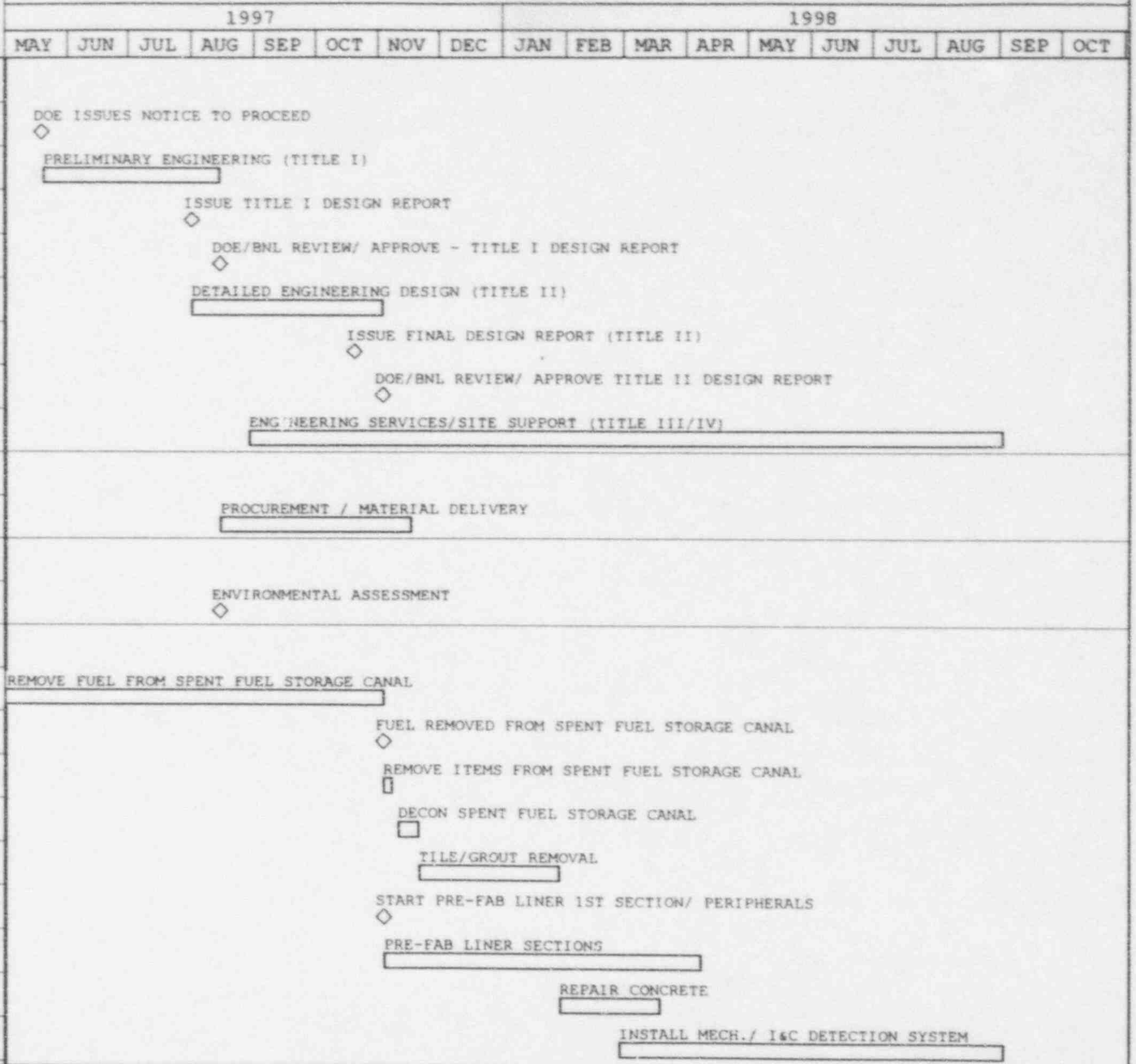
BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR NON-ACCELERATED OPT. COMPARISION

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

C.2.2 OPTION B

EARLY START	EARLY FINISH	ORIG DUR	ACTIVITY
OPTION B - 5/8 SINGLE SHIFT DESIGN/ENGINEERING SERVICES			
19MAY97 7:00		0	DOE ISSUES NOTICE TO PROCEED
20MAY97 7:00	15AUG97 10:59	500	PRELIMINARY ENGINEERING (TITLE I)
1AUG97 11:00		0	ISSUE TITLE I DESIGN REPORT
	15AUG97 10:59	0	DOE/BNL REVIEW/ APPROVE - TITLE I DESIGN REPORT
1AUG97 7:00	3NOV97 7:59	521	DETAILED ENGINEERING DESIGN (TITLE II)
20OCT97 7:00		0	ISSUE FINAL DESIGN REPORT (TITLE II)
	3NOV97 7:59	0	DOE/BNL REVIEW/ APPROVE TITLE II DESIGN REPORT
29AUG97 11:00	2SEP98 7:59	2042	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
PROCUREMENT			
15AUG97 11:00	17NOV97 7:59	517	PROCUREMENT / MATERIAL DELIVERY
ENVIRONMENTAL			
	15AUG97 7:59	0	ENVIRONMENTAL ASSESSMENT
CONSTRUCTION			
21FEB97 0:00A	3NOV97 14:59	1048	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
3NOV97 7:00		0	FUEL REMOVED FROM SPENT FUEL STORAGE CANAL
3NOV97 7:00	7NOV97 14:59	40	REMOVE ITEMS FROM SPENT FUEL STORAGE CANAL
10NOV97 7:00	20NOV97 12:59	70	DECON SPENT FUEL STORAGE CANAL
20NOV97 13:00	28JAN98 7:59	360	TILE/GROUT REMOVAL
3NOV97 8:00		0	START PRE-FAB LINER 1ST SECTION/ PERIPHERALS
3NOV97 8:00	7APR98 14:59	860	PRE-FAB LINER SECTIONS
28JAN98 8:00	18MAR98 7:59	272	REPAIR CONCRETE
26FEB98 8:00	2SEP98 7:59	1056	INSTALL MECH./ I&C DETECTION SYSTEM



Plot Date	4APR97 18:25
Data Date	1MAY97 7:00
Project Start	7JAN97 7:00
Project Finish	1OCT98 23:59 *

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

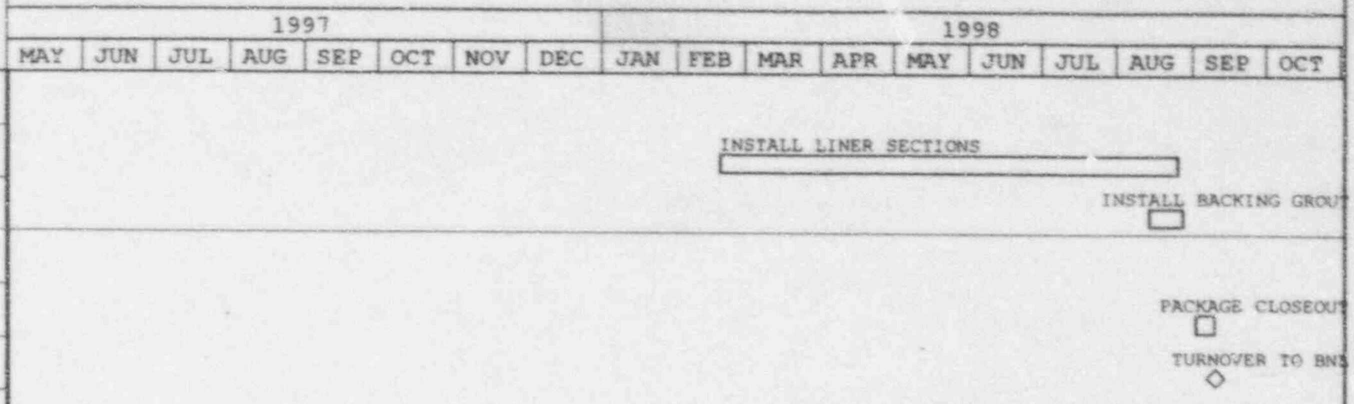
BOX5 Sheet 3 of 6

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR NON-ACCELERATED OPT. COMPARISION

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

EARLY START	EARLY FINISH	ORIG DUR
OPTION B - 5/8 SINGLE SHIFT CONSTRUCTION		
18FEB98 8:00	26AUG98 7:59	1056
14AUG98 8:00	28AUG98 7:59	80
PACKAGE CLOSEOUT		
2SEP98 8:00	10SEP98 7:59	40
	10SEP98 7:59	0



Plot Date	4APR97	18:25
Data Date	1MAY97	7:00
Project Start	7JAN97	7:00
Project Finish	1OCT98	23:59

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Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

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BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR NON-ACCELERATED OPT. COMPARISION

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

C.2.3 OPTION E

EARLY START	EARLY FINISH	ORIG DUR	ACTIVITY
OPTION E - 5/8 SINGLE SHIFT DESIGN/ENGINEERING SERVICES			
19MAY97 7:00		0	DOE ISSUES NOTICE TO PROCEED
20MAY97 7:00	15AUG97 10:59	500	PRELIMINARY ENGINEERING (TITLE I)
1AUG97 11:00		0	ISSUE TITLE I DESIGN REPORT
	15AUG97 10:59	0	BDE/BNL REVIEW/ APPROVE - TITLE I DESIGN REPORT
1AUG97 7:00	3NOV97 7:59	521	DETAILED ENGINEERING DESIGN (TITLE II)
15OCT97 7:00		0	ISSUE FINAL DESIGN REPORT (TITLE II)
	3NOV97 7:59	0	DOE/BNL REVIEW/ APPROVE TITLE II DESIGN REPORT
29AUG97 11:00	30JUL98 7:59	1850	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
PROCUREMENT			
15AUG97 11:00	17NOV97 7:59	517	PROCUREMENT / MATERIAL DELIVERY
ENVIRONMENTAL			
	15AUG97 7:59	0	ENVIRONMENTAL ASSESSMENT
CONSTRUCTION			
21FEB97 0:00A	3NOV97 14:59	1048	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
3NOV97 7:00		0	FUEL REMOVED FROM SPENT FUEL STORAGE CANAL
3NOV97 7:00	7NOV97 14:59	40	REMOVE ITEMS FROM SPENT FUEL STORAGE CANAL
10NOV97 7:00	20NOV97 12:59	70	DECON SPENT FUEL STORAGE CANAL
20NOV97 13:00	28JAN98 7:59	360	TILE/GROUT REMOVAL
3NOV97 8:00		0	START PRE-FAB LINER 1ST SECTION/ PERIPHERALS
3NOV97 8:00	1APR98 8:59	822	PRE-FAB LINER SECTIONS
28JAN98 8:00	17FEB98 7:59	112	INSTALL STRIP PLATE SUPPORTS
17FEB98 8:00	15MAY98 7:59	496	REPAIR CONCRETE & APPLY/CURE EPOXY

Timescale: 1997 (MAY–DEC), 1998 (JAN–OCT)

Plot Date	4APR97 18:25
Data Date	1MAY97 7:00
Project Start	7JAN97 7:00
Project Finish	1OCT98 23:59

Activity Bar/Early Dates; Critical Activity; Progress Bar; Milestone/Flag Activity

(c) Primavera Systems, Inc.

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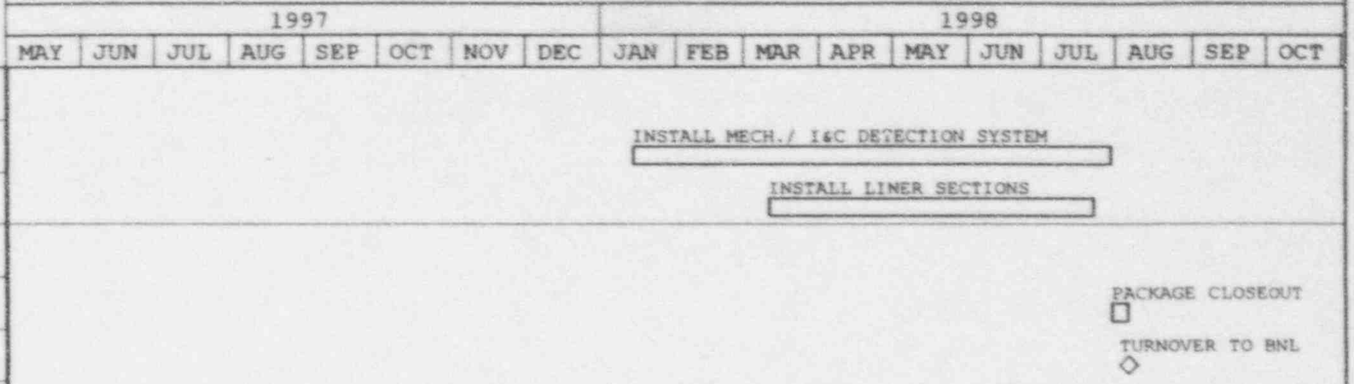
BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR NON-ACCELERATED OPT. COMPARISION

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

EARLY START	EARLY FINISH	ORIG DUR
OPTION E - 5/8 SINGLE SHIFT CONSTRUCTION		
14JAN98 8:00	30JUL98 7:59	1104
11MAR98 8:00	23JUL98 7:59	752
PACKAGE CLOSEOUT		
30JUL98 8:00	6AUG98 7:59	40
	6AUG98 7:59	0



Plot Date	4APR97	18:25
Data Date	1MAY97	7:00
Project Start	7JAN97	7:00
Project Finish	1OCT98	23:59 *

(c) Primavera Systems, Inc.

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

BOR5 Sheet 6 of 6

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR NON-ACCELERATED OPT. COMPARISION

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

EARLY START	EARLY FINISH	ORIG DUR	ACTIVITY
			OPTION E: 5/8 LINER, NO [illegible]LES, EPOXY COATED CONC
21FEB97 0:00A	15OCT97 14:59	1040	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
1MAY97 8:00	1AUG97 13:59	518	PRELIMINARY ENGINEERING (TITLE I)
15JUL97 8:00	15OCT97 7:59	520	DETAILED ENGINEERING DESIGN (TITLE II)
1AUG97 14:00	3NOV97 10:59	517	PROCUREMENT / MATERIAL DELIVERY
15AUG97 14:00	16JUL98 10:59	1850	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
3NOV97 8:00	6AUG98 7:59	1533	LINER/PERIPHERALS CONSTRUCTION

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL
CDR NON-ACCLRTD OPT. WITH BNL MOD.

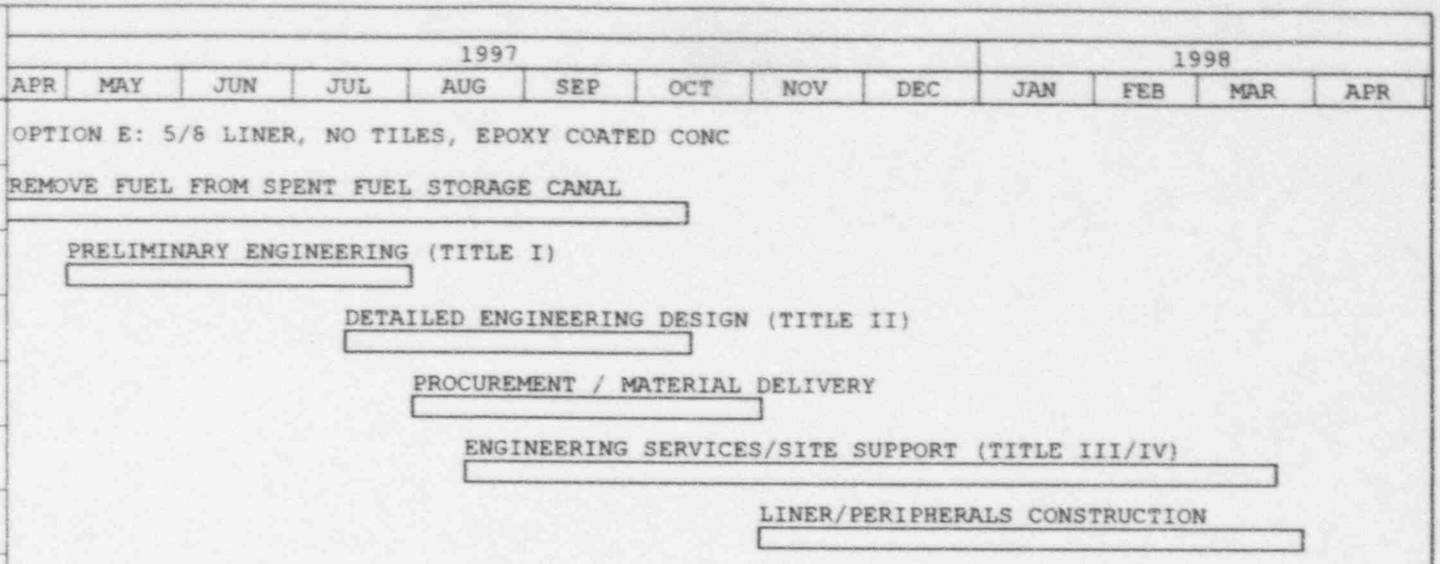
CONCEPTUAL DESIGN OPTIONS

Date	Revision	Checked	Approved

C.3 CDR ACCELERATED WITH BNL MOD OPTION E

OPTION E: 5/8 LINER, NO TILES, EPOXY COATED CONC

EARLY START	EARLY FINISH	ORIG DUR	ACTIVITY
21FEB97A	14OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
1MAY97	1AUG97	93	PRELIMINARY ENGINEERING (TITLE I)
15JUL97	15OCT97	93	DETAILED ENGINEERING DESIGN (TITLE II)
2AUG97	3NOV97	94	PROCUREMENT / MATERIAL DELIVERY
16AUG97	21MAR98	218	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
3NOV97	28MAR98	146	LINER/PERIPHERALS CONSTRUCTION



Plot Date 4APR97
Data Date 14APR97
Project Start 7JAN97
Project Finish 6JUN98 *

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL
CDR ACCELERATED OPTION WITH BNL MOD

Sheet 1 of 1

CONCEPTUAL DESIGN OPTIONS

Date	Revision	Checked	Approved

C.3.1 DETAIL CDR ACCELERATED SCHEDULE - BNL

EARLY START	EARLY FINISH	ORIG DUR	ACTIVITY
OPTION E: 6/10's, TWO SHIFT DESIGN/ENGINEERING SERVICES			
1MAY97		0	DOE ISSUES NOTICE TO PROCEED
1MAY97	1AUG97	93	PRELIMINARY ENGINEERING (TITLE I)
15JUL97		0	ISSUE TITLE I DESIGN REPORT
	1AUG97	0	DOE/BNL REVIEW/ APPROVE - TITLE I DESIGN REPORT
15JUL97	15OCT97	93	DETAILED ENGINEERING DESIGN (TITLE II)
2OCT97		0	ISSUE FINAL DESIGN REPORT (TITLE II)
	15OCT97	0	DOE/BNL REVIEW/ APPROVE TITLE II DESIGN REPORT
16AUG97	21MAR98	218	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
PROCUREMENT			
2AUG97	3NOV97	94	PROCUREMENT / MATERIAL DELIVERY
ENVIRONMENTAL			
	15AUG97	0	ENVIRONMENTAL ASSESSMENT
BNL MODIFICATION PACKAGE			
1SEP97		0	BNL ISSUE MOD PACKAGE: (INITIAL DRAFT)
1SEP97	15SEP97	15	BNL/DOE/NRC REVIEW
16SEP97	30SEP97	15	BNL MOD. PACKAGE: INCORPORATE COMMENTS
1OCT97	15OCT97	15	BNL MODIFICATION PACKAGE: REVIEW AND SIGNOFF
	15OCT97	0	BNL MODIFICATION PACKAGE: FINAL SIGNOFF/APPROVAL
CONSTRUCTION			
21FEB97A	14OCT97	184	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
31OCT97		0	FUEL REMOVED FROM SPENT FUEL STORAGE CANAL
31OCT97	6NOV97	7	REMOVE ITEMS FROM SPENT FUEL STORAGE CANAL

Timeline: 1997 — APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC; 1998 — JAN, FEB, MAR, APR, MAY

Plot Date 4APR97
Data Date 14APR97
Project Start 7JAN97
Project Finish 6JUN98

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

Sheet 1 of 2

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCH. WITH MOD

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

EARLY START	EARLY FINISH	ORIG DUR	Activity (1997: APR–DEC; 1998: JAN–MAY)
OPTION E: 6/10's, TWO SHIFT CONSTRUCTION			
7NOV97	17NOV97	11	DECON SPENT FUEL STORAGE CANAL
18NOV97	15DEC97	28	TILE, GROUT REMOVAL
3NOV97		0	START PRE-FAB LINER 1ST SECTION/ PERIPHERALS
3NOV97	8JAN98	67	PRE-FAB LINER SECTIONS
16DEC97	23DEC97	8	INSTALL STRIP PLATE SUPPORTS
24DEC97	1FEB98	40	REPAIR CONCRETE & APPLY/CURE EPOXY
24DEC97	21MAR98	88	INSTALL MECH./ I&C DETECTION SYSTEM
14JAN98	14MAR98	60	INSTALL LINER SECTIONS
PACKAGE CLOSEOUT			
22MAR98	28MAR98	7	PACKAGE CLOSEOUT
	28MAR98	0	TURNOVER TO BNL

Plot Date 4APR97
Data Date 14APR97
Project Start 7JAN97
Project Finish 6JUN98

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Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

Sheet 2 of 2

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR ACCELERATED OPTION SCH. WITH MOD

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

C.4 CDR NON-ACCELERATED WITH BNL MOD OPTION E

EARLY START	EARLY FINISH	ORIG DUR	1997–1998 (A MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT)
			OPTION E: 5/8 LINER, NO TILES, EPOXY COATED CONC
21FEB97 0:00A	15OCT97 14:59	1040	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
1MAY97 8:00	1AUG97 13:59	518	PRELIMINARY ENGINEERING (TITLE I)
15JUL97 8:00	15OCT97 7:59	520	DETAILED ENGINEERING DESIGN (TITLE II)
1AUG97 14:00	3NOV97 10:59	517	PROCUREMENT / MATERIAL DELIVERY
15AUG97 14:00	30JUL98 10:59	1930	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
3NOV97 8:00	6AUG98 7:59	1533	LINER/PERIPHERALS CONSTRUCTION

Plot Date
Data Date
Project Start
Project Finish

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL
CDR NON-ACCLRTD OPT. WITH BNL MOD.

CONCEPTUAL DESIGN OPTIONS

Date	Revision	Checked	Approved

C.4.1 DETAIL CDR NON-ACCELERATED WITH BNL MOD (OPTION E)

EARLY START	EARLY FINISH	ORIG DUR	Activity (1997: A, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC; 1998: JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT)
OPTION E - 5/8 SINGLE SHIFT DESIGN/ENGINEERING SERVICES			
1MAY97 7:00		0	DOE ISSUES NOTICE TO PROCEED
1MAY97 8:00	1AUG97 13:59	518	PRELIMINARY ENGINEERING (TITLE I)
15JUL97 14:00		0	ISSUE TITLE I DESIGN REPORT
	1AUG97 13:59	0	BCE/BNL REVIEW/ APPROVE - TITLE I DESIGN REPORT
15JUL97 8:00	15OCT97 7:59	520	DETAILED ENGINEERING DESIGN (TITLE II)
26SEP97 8:00		0	ISSUE FINAL DESIGN REPORT (TITLE II)
	15OCT97 8:59	0	DOE/BNL REVIEW/ APPROVE TITLE II DESIGN REPORT
15AUG97 14:00	30JUL98 10:59	1930	ENGINEERING SERVICES/SITE SUPPORT (TITLE III/IV)
PROCUREMENT			
1AUG97 14:00	3NOV97 10:59	517	PROCUREMENT / MATERIAL DELIVERY
ENVIRONMENTAL			
	15AUG97 7:59	0	ENVIRONMENTAL ASSESSMENT
BNL MODIFICATION PACKAGE			
2SEP97 7:00		0	BNL ISSUE MOD PACKAGE: (INITIAL DRAFT)
2SEP97 7:00	15SEP97 14:59	80	BNL/DOE/NRC REVIEW
16SEP97 7:00	30SEP97 14:59	88	BNL MOD. PACKAGE: INCORPORATE COMMENTS
1OCT97 7:00	15OCT97 14:59	88	BNL MODIFICATION PACKAGE: REVIEW AND SIGNOFF
	15OCT97 14:59	0	BNL MODIFICATION PACKAGE: FINAL SIGNOFF
CONSTRUCTION			
21FEB97 0:00A	15OCT97 14:59	1040	REMOVE FUEL FROM SPENT FUEL STORAGE CANAL
3NOV97 7:00		0	FUEL REMOVED FROM SPENT FUEL STORAGE CANAL
3NOV97 7:00	7NOV97 14:59	40	REMOVE ITEMS FROM SPENT FUEL STORAGE CANAL

Plot Date 4APR97 20:53
Data Date 14APR97 7:00
Project Start 7JAN97 7:00
Project Finish 1OCT98 23:59

(c) Primavera Systems, Inc.

Activity Bar/Early Dates; Critical Activity; Progress Bar; Milestone/Flag Activity

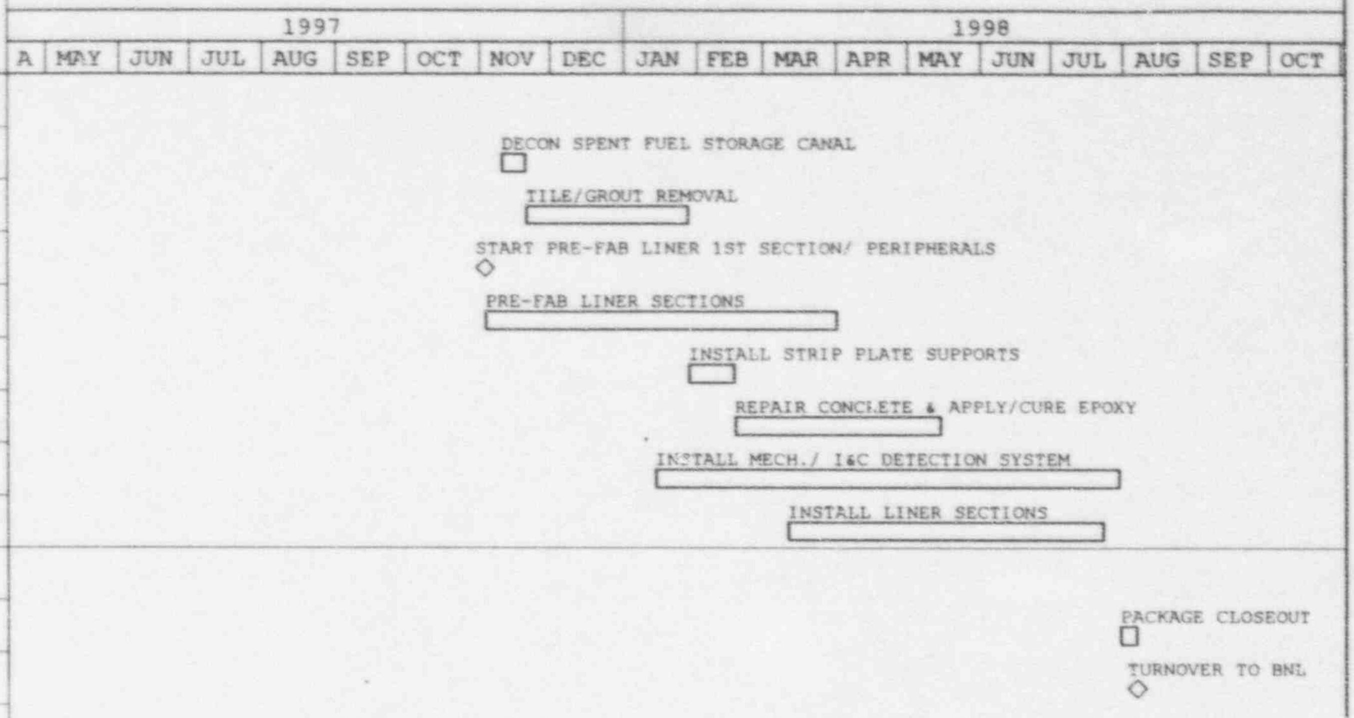
Sheet 1 of 2

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR NON-ACCLRTD OPT. WITH BNL MOD.

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

EARLY START	EARLY FINISH	ORIG DUR	ACTIVITY
OPTION E - 5/8 SINGLE SHIFT CONSTRUCTION			
10NOV97 7:00	20NOV97 12:59	70	DECON SPENT FUEL STORAGE CANAL
20NOV97 13:00	28JAN98 7:59	360	TILE/GROUT REMOVAL
3NOV97 8:00		0	START PRE-FAB LINER 1ST SECTION/ PERIPHERALS
3NOV97 8:00	1APR98 8:59	822	PRE-FAB LINER SECTIONS
28JAN98 8:00	17FEB98 7:59	112	INSTALL STRIP PLATE SUPPORTS
17FEB98 8:00	15MAY98 7:59	496	REPAIR CONCRETE & APPLY/CURE EPOXY
14JAN98 8:00	30JUL98 7:59	1104	INSTALL MECH./ I&C DETECTION SYSTEM
11MAR98 8:00	23JUL98 7:59	752	INSTALL LINER SECTIONS
PACKAGE CLOSEOUT			
30JUL98 8:00	6AUG98 7:59	40	PACKAGE CLOSEOUT
	6AUG98 7:59	0	TURNOVER TO BNL



Plot Date 4APR97 20:53
Data Date 14APR97 7:00
Project Start 7JAN97 7:00
Project Finish 1OCT98 23:59

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

BOB3 Sheet 2 of 2

BROOKHAVEN NATIONAL LABORATORY
HFBR SPENT FUEL STORAGE CANAL LINER
CDR NON-ACCLRTD OPT. WITH BNL MOD.

CONCEPTUAL DESIGN - BY DISCIPLINE

Date	Revision	Checked	Approved

D. Estimates for Options A, B, C, D and E

D.1 ESTIMATE SUMMARY ACCELERATED (OPTIONS A-E)

DESCRIPTION	OPTION A	OPTION B	OPTION C	OPTION D	OPTION E
	FREE STANDING DOUBLE LINER	GROUT BACKED DOUBLE LINER	FREE STANDING SINGLE LINER W/ LEAK DETECTION	GROUT BACKED SINGLE LINER W/ LEAK DETECTION	FREE STANDING LINER W/ LEAK DETECTION & CONCRETE COATING
MOBILIZE	BHL	BNL	BNL	BNL	BNL
MOBILIZE - LINER MODIFICATION	161,396	174,404	162,061	174,404	174,406
PRE-CONSTRUCTION ACTIVITIES	BNL	BNL	BNL	BNL	BNL
NDT CONCRETE TEST & EVALUATION	6,132	6,132	6,132	6,132	6,132
TILE /GROUT REMOVAL	46,157	579,401	99,994	582,910	582,910
CONCRETE REPAIR	89,555	113,028	91,399	144,055	105,055
LINER PLATE PRE FABRICATION	559,021	484,825	353,639	271,092	401,311
EPOXY SEALANT APPLICATION	N/A	N/A	N/A	N/A	68,887
CANAL LINER INSTALLATON	555,426	543,633	760,268	812,278	847,747
LEAK DETECTION SYSTEM INSTALLATION	165,685	168,313	166,923	166,923	166,923
RESTORE FUEL CANAL	BNL	BNL	BNL	BNL	BNL
DEMOBILIZE	57,070	57,070	57,070	57,070	57,070
TOTAL DIRECT COST	1,640,442	2,126,806	1,697,486	2,214,864	2,410,441
TOTAL INDIRECT COST	285,712	286,261	288,912	290,376	292,387
TOTAL CONSTRUCTION COST	1,926,154	2,408,115	1,986,398	2,499,388	2,702,828
A/E COST (INCLDS TITLE I, II, III, & PM)	1,118,120	1,118,120	1,118,120	1,118,120	1,118,120
CONSTRUCT. MANAGEMENT	677,812	677,812	677,812	677,812	677,812
TOTAL SPECIFIC COST	3,722,086	4,204,047	3,782,330	4,295,320	4,498,760
CONTINGENCY (@15%)	558,313	630,607	567,350	644,298	674,814
OH & FEE	254,906	311,773	262,014	322,542	346,546
TOTAL PROJECT COST	4,535,305	5,146,427	4,611,694	5,262,160	5,520,120

D.2 ESTIMATE SUMMARY NON-ACCELERATED (OPTIONS A-E)

BROOKHAVEN NATIONAL LABS
HFBR SPENT FUEL STORAGE
SUMMARY NON-ACCELERATED

DESCRIPTION	OPTION A		OPTION B		OPTION C		OPTION D		OPTION E	
	FREE STANDING DOUBLE LINER		GROUT BACKED DOUBLE LINER		FREE STANDING SINGLE LINER W/ LEAK DETECTION		GROUT BACKED SINGLE LINER W/ LEAK DETECTION		FREE STANDING LINER W/ LEAK DETECTION & CONCRETE COATING	
MOBILIZE	BNL		BNL		BNL		BNL		BNL	
MOBILIZE - LINER MODIFICATION		161,396		174,404		162,061		174,404		174,406
PRE-CONSTRUCTION ACTIVITIES	BNL		BNL		BNL		BNL		BNL	
NDT CONCRETE TEST & EVALUATION		4,345		4,345		4,345		4,345		4,345
TILE /GROUT REMOVAL		31,807		553,739		69,389		556,104		556,104
CONCRETE REPAIR		29,532		93,438		64,645		116,438		82,274
LINER PLATE PRE FABRICATION		559,021		484,825		353,639		271,092		401,311
EPOXY SEALANT APPLICATION	N/A		N/A		N/A		N/A			60,579
CANAL LINER INSTALLATON		322,171		320,345		484,367		516,632		543,533
LEAK DETECTION SYSTEM INSTALLATION		128,482		130,462		129,472		129,472		129,472
RESTORE FUEL CANAL	BNL		BNL		BNL		BNL		BNL	
DEMOBILIZE		54,808		54,808		54,808		54,808		54,808
TOTAL DIRECT COST		1,291,562		1,816,366		1,322,726		1,823,295		2,006,832
TOTAL INDIRECT COST		288,467		289,417		291,308		291,984		293,775
TOTAL CONSTRUCTION COST		1,580,029		2,105,783		1,614,034		2,115,279		2,300,607
A/E COST (INCLDS TITLE I, II, III, & PM)		1,252,120		1,252,120		1,252,120		1,252,120		1,252,120
CONSTRUCT. MANAGEMENT		920,483		920,483		920,483		920,483		920,483
TOTAL SPECIFIC COST		3,752,632		4,278,386		3,786,637		4,287,882		4,473,210
CONTINGENCY (@15%)		562,895		641,758		567,996		643,182		670,982
OH & FEE		219,864		281,898		223,876		283,018		304,885
TOTAL PROJECT COST		4,535,391		5,202,042		4,578,509		5,214,082		5,449,076