MILLSTONE NUCLEAR POWER STATION

UNIT NO. 2

DOCKET NO. 50-335

LICENSE NO. DPR-65

SPENT FUEL DISPOSITION PLANS

March, 1984

CONTENTS

7.0 Rerack

1.0 INTRODUCTION

1.1 The Importance of Spent Fuel Storage Capacity

Effective utilization of industry's substantial investment in nuclear power generation facilities requires that they continue to be operated for their full design life. Continuing operation requires adequate provisions for accommodating the spent fuel which must be discharged periodically. Only limited spent fuel storage capacity has been provided in commercial nuclear power station site facilities because it generally has been assumed that longer term fuel disposition provisions such as reprocessing or ultimate disposal in geologic repositories would be available relatively early in the design life of such plants.

However, it is not clear that this will be the case. Furthermore, under current Federal policy, industry is responsible for interim storage of spent fuel until longer term disposition provisions are available. This mandates that fuel owners give priority attention to meeting their own needs for spent fuel storage capacity.

1.2 General Description of the Millstone Unit No. 2 Spent Fuel Pool

Northeast Nuclear Energy Company's (NNECO) Millstone Unit No. 2 facility received its operating license (DPR-65) in August, 1975. At that time there was capacity to store 301 spent fuel assemblies or about 1.3 full cores in the spent fuel storage pool.

In November 1976, NNECO concluded that a capacity expansion of the spent fuel pool was necessary to support the engineering practice and corporate policy of reserving storage space in the spent fuel pool to receive an entire discharged reactor core ("full-core-off-load") should it become necessary due to operational considerations. Additionally, spent fuel reprocessing facilities were not expected to be available in the near-term.

The spent fuel pool rerack license amendment[1] was obtained and the project was completed prior to the first refueling in the fall of 1977. The modified storage pool provided storage locations for 667 fuel assemblies. The increased spent fuel storage capacity provided for the "full-core-off-load" capability needed beyond the 1978 refueling, as well as the capacity needed for the spent fuel discharges through 1984. The pool design configuration is composed of nine rack modules, each containing 63 fuel assembly storage locations in a 7 x 9 array and one rack module containing 100 fuel assembly storage locations in a 10 x 10 array. The modules are arranged as shown in Figure 1.0 and store the fuel assemblies with a nominal center-to-center spacing of 12.19 inches.

1.3 Basis for the Millstone Unit No. 2 Capacity Expansion Program

In 1985, Millstone Unit No. 2 will lose the reserve capacity necessary to discharge the entire reactor core into the spent fuel pool with the present capacity of 667.

Current circumstances in the back-end of the nuclear fuel cycle make it necessary that fuel owner's establish and implement a plan for "life-of-reactor-storage" of nuclear spent fuel. Numerous utilities are presently planning capacity expansion projects for which interim storage of spent fuel will have to be provided over the next fifteen to twenty years.

Spent fuel consolidation has the potential to meet the needs of a large number of utilities for additional storage capacity in their existing pools at reasonable costs. Spent fuel consolidation refers to a process whereby individual fuel rods are removed from the fuel assembly and arranged in a compact array. Spent fuel consolidation can effectively double the storage capacity of the spent fuel pool by providing a more efficient use of available storage space. Storage of consolidated fuel in spent fuel racks properly designed for the service

loadings associated with consolidated fuel is the best approach to the maximum utilization of storage space available in the spent fuel pool. Moreover, when other modes of interim storage are dictated by weight limitation on existing spent fuel pools, consolidation holds the prospect of substantially reducing the cost associated with the transport and/or storage of the spent fuel.

NNECO intends to apply for the license amendments necessary to support the reracking and the storage of consolidated spent fuel in the Millstone Unit No. 2 spent fuel pool. NNECO intends to develop benchmarked analytical methods and related data on consolidated fuel characteristics that will support the licensing of a spent fuel pool with storage racks that have been designed to criteria for consolidated spent fuel. Additionally, NNECO intends to conduct a "hot demonstration" of spent fuel consolidation with production-scale equipment and processes on approximately five to ten spent fuel assemblies.

1.4 General Description of Proposed Pool

Several recent developments within the nuclear industry have produced new design considerations that influence the spent fuel storage options available to utilities currently planning capacity expansion projects.

The first development is the Nuclear Waste Policy Act (NWPA) of 1982, which requires fuel owners' to provide on-site spent fuel storage until a government repository is available. The second development is proposed NRC Regulatory Guide 1.13, Revision 2, which permits credit to be taken for reactivity depletion in nuclear spent fuel. In particular, this proposed NRC policy permits a new approach to the design of a spent fuel storage rack which will provide a substantially closer center-to-center spacing for increased capacity while eliminating the use of poison material and its

associated engineering complications, complexities and costs. Additionally, the new policy introduces the concept of a "region strategy" that can be employed to achieve the maximum utilization of the storage space available in the spent fuel pool.

The "region strategy", proposed by NNECO for the spent fuel pool design configuration is a two-region dual-pitch pool of both poisoned and non-poisoned spent fuel racks as shown on Figure 1.1.

Region 1 would contain the high-enrichment, core off-load assemblies. Fuel assemblies would be stored in every location. The region consists of poisoned spent fuel racks with a nominal center-to-center cell spacing of 9.8 inches. The five modules of Region 1 totaling 362 storage locations are designed to accommodate 1.6 reactor cores of high enrichment nuclear spent fuel.

The spent fuel rack design for Region 1 is based upon the commonly accepted physics principle of a "neutron flux trap" with the use of neutron absorber materials. The racks are designed to store Millstone Unit No. 2 14 x 14 fuel with an initial enrichment of 4.5 w/o U-235. The poison material to be used is Boroflex.

Region 2 is reserved for fuel that has sustained at least 85% of its design burn-up. Fuel assemblies are stored in a three-out-of-four logic pattern as shown on Figure 1.2. The spent fuel rack design is based on the criticality acceptance criteria specified in Revision 2 of Regulatory Guide 1.13 which allows credit for reactivity depletion in spent fuel. (Previously, the physics criteria for fuel stored in the spent fuel pool were defined by the maximum unirradiated initial enrichment of the fuel.) The fourth location of the storage configuration remains empty to provide the flux trap for reactivity control. Blocking devices will be used to prevent inadvertent placement of a fuel assembly into the fourth location.

Region 2 consists of twelve modules of non-poisoned spent fuel racks whose nominal center-to-center cell spacing is 9.0 inches. The

modules consist of 907 cells with storage capacity for 680 fuel assemblies that have sustained at least 85% of design burn-up.

NNECO intends to utilize the "state of the art" techniques developed for measuring the many properties of irradiated nuclear spent fuel to verify that a fuel assembly complies with the burnup criterion. In particular, a reactivity monitor, an apparatus for measuring directly the subcritical multiplication of individual fuel assemblies, is being developed.

The reactivity monitor is an improved, more precise method for determining the characteristics of the discharged spent fuel. Current practice relies upon administrative procedures which require the detailed power history be made available for each fuel assembly. The power history is then carefully reviewed with complex and time-consuming calculations to determine the burn-up of each assembly.

The reactivity meter places the emphasis on the direct measurement that improves the speed of operation with increased reliability of the burnup determination and verification.

With the reactivity meter, the fuel assembly burn-up determination will be performed in the fuel upender prior to placement of the discharged fuel into the spent fuel pool. Fuel intended for storage in Region 2, once it has passed the reactivity monitor test, could be placed directly into Region 2 of the pool. If the fuel does not pass the reactivity test, it would be placed into Region 1 of the pool.

The spent fuel rack modules in both regions of the fuel pool are designed to be free-standing and direct bearing onto the spent fuel pool floor liner. The rack modules will be fabricated from 304 stainless steel and will be seismically qualified without mechanical dependence on neighboring modules or the pool walls.

The spent fuel rack modules in both regions of the fuel pool will be structurally capable of accommodating the loads generated by the

storage of intact fuel assemblies as well as consolidated spent fuel in every storage location with a consolidated assembly compaction ratio of not less than 2:1.

Since consolidated spent fuel with the water gaps removed is less reactive than intact spent fuel assemblies, storage of consolidated spend fuel can be achieved in every location of the pool.

Both regions of the spent fuel pool have been designed to store both intact fuel assemblies and consolidated spent fuel in a safe, coolable, subcritical configuration with K_{eff} less than 0.95.

The new spent fuel storage racks and supporting analyses will be provided by Combustion Engineering (C-E), Inc.

1.5 Generic Applications

Aspects of the Spent Fuel Capacity Expansion Project at Millstone Unit No. 2 are being performed under cooperative agreements with the Electric Power Research Institute (EPRI). Specifically, one aspect of the project will be the demonstration of the applicability and cost-effectiveness of spent fuel consolidation as a means of meeting future needs for interim on-site spent fuel storage. NNECO intends to apply for a license amendment authorizing spent fuel consolidation at Millstone Unit No. 2.

Fuel consolidation can double the effective storage capacity of properly designed spent fuel storage racks. Loading densities for some pools will be greater than the original design basis. Pool cooling and purification systems and structural capabilities must be examined in detail. Spent fuel racks must be designed to carry the greater loads associated with consolidated fuel. Methods must be developed to model the consolidated spent fuel envelope for seismic, structural, criticality, and thermal-hydraulic analyses.

The NNECO Spent Fuel Capacity Expansion Project will develop benchmarked analytical methods and related data on consolidated fuel characteristics in support of a license amendment for the storage of consolidated fuel in the Millstone Unit No. 2 spent fuel pool. A demonstration of fuel consolidation with production-scale equipment and processes is also planned.

Specific outputs of the project that are expected to be of generic value include the following:

- o Application for appropriate licenses to the NRC for fuel consolidation in the Millstone Unit No. 2 spent fuel pool.
- o Development of non-proprietary codes (where applicable) for use in licensing activities for fuel consolidation.
- o Design, fabrication, and demonstration of advanced fuel consolidation equipment.
- o Demonstration of equipment to handle, disposition and package waste fuel assembly skeleton hardware.
- o Generation of a Thermal/hydraulic data base by performing heated flow experiments which simulate consolidated fuel conditions.

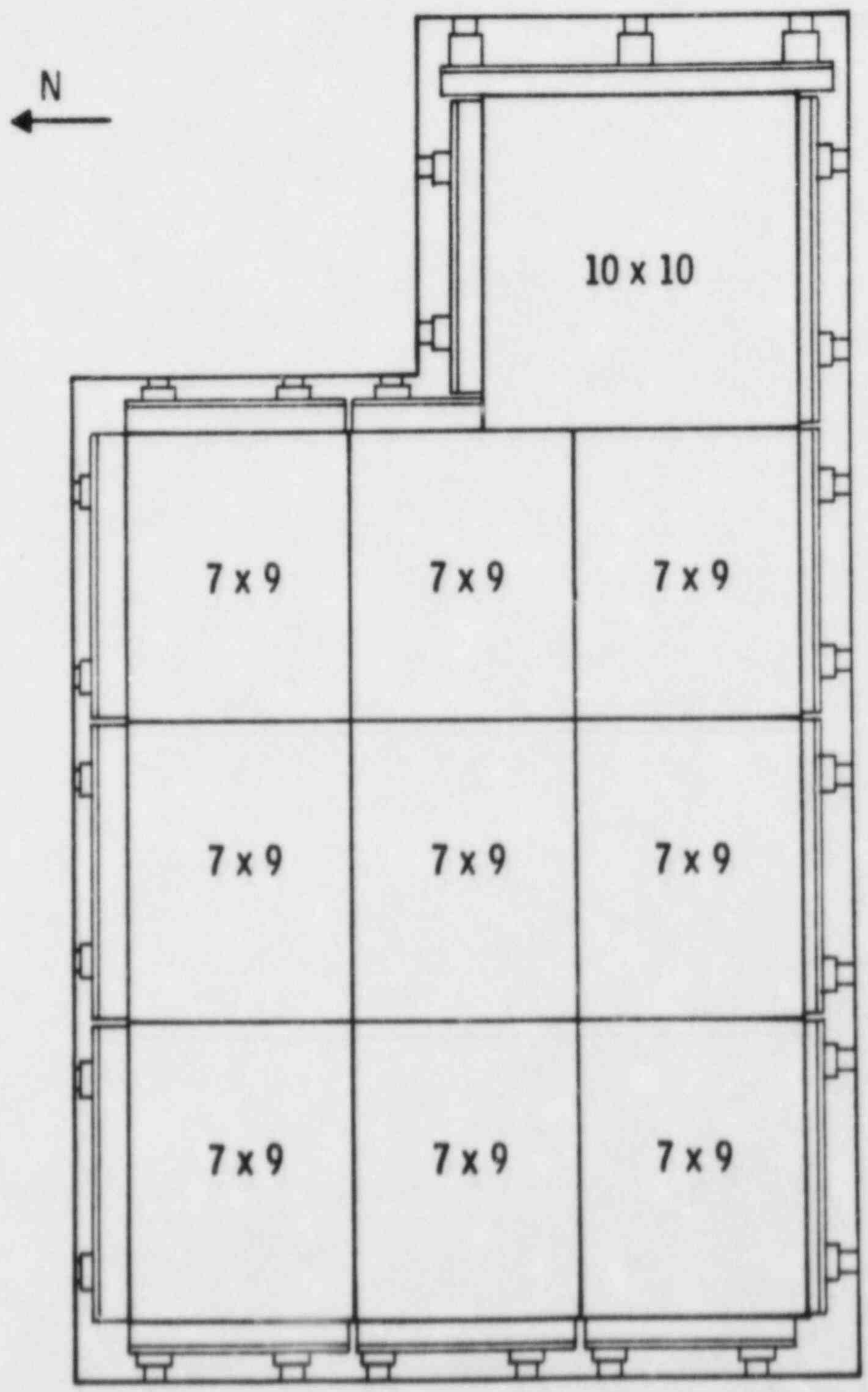
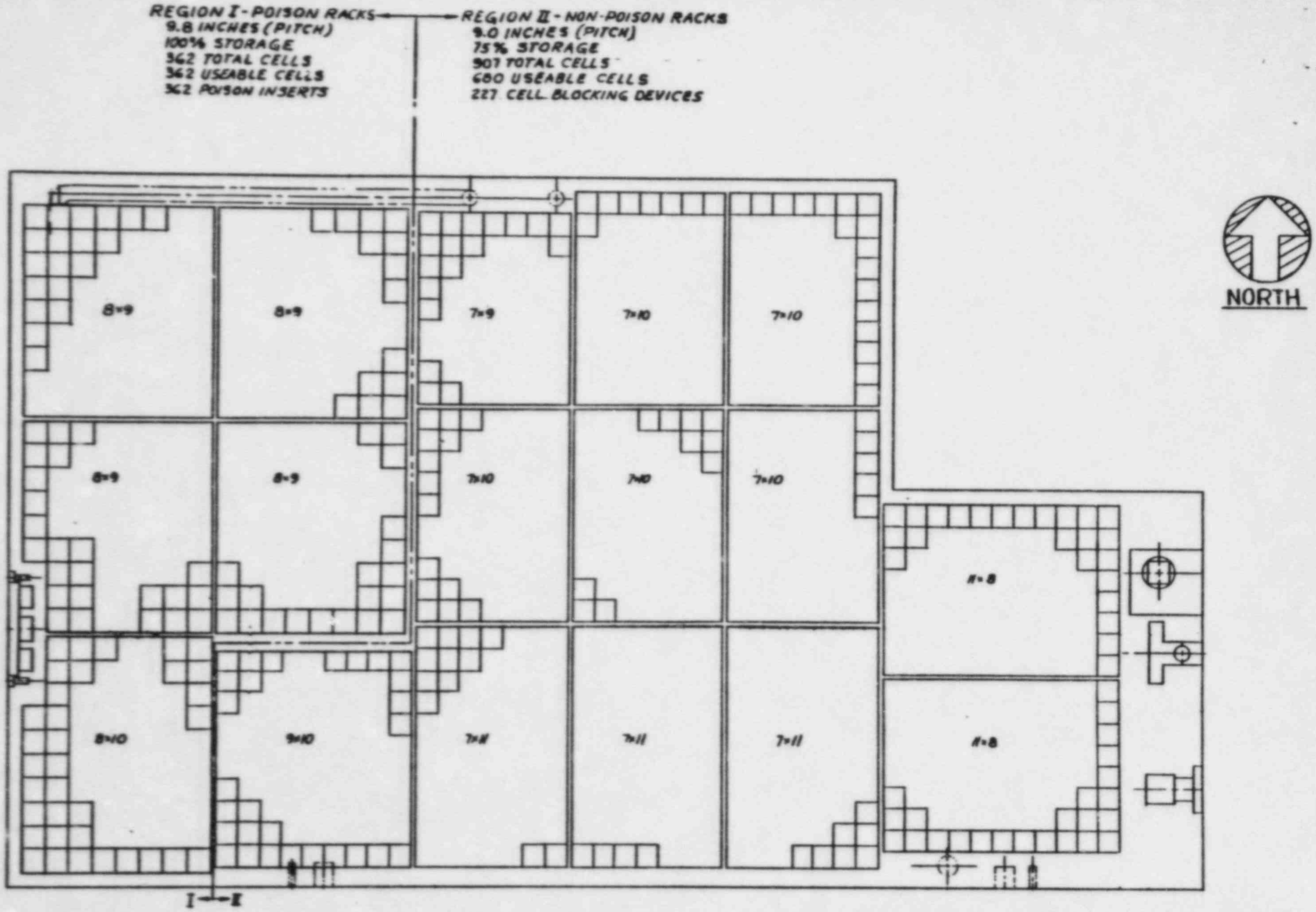


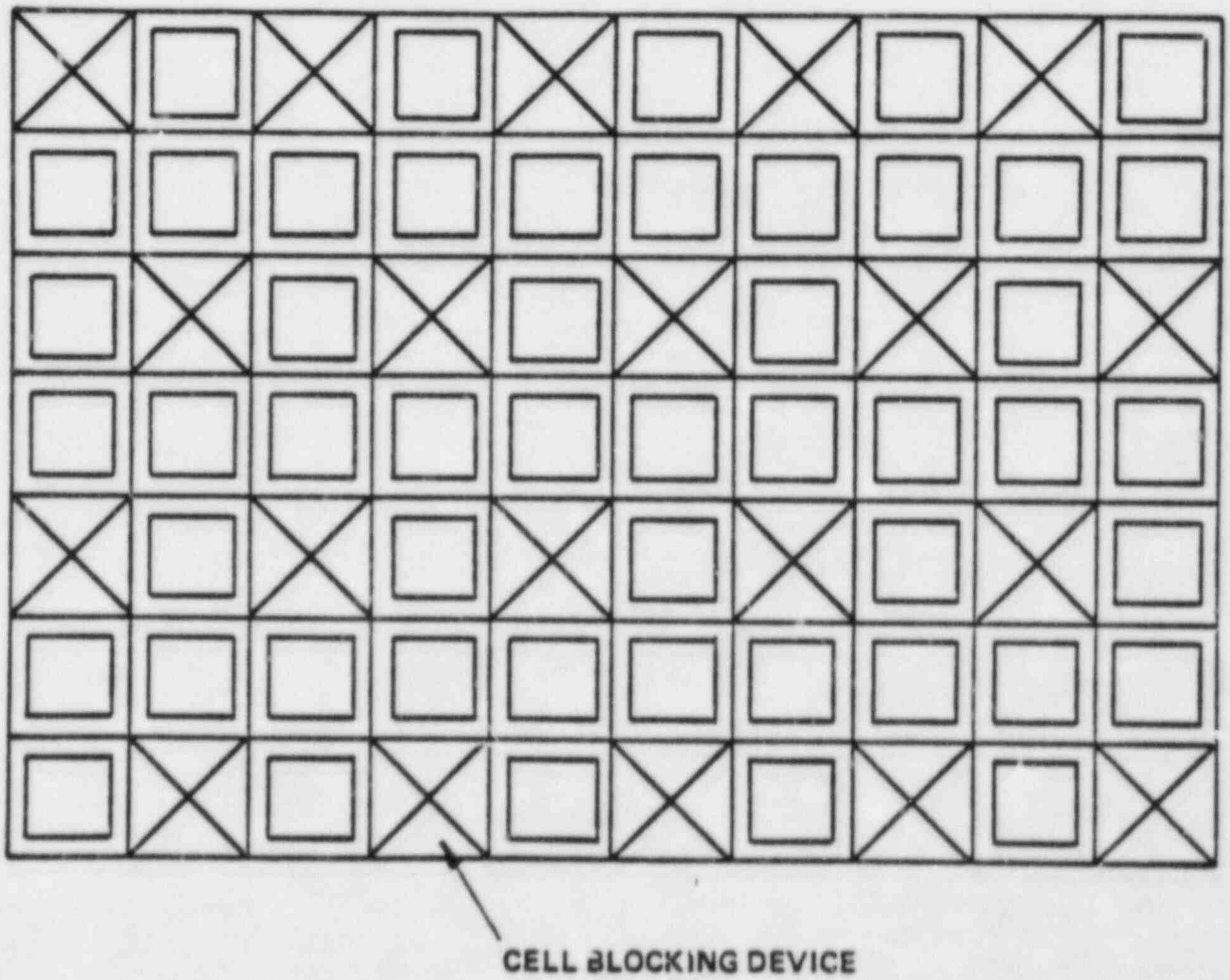
Figure 1.0



SPENT FUEL STORAGE MODULE INSTALLATION

FIGURE 1.1

MAX-CAP^{TM}
POOL ARRANGEMENT OF REGION II



POWER SYSTEMS COMBUSTION ENGINEERING INC	MAX-CAP^{TM} REGION II SPENT FUEL STORED IN 3 OF 4 CAVITIES	Figure 1.2

2. NUCLEAR CONSIDERATIONS

2.1 Criticality Determinations

C-E will perform calculations of the criticality of the fuel rack design, using developed methodologies covering the design of closer center-to-center spacing fuel racks. Within the scope of the proposed design, C-E will perform criticality safety calculations. Composition dependent nuclear cross-sections for the spent fuel will be generated using the CEPAK[2] code or other codes developed during this study as well as auxiliary processing codes. Spatial calculations employed in the determination of the multiplication factor will be performed using the two dimensional transport code, DOT[3]. Three dimensional and benchmark cases will be solved using KENO.[4]

The 123 group cross-sections from Oak Ridge National Laboratory (ORNL) will be used as a starting point, since this cross-section set apparently will be utilized by the NRC during licensing reviews. The DOT code will be utilized to describe the pin geometry in the compacted fuel criticality analyses. In using DOT, the space limitations of DOT will require that the analyses be limited to a single fuel array. Therefore, the K-infinity will be calculated by DOT and then compared to the KENO analyses for a homogenized fuel array. If this results in an acceptable comparison, KENO will then be run using the critical geometries.

These codes are the same codes used in C-E's design of the Millstone Unit No. 2 reactor core and internals. The codes have broad empirical data bases to support them and have been accepted by the nuclear industry. In addition, the NRC has licensed C-E's nuclear steam supply systems and spent fuel racks based on the use of CEPAK and DOT.

The calculations will be performed for an infinite array, and include both nominal and minimum compacted rack dimensions. The minimum dimensions will include the effects of concurrent adverse dimensional tolerances and the effects of structural elements within the compact fuel racks. Calculations will be performed at several pool temperatures to insure that the multiplication factor changes are considered in the design.

2.2 Two Region Fuel Storage

Region I

Region I is being designed as the core off-load region with a monolith to accommodate Millstone Unit No. 2 fuel in the rack structure utilizing borated poison. The fuel assemblies are to be stored in every location because of the use of poison plates and the corresponding space left for water flux traps. In addition to the Region I storage capacity needed for a full core off-load, storage space is also provided for storage of a batch of fresh fuel and space for some other fuel assemblies.

Region II

Region II is reserved for fuel that has sustained at least 85 percent of its design burnup. Within Region II, fuel assemblies are stored in 75 percent of the total cavities with a tighter rack center-to-center pitch and no poison utilized. The unconsolidated fuel is stored in a 3 out of 4 storage configuration as illustrated in Figure 1.2. Cell blocking devices are used to preclude inadvertent placement of fuel assemblies into every fourth cavity which will ensure the flux trap for reactivity control.

Both regions of the pool have been designed to store fuel in a safe, coolable, subcritical (K-effective less than 0.95) configuration. Region II presents a criticality philosophy which is approved for use by the most recent proposed revision to Regulatory Guide 1.13 on Spent Fuel Storage. Before Regulatory Guide 1.13, the physics criteria for fuel placed into the spent fuel pool were defined by a maximum unirradiated initial enrichment. Regulatory Guide 1.13 currently allows for credit to be taken for the reactivity depletion in spent fuel. It is important to note that reactivity depletion is not a function of the initial enrichment of the fresh fuel or of its target burnup but is a function of the subsequent percentage of target discharge burnup achieved for that particular fuel assembly.

Since consolidated fuel (with water gaps removed) is less reactive than intact spent fuel assemblies, it can be stored in every location in Region II. Preliminary analysis indicates that the consolidated fuel could also be stored in Region I among the fresh fuel.

2.3 Reactivity Monitoring

The reactivity monitor is an apparatus and method for measuring the subcritical multiplication of individual fuel assemblies. The device will allow verification of the predicted credit for the burnup of the fuel when storing consolidated fuel in the spent fuel racks. In actual practice, a fuel assembly with a reactivity that meets the spent fuel rack requirements is used to calibrate the device.

Thereafter, each spent fuel assembly is measured using the same apparatus, and only those assemblies having a lower subcritical multiplication than the calibration fuel assembly are placed in the spent fuel rack. Those assemblies having a higher multiplication are stored separately in racks designed for unburned fuel. In this way, it is possible to verify that the consolidated fuel has a reactivity within

the design limits of the rack design.

The apparatus and method include placing a neutron flux detector in one control rod guide tube of a spent fuel assembly and a neutron source in another guide tube. The subcritical multiplication is measured, and compared with the measurement for the standard assembly. The detector and source are attached to rods on a movable support member, as seen in Figure 3.0; the arrangement very closely resembles a control element assembly. Since the rods carrying the source and detector are maintained in a constant spatial relationship due to the close fit of each rod within a respective rigid guide tube, the distance and angle between the detector and source used in the measurement of the standard fuel assembly can be accurately repeated for measuring each spent fuel assembly.

METHOD OF VALIDATION

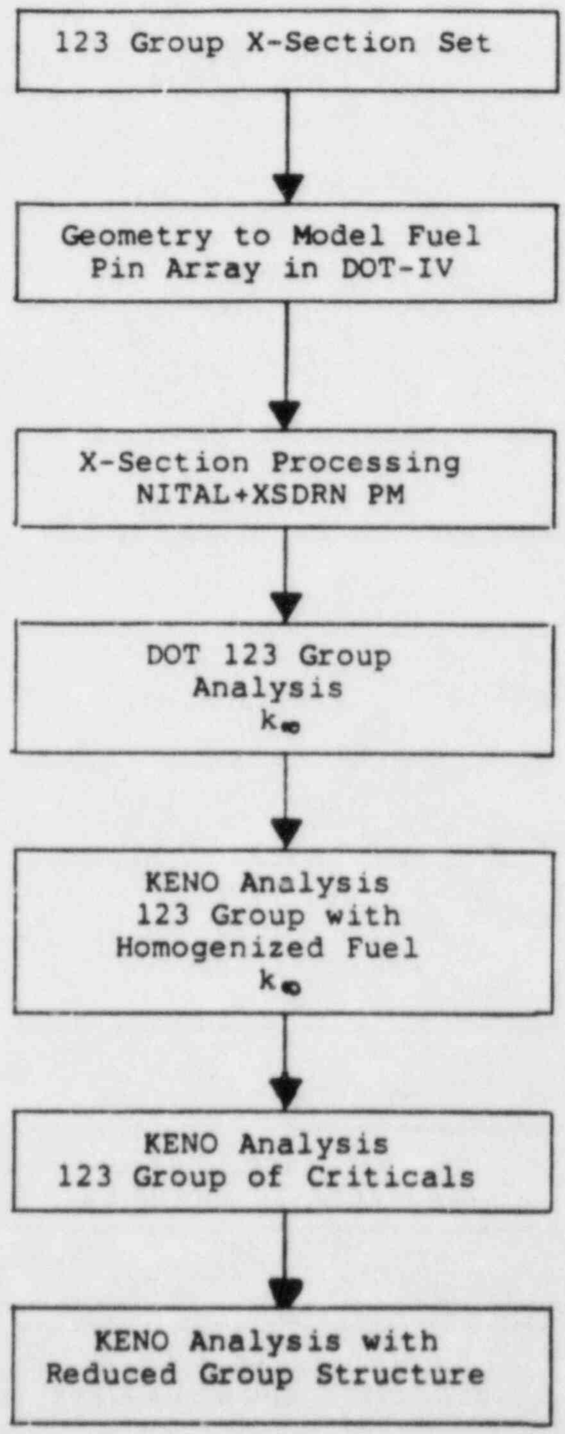
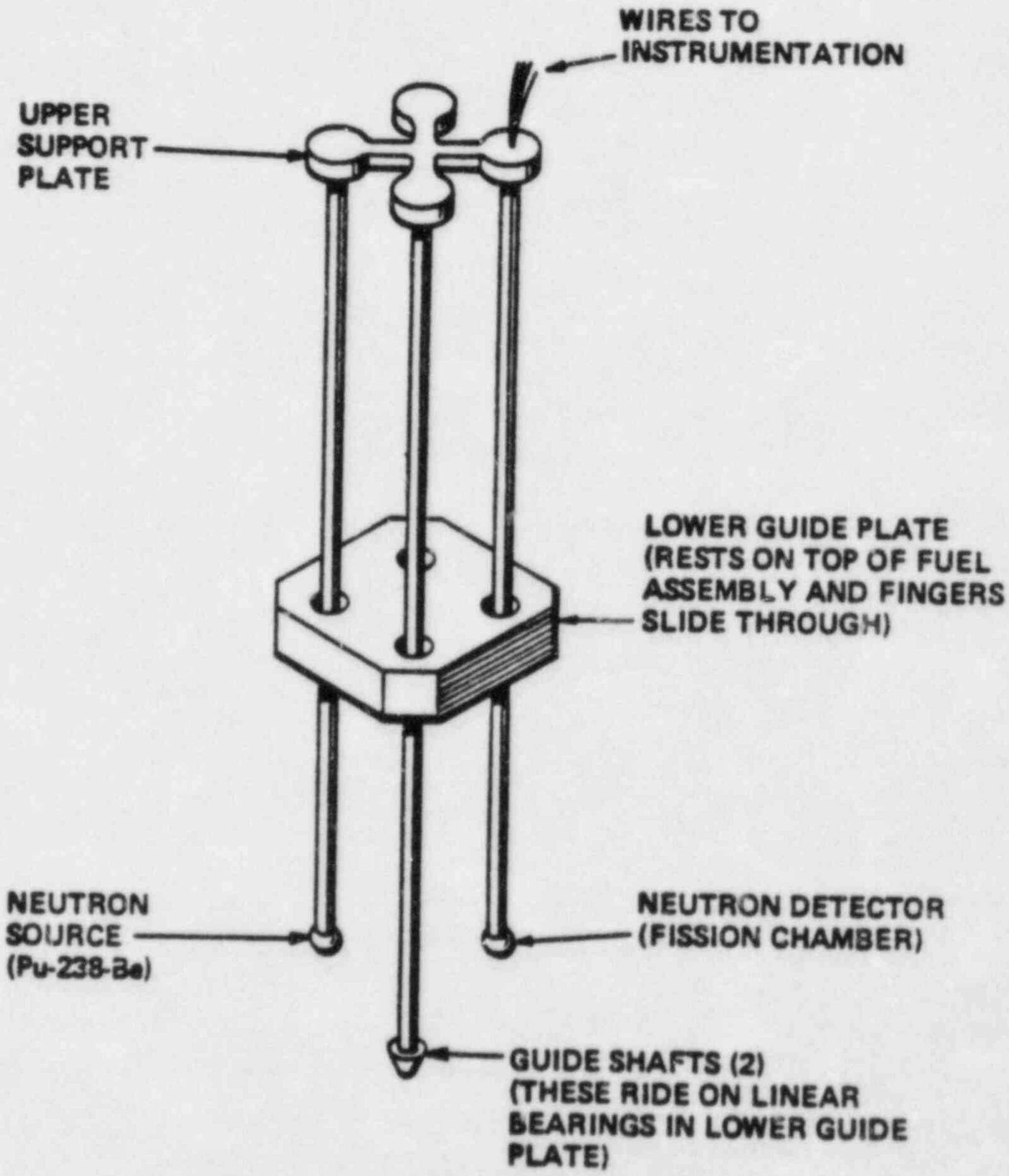


FIGURE 2.0



POWER SYSTEMS COMBUSTION ENGINEERING INC	FUEL ASSEMBLY REACTIVITY CHECK GAUGE	Figure 2.1

3. THERMAL-HYDRAULIC CONSIDERATIONS

3.1 Review of Current SFP Cooling System

The process of fuel consolidation may impose requirements upon the Spent Fuel Pool Cooling System above those originally considered in the design basis of the system. These new requirements are:

- o The ability to cool and purify an isolated portion of the fuel pool (the fuel cask area) during fuel consolidation operations and insertion into the consolidation storage canisters, and
- o The ability to provide cooling for an increased quantity of spent fuel (more than twice the amount prior to consolidation) in the spent fuel pool in a new arrangement after the fuel is returned to the storage racks.

The existing system must be evaluated in terms of its ability to provide these new services and appropriate modifications must be made to the system should it be necessary.

The demand for additional cooling, despite the approximate doubling of the density of stored fuel, is not expected to be a major concern as consolidation is anticipated to occur after the fuel has been discharged from the core for a minimum of five years. Decay heat generation rates at that time are relatively low and therefore the additional cooling requirements will also be low. In contrast, purification during fuel disassembly may require some system modifications due to the potential for additional crud not normally encountered during normal operation of the spent fuel cooling system. A temporary crud filtration vacuum system connected directly to the work location will substantially mitigate this phenomenon. Regardless of the anticipated impact, however, both of the new system design requirements will be evaluated prior to the performa ce of a fuel consolidation operation.

The new demands upon the spent fuel pool cooling system will be quantified to provide a basis for the evaluation of the existing systems' capability to meet the needs of fuel consolidation. Heat load requirements in the consolidation area during the fuel consolidation operation and in the fuel pool itself after the consolidated fuel is returned for long term storage will be developed assuming finite fuel irradiation and anticipated consolidation sequences (i.e., when after removal from the reactor core, the fuel from a specific batch is to be consolidated). Filtration system demands will be developed based upon experience in crud release during fuel reconstitution processes which are physically similar to the consolidation operation and should provide the basis for a reasonable estimate of the crud release during consolidation. Current regulatory standards will be considered in the development of the requirements, particularly with respect to fuel pool temperatures and radiological considerations.

The capacity of heat exchangers, filtration devices, and ion exchangers will be compared with the new demands. The adequacy of flow paths - particularly in the fuel cask areas where the consolidation will be performed - will be examined. This evaluation will provide a listing of these requirements for the consolidation process which are not met by the current systems.

For those areas where the existing system needs modification, system modifications will be developed. Additional components, instrumentation, and controls will be sized and appropriate design information provided along with necessary document changes. If changes to the system must be made, a description of the changes and the impact of the changes in terms of the modified systems' ability to meet regulatory requirements will be prepared. This description will be in the sufficient detail to support additional licensing, if necessary.

3.2 Methodology and Analysis

A thermal-hydraulic analysis is being performed to verify under normal and accident conditions the Millstone Unit No. 2 spent fuel racks can be cooled adequately for the storage of unconsolidated and consolidated fuel.

The proposed design bases for the analysis are shown in Table 3-1. The maximum bulk water temperature (150°F) is assumed to be kept constant by the external cooling system during normal operation. It is assumed that the rack contains fuel assemblies which are loaded at the rate of about one-third core per calendar year plus the option of loading a full core at any time. The shortest decay time for one assembly of a core is three days. The shortest decay time for the entire core is six days, given that it takes at least three days to transfer the full core into the rack. It is assumed that part of the rack will be loaded with fuel assemblies and the other part will contain consolidated fuel cells. Fuel assemblies will decay for a specified amount of time in the rack and then fuel rods will be removed and placed into a Consolidated Fuel Storage Box. The number of consolidated cells and the minimum cooling time for an assembly before its consolidated will be determined from the thermal hydraulic analysis.

The thermal-hydraulic analysis acceptance criteria are as follows:

- o Bulk boiling of the entire pool must not exist during normal operation.

- o Maximum fuel clad temperature will not exceed 650°F during both normal operation and accident conditions.

The thermal-hydraulic accident analysis meets the double contingency principle of ANSI N 16.1-1975, that is, that two unlikely, independent, concurrent events must be assumed to occur. The events to be evaluated are:

- o dropped fuel assembly in pool
- o dropped fuel cask or large object in pool
- o tornado, earthquake, or other severe, external phenomena occurring
- o loss of coolant from pool

To meet these criteria, normal operation is defined as any arrangement of the fuel assemblies in the rack for which the conditions of maximum pool fluid temperature of 150°F and minimum pool depth of 23 feet of water above the fuel are maintained. Accident conditions are defined by two concurrent events; namely a dropped fuel assembly and a loss of coolant event. A loss of coolant event assumes that coolant is evaporated because of loss of external cooling. The decay heat of the fuel is removed by boiling the pool coolant. The loss of coolant event is bounded by assuming a minimum pool depth of 10 feet of water above the racks and a maximum fluid temperature in the rack region of 235°F.

3.3 Thermal Hydraulic Test Program

An experiment, using a heated test section, will be performed to confirm the results of the thermal/hydraulic analyses. In the experiment, electrically heated rods will simulate the heat generation of the fuel rods.

The test section will contain 19 full length fuel rod simulators which are arranged in a hexagonal lattice. The test section will be placed in a vessel so that the pressure and temperature conditions in the

actual spent fuel rack may be simulated. Instrumentation will be installed to measure the coolant and cladding temperature distribution, flow rate and pressure drop in the test section under natural circulation conditions.

The benefits of the test would be:

1. Experimental verification of the thermal-hydraulic computer codes utilized.

2. Confirmation of the adequacy of the correlations chosen for heat transfer coefficients and pressure drop in the triangular flow channel over the range of interest for the spent fuel pool.

3. A verification of predicted flow rates produced by natural convection in a triangular flow channel.

If considered necessary, NNECO will install a test rig in the spent fuel pool to verify the predicted heat generation rates in spent fuel assemblies and to further determine whether a fuel assembly is ready for fuel consolidation. In this test rig, a fuel assembly is placed in a closed canister filled with pool coolant. Thermocouples are placed in the canister to measure the coolant temperature rise within the canister. The heat generation rate for the fuel assembly is then calculated using the temperature rise data. The assembly will be consolidated if the heat generation determined from the thermocouple measurements is lower than the minimum value required for fuel consolidation. The required value will be based upon analytical methods and the results of the triangular flow channel test.

4. MECHANICAL CONSIDERATIONS

4.1 Materials of Construction

The new spent fuel racks will be designed similar to C-E standard Super HI-CAP and MAX-CAP fuel storage racks which are fabricated from 304 stainless steel with a maximum carbon content of 0.065 percent. The racks are monolithic honeycomb structures. Each storage location is formed by welding stainless steel sections along the intersecting seams, permitting the assembled cavities to become the load bearing structure, as well as framing the storage cell enclosures.

Stainless steel bars, which are inserted horizontally through the rectangular slots in the lower region of the module, support the fuel assemblies. These support bars when welded in place support an entire row of fuel assemblies.

The relevant standards are listed below:

American Society for Testing Materials Documents

A. ASTM - A240 - Specification for Corrosion Resisting Chromium Nickel Steel Plate, Sheet & Strip for Fusion Welded Unfired Pressure Vessels.

B. ASTM - A479 - Specification for Stainless and Heat Resisting Bars and Shapes

Other codes and standards may be invoked as necessary by applicable C-E specifications, drawing procedures, or other documents.

4.2 Seismic Methods Development

1. Seismic

a. Test Program in Support of Seismic Analysis of the Consolidated Spent Fuel Rack System

CFC Lateral Load Deflection Tests

A single Consolidated Fuel Storage Box, filled with depleted UO_2 fuel rods, will be supported in a vertical orientation at both ends. The end conditions will be of the pinned-pinned type. A horizontal load will be applied externally to the fuel canister at its midpoint and the static deflection behavior of the structure will be monitored at up to 12 elevations by means of LVDT type displacement transducers. The hysteresis effects of the canister will be determined by a series of push-pull cycles with increasing force amplitudes. The test results will be condensed into representative stiffness properties and deflection curves. All the testing will be performed in the elastic deflection range which will be monitored by a series of strain gauges attached to the fuel storage box.

Consolidated Fuel Storage Box Forced Vibration Testing

The fuel storage box, filled with fuel rods, will be supported vertically at its upper location. The attachment to a horizontal sliding fixture will be of the "pinned" type. A large water tank enclosure will be placed around the Fuel Storage Box, which allows for both air and still water testing. Closed-loop controlled sinusoidal excitations will be introduced to the test specimen by a hydraulic actuator connected directly to the horizontal sliding fixture.

The fuel storage box behavior will be monitored along its length by a series of LVDT type displacement transducers and strain gauges. Initially, low level sine sweep tests will be conducted over a frequency range from 1 to 33 Hertz. Frequency response plots will be developed for all monitoring locations and the test intensity will be increased incrementally up to a maximum acceptable level. From the frequency response plots, the natural frequencies and associated model deflection patterns, as well as the model damping properties, will be determined. The non-linear response characteristics will then be presented as a function of excitation level for use in model correlation efforts. The hydrodynamic effects of a water medium on the dynamic behavior of the fuel canister will be determined by comparison of air and water environment test results.

Box Section Stiffness Properties

During a seismic event, the fuel storage box can impact the storage rack walls. In the model, the stiffness properties of the impacting components have to be simulated by springs and gap-elements. These spring properties are a combination of storage box and "stand-off" flexibilities.

A series of static load deflection tests are proposed whereby the load is applied in different axies directly to the stand-offs. The deflection behavior of the box section, as well as the stand-offs, will be measured by a combination of displacement transducers. The load versus deflection results will be reduced into stiffness properties representative of the respective components. Testing

again will be confined to the elastic range and be monitored by strain gauge applications.

b) <u>Consolidated Fuel Storage Box/Fuel Rack/Pool Modeling and Interfaces</u>

Analytic methods and models will be developed for performing the seismic anlaysis of the Consolidated Fuel Storage Racks. the effort will be focused on two areas of model development: 1) Formulation of an analytic model of the Consolidated Fuel Storage Box for use in a nonlinear time history seismic anlaysis; and 2) development of a model of the spent fuel rack modules.

Modeling of the fuel storage box will be based upon full-scale dynamic testing. Because the dynamic characteristics of the fuel storage box are unknown and not easily determined by analytic means, tests are performed to determine natural frequency, damping and local canister stiffnesses. Model simulations of the actual tests will be performed to develop a storage box model consisting of a simple vertical array of lumped masses interconnected by massless springs. Separate models will be developed to represent different degrees of compaction and in cases where complete compaction is not achieved, the models will account for possible fuel rod impacting. The hydrodynamic effects of fuel storage box natural frequency and damping determined from tests will also be incorporated into the models. For less than complete compaction, the hydrodynamic effects of fuel rods for various degrees of compaction will be modeled.

Model development of the spent fuel rack module including effects of interaction with the fuel storage box will also be performed. Because fuel consolidation leads to additional seismic loadings on the coupled fuel rack/pool structures, new rack supporting schemes will be investigated. Since the method of fuel rack support affects the dynamic characteristics of the modules and their seismic response, methods will be developed to include the effects of rack support in the dynamic models. Previous seismic analysis experience with monolith type designs indicated that the gap and amount of structural coupling between the rack and the fuel container has a significant effect on peak seismic loads. A model of the interface between the fuel storage box and fuel rack will be developed to minimize relative motion between the components and consequently, the seismic loads. Because submergence of the racks affects both the dynamic characteristics of the storage box and fuel rack and their motion relative to the pool, methods for modeling this hydrodynamic action between the rack and pool will be investigated.

Studies will be made to determine the sensitivity of seismic loading to both the rack design and the rack-to-pool hydrodynamic representation. The results of these studies will be used to develop fuel storage box and rack designs that are compatible with the seismic loading associated with consolidated fuel.

4.3 Seismic Analysis

A site specific seismic analysis of Millstone Unit No. 2 spent fuel racks with consolidated fuel will be performed using the analytic methods and models described in Section 4.2.1. The seismic analysis will consist of nonlinear time history analyses in the two horizontal directions and a response spectrum analysis in the vertical direction.

The first step in the seismic analysis is the determination of the dynamic characteristics of the basic module as supported in the proposed design. These characteristics are obtained from a frequency analysis of a linear three-dimensional model of a module using SAP4, a general purpose finite element computer code. The results of the frequency analysis are then incorporated into a nonlinear representation of the fuel rack structures based upon the methods and models used or developed in this program. This nonlinear model includes a mathematical model of the Consolidated Fuel Storage Box, based upon both the box testing and model development. Because of the close proximity of the fuel storage box and the rack structure to the spent fuel pool walls, the hydrodynamic effects will be accentuated and are, therefore, considered explicitly in the nonlinear model. The results of the engineering development effort addressing the sensitivity of seismic loadings to these hydrodynamic representations will be used in formulating the hydrodynamic portion of the model. The nonlinear model will also consider friction forces between the Consolidated Fuel Storage Box and the rack module.

The program used for the nonlinear time history analysis is called CESHOCK, which is a C-E proprietary computer code. CESHOCK generates equations of motion for the dynamic system and solves them by direct numerical integration to obtain the system response to an earthquake time history. The model used consists of mass nodes being interconnected not only by linear spring elements but also by elements that duplicate the action of friction, nonlinear springs, gaps between structural elements and hydrodynamics. A series of CESHOCK runs are required to determine the effects of dynamic parameters on fuel storage box, rack and pool loadings.

The seismic excitation to be used for the nonlinear time history analyses consists of the acceleration time history of the fuel pool floor derived from a seismic analysis of the auxiliary building which includes the effects of the added weight associated with consolidated fuel. The stress contributions from the seismic analyses of the two horizontal directions and the vertical direction are combined in accordance with Regulatory Guide 1.92 and the results are used to determine the structural adequacy of the proposed design.

4.4 Pool/Auxiliary Building Analysis

The Millstone Unit No. 2 fuel consolidation program requires an analysis of the spent fuel pool and auxiliary building for the increased loads caused by the addition of additional spent fuel and consolidated fuel. This document addresses the guidelines and acceptance criteria that NNECO plans to follow to qualify the spent fuel pool and auxiliary building for the new loadings.

The Millstone Unit No. 2 auxiliary building is a multistory concrete structure. Spent fuel storage is provided between column lines H.4 and L.5 at elevation (-)2' -0". The storage area consists of a reinforced concrete pool lined with a one-quarter inch thick stainless steel liner to elevation 38'-6". Normal water level is to elevation 36'-6". A leak chase system consisting of channels embedded behind the liner at all seams and connected to a collector system is used to monitor and control any possible leak from the pool. Construction materials used in the construction of the pool include ASTM A-240, Type 304 stainless steel, ASTM A-615 Grade 60 deformed bar reinforcing steel, and 3,000 psi 28-day strength concrete.

The spent fuel rack support system that presently exists in the spent fuel pool consists of several built-up plate members framing into a set of tees that run in the north-south direction across the pool floor with their flange welded to bearing plates which are welded to the pool liner plate. These built-up beams frame into the tees with a complicated hanger system that is designed to allow the beams to undergo free thermal expansion yet not impose any horizontal load on the support tees. This is accomplished through a system of plates, connected by pins in such a manner that the ends of the beams hang freely from the tees. The vertical support loads from the present fuel racks are supported on this system of built-up members. The horizontal seismic load is carried to the spent fuel pool walls and resisted by a series of snubbers at two elevations. The present fuel rack system was shown to have been designed with no additional capacity to carry higher loads such as loads associated with consolidated fuel. Based on this information, the decision was made to remove the present rack support

system to accommodate the installation of free standing fuel racks.

The analysis of the spent fuel pool and associated components of the auxiliary building to accommodate the loadings associated with consolidated fuel will be accomplished with the use of a large finite element model. The finite element model will include the entire spent fuel pool, fuel transfer canal, and cask laydown area. The foundation of the pool will be included and terminated at points where it is considered the local effects are negligible with regard to the overall pool response. The effect of the auxiliary building floors and walls that frame into the pool will be included so that advantage can be taken of the stiffening action and load resisting capacity that this structural system provides.

The spent fuel pool analysis will proceed with the formation of composite load cases. The composite loads consist of a combination of basic load cases which are grouped together for the purpose of application of the Standard Review Plan load factors. The composite load cases include dead load, live load, operating thermal and accident thermal, and SSE and OBE earthquake loads. Dead load will consist of a combination of the dead weight of concrete, hydrostatic pressure, and the weight of the fuel rack modules without their fuel components. Live load consists entirely of the submerged weight of the consolidated fuel and its storage box. Normal operating thermal loads place the pool water at 150°F with the temperature outside the pool at 55°F. The 212°F pool/wall interface temperature for accident thermal was deemed applicable when determining the gross structural effects on the pool walls. OBE earthquake loads involve four composite load cases. These load cases result from

the specification in the Standard Review Plan that the three directions of earthquake must be applied simultaneously and permutation of signs must be included. For this reason four load cases are specified with appropriate permutations of signs of the three orthogonal accelerations. An additional four load cases are developed by multiplying each of the originals by (-)1.0. Load combinations involving SSE earthquake loads utilize these OBE earthquake loads with a coefficient applied.

The Standard Review Plan specifies service load and factored load combinations for Category 1 concrete structures. Upon examination of these load cases, it can be shown that eight of the composite loads comprising them are not under consideration when analyzing the spent fuel pool. Other accicent loads such as flood loads, tornado loads, or any piping loads will be included, consistent with their definition and in the manner in which they affect the spent fuel pool structure.

Upon examinations of the Standard Review Plan load combinations, it is readily apparent that some load cases are duplicates or envelop other load cases. These combinations will be reviewed and controlling load combinations will be chosen from this group. Following the load combinations, the concrete sections will be checked against criteria set forth in the latest revision of the American Concrete Institute Code Requirements for Nuclear Safety Related Concrete Structures-ACI 349-80.

Cask drop loads have been addressed in the Millstone Unit No. 2 FSAR. Guidelines set forth for the areas of the pool where the cask may be safely handled will remain as stated.

The above guidelines and acceptance criteria will be used by NNECO. By following these guidelines and acceptance criteria, NNECO plans to demonstrate the adequacy of the Millstone Unit No. 2 spent fuel pool and auxiliary building to accommodate the loads associated with consolidated fuel.

5. RADIOLOGICAL CONSIDERATIONS

The rod consolidation project will be evaluated to ensure that personnel exposures are limited in keeping with the principles of ALARA and in conformance with NRC Regulatory Guide 8.8. Special attention will be paid to the radiological considerations created by the fuel bundle crud that may be freed in the pool and by the handling and packaging of waste bundle hardware.

The results of detailed radiological evaluations of both the spent fuel pool modifications and the storage of consolidated fuel in the pool will be provided to the NRC.

Calculations will be performed to determine the incremental dose at certain areas around the spent fuel pool due to the proposed increase in spent fuel pool capacity. The dose will be calculated with the pool filled to its proposed capacities with both unconsolidated and consolidated spent fuel.

Special attention will be given to the radiological considerations created by the handling and packaging of consolidated spent fuel assemblies and associated waste hardware, to ensure that personnel exposures are in keeping with the principles of ALARA and in conformance with NRC Regulatory Guide 8.8.

6. ACCIDENT ANALYSES

The following accidents will be analyzed and the results provided to the NRC for review:

- o dropped fuel assembly in pool
- o dropped fuel cask or large object in pool
- o external phenomena
- o loss of spent fuel pool coolant

For thermal-hydraulic analyses, normal operation is defined as any arrangement of the fuel assemblies in the rack for which the conditions of maximum pool bulk temperature of 150°F and minimum pool depth of 23 feet of water above the fuel are maintained. Accident conditions are defined by two concurrent events; namely a dropped fuel assembly and a loss of coolant event. A loss of coolant event assumes that coolant is evaporated because of loss of external cooling. The decay heat of the fuel is removed by boiling the pool coolant. The loss of coolant event is bounded by assuming a minimum pool depth of 10 feet water above the racks and a maximum fluid temperature in the rack region of 235°F.

7.0 PLANT MODIFICATION

7.1 General Description of Procedure

NNECO intends to begin reracking modifications at Millstone Unit No. 2 during 1985 with a spent fuel pool inventory of approximately 446 spent fuel assemblies. As stated previously, the existing pool configuration consists of ten spent fuel rack modules with a total capacity of 667 storage locations.

The reracking modifications require that a series of activities be sequenced to permit removal of the existing fuel racks together with the installation of the proposed racks.

The spent fuel population will be concentrated into one section of the pool to vacate the maximum number of fuel rack modules. Additionally, a temporary spent fuel rack will be placed in the cask laydown area for storage of fuel assemblies in order to facilitate the rerack installation. Engineering analyses will be performed to support the temporary placement of one module in the cask laydown area.

The reracking transition between removal of the old racks and installation of the new racks requires that several pool modifications be implemented. The existing fuel rack support steel on the floor of the spent fuel pool must be removed to permit installation of the new racks.

Additionally, NNECO will evaluate the need for temporary fuel pool modifications during transition periods to maintain reasonably achievable seismic integrity of the spent fuel pool configuration.

The pool layout portrayed on Figure 7.0 represents an arrangement whereby an optimum number of fuel racks can be vacated and removed from the pool and a large area of the flooring steel exposed for access, support, and removal.

7.2 Seismic Considerations

The Millstone Unit No. 2 spent fuel pool design configuration consists of ten spent fuel rack modules that are horizontally braced to the pool walls and vertically supported by a built-up flooring system of structural steel beams (Figures 7.1 and 7.2). By design, the spent fuel rack modules and the floor support system are intended to function together as a composite unit.

Horizontal seismic loadings are transferred between rack modules in bearing to hydraulic "Lock-up" snubbers then to the pool walls. The hydraulic snubbers are mounted between the outer rack periphery and the pool walls to maintain continuous contact between the racks and the walls.

Vertical deadweight and seismic loadings are transferred through the floor support structure to the pool floor in bearing.

The spent fuel storage racks, peripheral equipment, and all associated structures are designed to the qualifications of a seismic Category I structure.

The rerack transition from a braced pool design to a free-standing pool design requires the removal of the floor support structures to permit installation of the free-standing racks. Analyses conducted by NU indicate that the structural design of the floor support system is not capable of seismic qualification under a higher vertical service loading criterion than presently specified by design. Since the floor support system is built up above the pool liner and transfers all

vertical loads to the pool floor in bearing, temporary supports will be installed between the structure and the pool floor to provide alternate load paths and maintain vertical stability.

NNECO will evaluate the need for temporary fuel pool modifications during the period when the primary horizontal load path of the racks is interrupted during the reracking transition.

7.3 Load Handling

The reracking operation at Millstone Unit No. 2 will be conducted in accordance with strict procedures to prevent inadvertent dropping of heavy objects into the pool during the reracking operations. Strict procedural controls, technical specifications, and mechanical controls prohibit the movement of heavy objects over spent fuel stored in the pool.

During the reracking no objects routinely supporting the activities in the spent fuel pool will have a handling path that brings the objects above or in the immediate vicinity of the stored spent fuel unless it is absolutely necessary. Additionally, during the reracking transition, no fuel racks old or new will have a handling path directly over stored spent fuel.

Table 3-1

Proposed Thermal Hydraulic Design Bases

Assemblies

Number Assemblies Normal Reload	1/3 core
Minimum Decay Time One Assembly	3 days
Minimum Decay Time Full Core	6 days
Minimum Cooling Time of a Fuel Assembly before the Rods are Consolidated	To be determined
Water Height Above Fuel	23 feet
Minimum Water Height Above Rack (Accident)	10 feet
Maximum Bulk Water Temperature (Normal)	150°F
Maximum Water Temperature In the Rack Region (Accident)	235°F

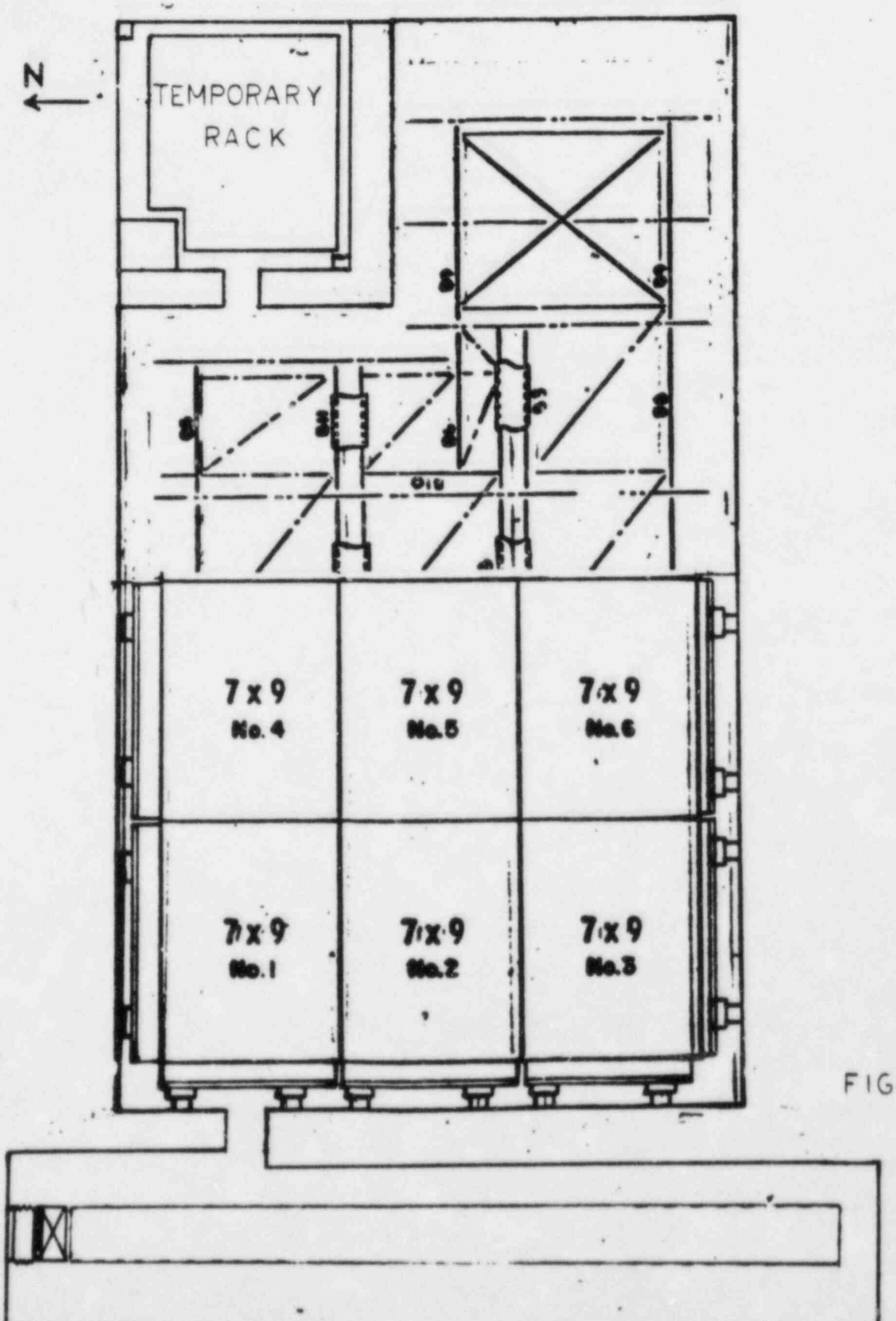

N
TEMPORARY RACK
7x9
No. 4
7x9
No. 5
7x9
No. 6
7x9
No. 1
7x9
No. 2
7x9
No. 3

FIGURE 7.0

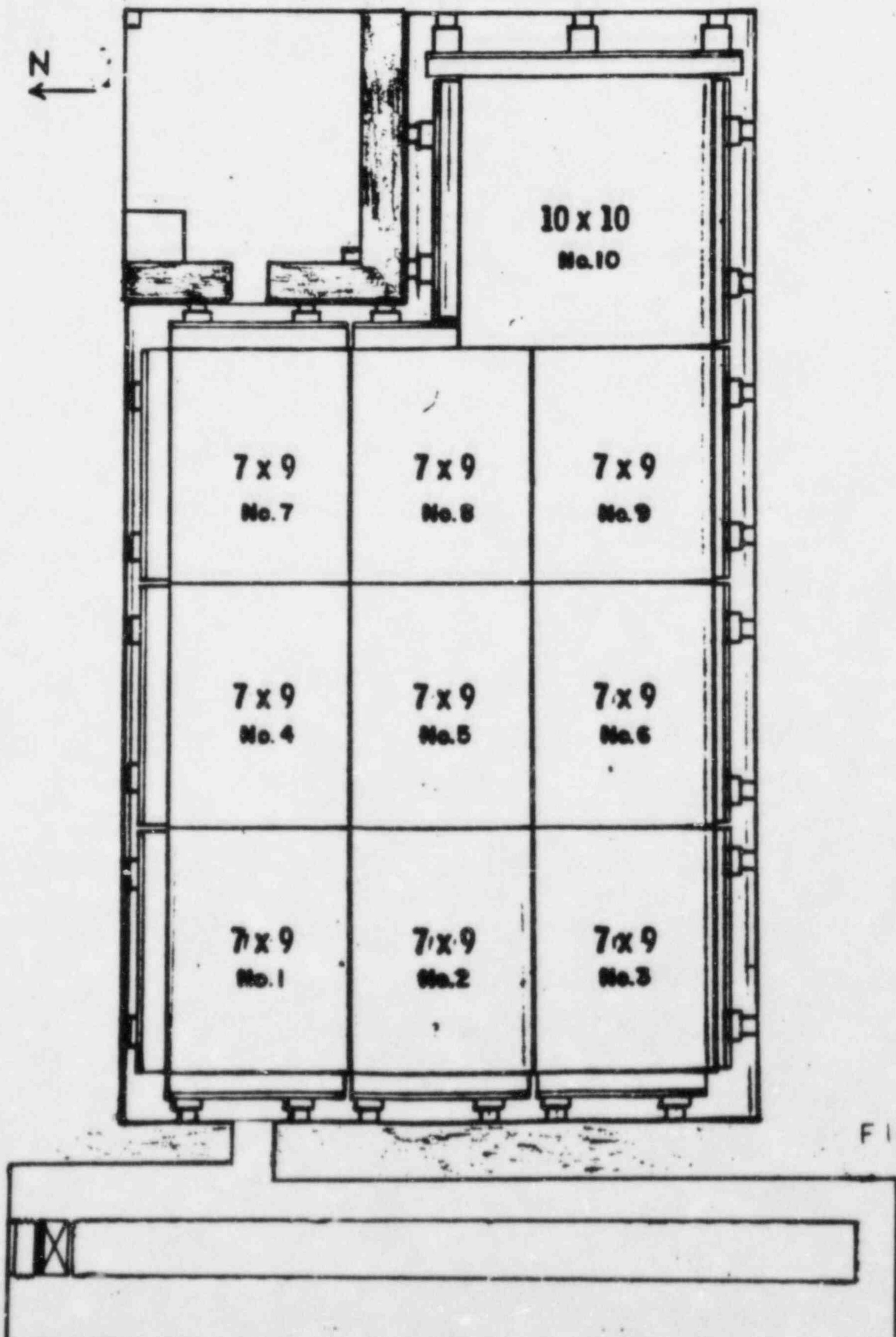
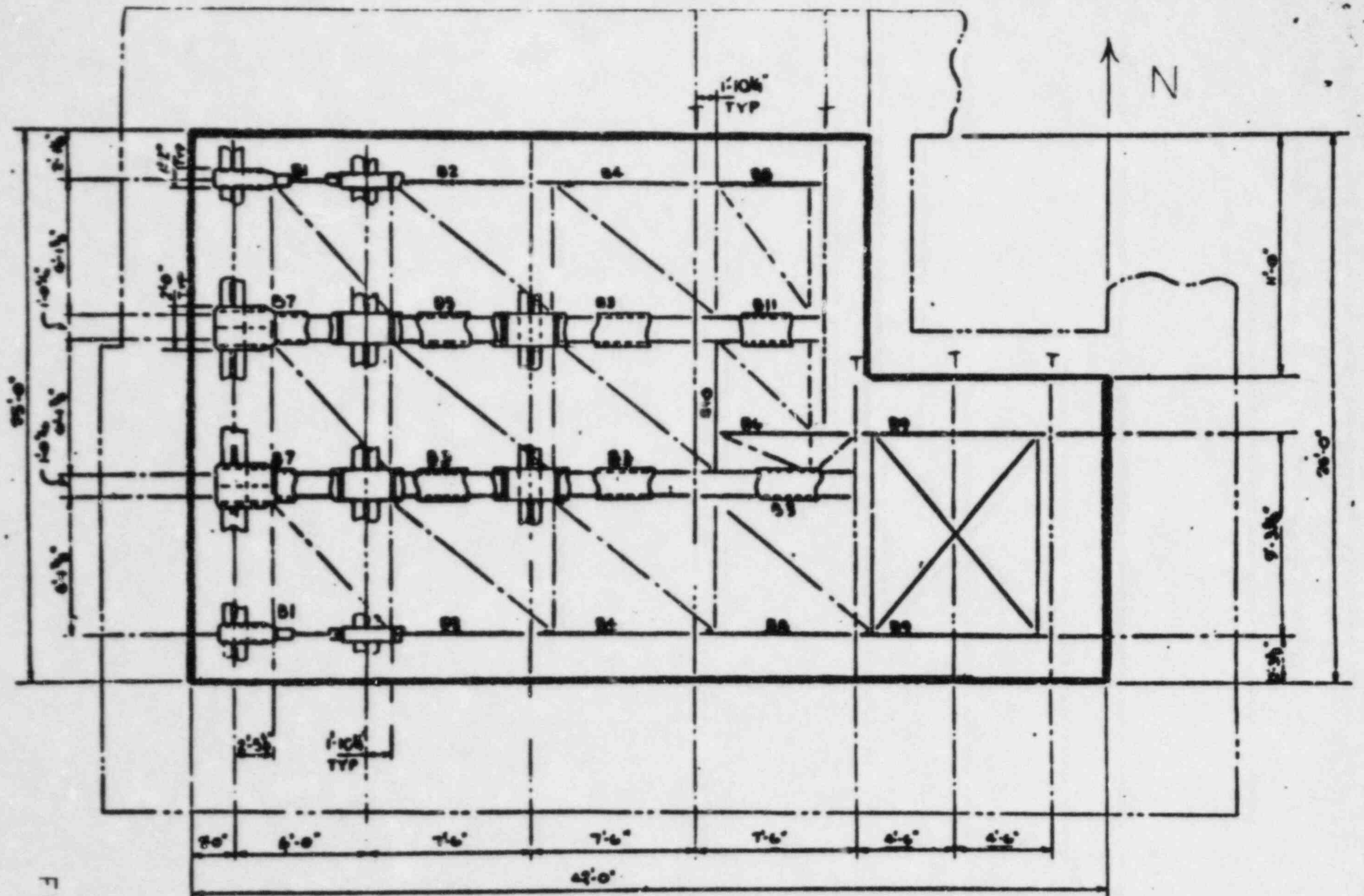

N
10 x 10
No.10
7 x 9
No.7
7 x 9
No.8
7 x 9
No.9
7 x 9
No.4
7 x 9
No.5
7 x 9
No.6
7 x 9
No.1
7 x 9
No.2
7 x 9
No.3

FIGURE 7.1



SPENT FUEL RACK SUPPORTS
PLAN

FIGURE 7.2

LIST OF FOOTNOTES

(1) G. Lear letter to D. C. Switzer, date November 22, 1976, transmitting license amendment Nos. 39 and 30 to DPR-21 and DPR-65, respectively.

(2) CEPAK is a synthesis of the following computer codes:

FORM - A Fourier Transform Fast Spectrum Code for the IBM-709, McGoff, D. J., NAA-SR-Memor 5766 (September 1960)

THERMOS - A thermalization Transport Theory Code for Reactor Lattice Calculations, Honeck, H., BNL-5816 (July 1961)

CINDER - A One Point Depletion and Fission Product Program, England, T. R., WAPD-TM-334 (Revised June 1964)

(3) DOT is a multigroup Two-Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering

R. G. Sottesy, R. K. Disney, A. Collier "User's Manual for the DOT-11W Discrete Ordinates Transport Computer Code", WANL-TME-1982, December 1969

(4) KENO is a multigroup Three-Dimensional Monte Carlo Code

L. M. Petrie and N. F. Cross, "KENO IV An Improved Monte Carlo Criticality Program", ORNL-4938, November 1975