A. T. Clark

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DESIGN CRITERIA FOR CONSOLIDATION OF LWR SPENT FUEL

FOREWORD

This standard provides design criteria for the equipment and systems comprising the rod consolidation process for commercial Light Water Reactor (LWR) Spent Fuel Assemblies. The criteria are applicable to wet and dry, and horizontal and vertical consolidation concepts.

The standard is intended to be consistent with the requirements of the regulations in Title 10, Code of Federal Regulation, Parts 50 and 72.

The rod consolidation process is intended to produce canisters filled with full length fuel rods that have been removed from spent nuclear fuel. The process removes those components that maintain rod spacing and thereby allows the individual fuel rods to be reconfigured into a close packed array.

The standard does not present the storage requirements of the spent nuclear fuel either prior to performing consolidation or upon completion of the process. These criteria are presented in other American National Standards. There is a section in the standard which identifies interface considerations of the process with the facility or installation in which consolidation will take place.

The membership of Working Group ANS-57.10 of the American Nuclear Society Standards Committee during the development of this standard was:

John A. Nevshemal, Chairman, WESTEC Services, Inc.

Wendell J. Bailey, Battelle Pacific Northwest Laboratory

Elmer A. Bassler, Westinghouse Electric Corp.

C. Les Brown, Rockwell Hanford Operations

Dr. Klaus Einfeld, DWK - West Germany

Eugene Krinick, Northeast Utilities

Ray W. Lambert, Electric Power Research Institute

James B. Moegling, Tennessee Valley Authority

Robert L. Moscardini, Combustion Engineering, Inc.

Robert W. Rasmussen, Duke Power Company

Dennis W. Reisenweaver, US Nuclear Regulatory Commission

George A. Townes, BE Inc.

James M. Viebrock, Nuclear Assurance Corp.

William J. Wachter, U.S. Tool and Die, Inc.

Other idividuals who contributed directly to the development of this standard by providing text, review and comment at the Working Group sessions were:

Vic Barnhart, Chem-Nuclear Systems Inc.

Wayne L. Dobson, Gilbert Associates, Inc.

Penney A. File, Baltimore Gas and Electric Co.

John A. McBride, E.R. Johnson Associates, Inc.

Dave H. Schoonen, EG and G Idaho, Inc.

Stanley P. Turel, US Nuclear Regulatory Commission

1.0 INTRODUCTION AND SCOPE

1.1 **Introduction.** This standard is intended to be used by a) those involved in specifying the requirements for the equipment and systems necessary to consolidate LWR spent nuclear fuel (rod consolidation), b) the designer of consolidation equipment and systems to define the minimum requirements and, c) regulatory agencies in their evaluation of applications to perform the process of rod consolidation.

This standard continues the set of American National Standards on the subject of spent nuclear fuel storage and handling. Similar Standards (1) are ANSI/ANS-57.7, **Design Criteria for an Independent Spent Fuel Storage Installation Water Pool Type)**[1] and ANSI/ANS-57.9, **Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Types)** [2].

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(1) Similar Standards as defined in American National Standards Institute Executive Standards Council-525, "ANSI Guide to Resolving Similar/Duplicate Standards Problems."

1.2 **Scope.** This standard provides design criteria for the process of consolidating LWR spent nuclear fuel in either a wet or dry environment performed either horizontally or verticaly. The process includes the equipment and systems used to perform consolidation, handle fuel rods and nonfuel-bearing components as well as handle broken fuel rods. This standard also contains requirements for facility and installation interfaces, nuclear safety, structural, thermal, accountability, safeguards, decommissioning, and quality assurance.

1.3 **Limits of Application.** This standard applies to the process of rod consolidation. The process is intended to be performed at commercial LWR nuclear power plants, reprocessing facilities or other installations which receive, store or dispose LWR spent fuel. Other limits of applications are a) the spent nuclear fuel to be consolidated is commercial LWR fuel which b) has a minimum of one year cooling after discharge from the reactor core.

1.4 **Overall Design Consideration.** This standard is based on the following overall considerations which reduce the potential hazards during the rod consolidation process; a) short lived high specific activity radionuclides, particularly those of Iodine and Xenon are no longer present in significant quantities due to the minimum one year cooling time after discharge from the reactor core, b) very little remaining radioactivity is in a dispersible form, and c) decay heat is greatly reduced again due to the minimum one year cooling time after discharge from the reactor core.

2.0 DEFINITIONS

2.1 **Canister.** A container or restraints used to hold Rods in a close-packed array. The Canister may or may not have grids and may or may not act as a Confinement barrier.

2.2 **Confinement.** The structure, system or component provided for the purpose of preventing the release of radioactive particulate matter above the radiological protection limits; it may be either a physical barrier or a high efficiency filtration system.

Confinement is a philosophy, not a physical "thing".

2.3 **Commercial Component.** A commercially available standard product line items such as optical, electrical, mechanical, or hydraulic equipment; manually or power operated devices; and associated parts.

why this?

2.4 **Crud.** The deposits on a Spent Fuel Assembly that primarily result from mass transfer processes operating on the corrosion/erosion products from the various structural materials in contact with the primary coolant circuit in the LWR.

2.5 **Damaged Rod.** A Rod which exhibits visible evidence of structural damage to the fuel cladding.

2.6 **Design Event.** Postulated occurance used to establish design requirements to satisfy operational and safety criteria of the Rod consolidation system.

Evaluation of the consequences of such occurances can then be used to specify the performance requirements of the Rod consolidation system.

2.6.1 **Design Event I**

2.6.1.1 Definition. An event that is expected to occur regularly or frequently in the course of normal operation of the Rod consolidation system.

2.6.1.2 Examples:

2.6.1.2.1 Loading of the Spent Fuel Assembly into the consolidation equipment.

2.6.1.2.2 Removal of the End Fittings.

2.6.1.2.3 Removal of the Rods.

2.6.1.2.4 Rod array reconfiguration.

2.6.1.2.5 Transfer of the Canister of consolidated Rods from the consolidation machine back to storage.

2.6.1.2.6 Confinement and control of debris (e.g. Crud).

2.6.2 **Design Event II**

2.6.2.1 Definition. An event that although not occurring regularly, can be expected to occur with moderate frequency or on the order of once during any calendar year of Rod consolidation system operation. A calendar year of Rod consolidation operation is considered to be the processing of approximately 25 MTU.

year = time
MTU = mass
time ≠ mass

2.6.2.2 Examples:

2.6.2.2.1 A loss of external power supply (single failure in the electrical system) for a limited duration.

2.6.2.2.2 Handling of Stray Rod(s) and broken Rod(s).

2.6.2.2.3 Spurious operation of certain active components.

This is very definitive.

2.6.2.2.4 A single operator error followed by corrective action.

This too!

2.6.3 **Design Event III**

2.6.3.1 Definition. An infrequent event that could reasonably be expected to occur once during the lifetime of the Rod consolidation system.

2.6.3.2 Examples:

2.6.3.2.1 A loss of power for an extended interval.

2.6.3.2.2 Dropping of a Canister of consolidated Rods, but with no spilling of Rods.

2.6.3.2.3 Failure of a major component of the Rod consolidation system that cannot be repaired in place.

2.6.3.2.4 Spilling of Rods from a Canister of consolidated Rods.

2.6.3.2.5 Incorrect administrative control of the ?

characteristics of the Spent Fuel Assembly to be consolidated.

2.6.4 **Design Event IV**

2.6.4.1 Definition. A possible event that, because of their consequences, may result in the maximum potential impact on the immediate environs. The design of the Rod consolidation equipment need not consider those events for which the facility or installation is capable of mitigating the consequences thereof.

2.6.4.2 Examples:

2.6.4.2.1 Natural phenomena such as earthquakes, tornadoes, tornado-induced missiles, fires and floods.

2.6.4.2.2 Man-induced, low-probability events such as aircraft impact, flammable material explosions, explosion-induced missiles.

2.7 **End Fitting (Nozzle).** The portion of the Spent Fuel Assembly which defines the upper and lower extremities. Removal of an End Fitting allows access to the individual Rods.

2.8 **Handling Equipment.** Manually or power operated devices used for performing relocation operations on Rods, Spent Fuel Assemblies or Canisters.

2.9 **Nonfuel-Bearing Components (NFBC).** All components of a Spent Fuel Assembly except the fuel Rods such as; End Fittings, Spacer Grids, control Rod guide tubes, springs.

2.10 **Rod.** Those parts of a Spent Fuel Assembly which are long, thin walled tubes closed by end caps. A Rod may either contain fuel (uranium, plutonium and fission products) or nonfuel material.

2.11 **Rod Consolidation.** The process of reducing the spacing between Rods.

2.12 **Rod Removal.** Pulling or pushing a Rod out of a Spent Fuel Assembly. Rods can be removed from a Spent Fuel Assembly singularly, in groups, in rows, or all simultaneously.

2.13 **Shall, Should, and May.** "Shall" denotes a requirement. "Should" denotes a recommendation. "May" denotes permission, neither a requirement nor recommendation.

2.14 **Spacer Grid.** Component which maintains the Rods spaced in a square array in Spent Fuel Assemblies and are axially located between the End Fittings. The function of the Spacer Grid is to restrain the Rod laterally from bowing and vibrating by means of a spring support.

2.15 **Spent Fuel Assembly.** A single fabricated unit discharged from a commercial light water power reactor, still in the same mechanical configuration as when irradiated, containing Rods and Nonfuel-Bearing Components.

2.16 **Stray Rod.** A Rod in any one of the following conditions during the Rod Consolidation process:

a) partly inserted into a Canister,

b) in a position not normal for the process, or

c) dropped.

2.17 **Stuck Rod.** Any Rod which is not removed from the Spent Fuel Assembly during the normal operation of Rod Removal.

3.0 PROCESS FUNCTIONS

The function of this process is to perform Rod Consolidation. The following activities will typically take place during the Rod Consolidation process:

a) Consolidation equipment is prepared for operation,

b) Spent Fuel Assembly identification is verified,

c) Spent Fuel Assembly is placed into the consolidation equipment,

d) The End Fitting is removed to gain access to the Rods,

e) The Rods are removed from the Spent Fuel Assembly using multiple or single Rod removal techniques,

f) The Rod array is reconfigured and placed into a Canister,

g) The remaining Nonfuel-Bearing Components are processed to facilitate storage and disposal, and

h) The Canisters are prepared for storage or subsequent disposal.

4.0 PROCESS DESCRIPTION

The process of Rod consolidation has been divided into subfunctions for the purpose of this standard. The following are the descriptions of the subfunctions and will be the basis on which the design criteria are presented.

4.1 **End Fitting Removal.** End Fitting Removal permits access to the fuel Rods. This can be accomplished by cutting or mechanical unfastening of one or both of the End Fittings from the fuel assembly. This portion of the Rod Consolidation process also provides for handling of the End Fittings.

4.2 **Rod Removal.** The separation of the individual fuel Rods from the Spacer Grids and other Nonfuel-Bearing Components is accomplished in the Rod Removal portion of the Rod Consolidation process. In order to do this, the Spent Fuel Assembly is restrained as necessary. To facilitate fuel Rod separation, the removal device may be attached to the Rods by clamping mechanically or bonding. Rod Removal is accomplished by controlled separation from the Spent Fuel Assembly. Rods can be removed either as a group or individually.

4.3 **Rod Array Reconfiguration.** Rod array reconfiguration is the transformation of the Rod array from that found in the fuel assembly to a closer array required by the consolidated Rod Canister. A transistion device may be used to accomplish reconfiguration.

4.4 **Consolidated Rod Packaging.** Packaging of fuel Rods is performed in order to:

a) maintain the reconfigured geometry,

b) provide structural support for the Rods, and

c) facilitate handling and storage of the Rods.

4.5 **Nonfuel-Bearing Component Handling.** Nonfuel-Bearing Component (NFBC) handling provides for volume reduction, packaging, or other processing of residual Spent Fuel Assembly structural materials and other nonfuel items. Examples of these components are End Fittings, Spacer Grids and guide tubes. This subfunction could include the following steps:

a) cutting/shearing,

b) compaction,

c) component and/or material segregation.

d) packaging.

4.6 **Off-Normal Rod Handling.** Off-normal Rod handling includes the capability to retrieve, transfer, and prepare for storage, Damaged, Stray, and portions of broken Rods encountered during Rod Consolidation activities. Examples of the required operations involved are: tools designed for remote removal of broken or Damaged Rods from Spent Fuel Assemblies and consolidated Rod Canisters; and the collection of loose material, Stray Rods and fuel pellets.

4.7 **Auxiliary Operations.** This includes operations that are necessary to support Rod Consolidation or that are for general use throughout the consolidation process. Examples of auxiliary operations are:

a) decontamination,

b) accountability and safeguards,

c) photographic or videotape recording,

d) maintenance,

e) lifting and transfer,

f) visual monitoring.

5.0 PERFORMANCE REQUIREMENTS

The equipment and subsystems which comprise the LWR Rod Consolidation process shall be designed to perform the following functions under the designated Design Events.

5.1 **End Fitting Removal.** Equipment provided for End Fitting removal shall meet the following performance requirements:

5.1.1 Perform normal process function under Design Event I.

5.1.2 Prevent Rod damage during fastener removal or the cutting operations for Design Event I.

5.1.3 Preclude dropping End Fittings during or following End Fitting removal operations for Design Events I and II.

5.1.4 Maintain support of the Spent Fuel Assembly during Design Events I and II.

5.1.5 To the extent required by the facility, provide for local Confinement of radioactive particulate during Design Events I and II.

5.2 **Rod Removal.** Equipment provided for disassembly operations shall meet the following performance requirements:

5.2.1 Perform normal process function under Design Event I.

5.2.2 Prevent Rod damage and breach during Design Event I.

5.2.3 Preclude uncontrolled fuel Rod movement during Design Events I and II.

5.2.4 Prevent Rod damage due to loads, distortions, displacements, or deflections imposed on fuel Rods by equipment during of Design Event II.

5.2.5 Maintain fuel Rods and Spent Fuel Assemblies in a subcritical configuration for Design Events I through IV.

5.2.6 To the extent required by the facility, provide for local Confinement of radioactive particulate during Design Events I and II.

5.2.7 Provide for fuel removal and decontamination/ decommissioning following Design Events II through IV.

5.3 **Rod Array Reconfiguration.** Equipment provided for reconfiguration of the fuel Rod array shall meet the following performance requirements:

5.3.1 Perform normal process function under Design Event I.

5.3.2 Prevent Rod damage due to loads, distortions, displacements, or deflections imposed on fuel Rods by equipment during Design Event II.

5.3.3 Maintain fuel Rods in a subcritical configuration for Design Events I through IV. alone?

5.3.4 Prevent Rod damage during Design Event I.

5.3.5 Preclude uncontrolled fuel Rod movement for Design Events I and II.

5.3.6 To the extent required by the facility, provide for local Confinement of radioactive particulate during Design Events I and II.

5.3.7 Provide for fuel removal and decontamination/decommissioning following Design Events II through IV.

5.4 **Consolidated Rod Packaging.** Packaging of Rods is accomplished through the use of a Canister.

5.4.1 The Canister shall meet the following performance requirements:

5.4.1.1 Be dimensionally compatible with interfacing equipment for Design Event I.

5.4.1.2 Be structurally adequate to withstand handling and operating loads with a full complement of Rods during Design Events I and II.

5.4.1.3 Allow for adequate cooling capability to protect the rods from temperatures that would jeopardize the integrity of the fuel cladding for Design Events I through IV.

5.4.1.4 If the Canister is of a sealed configuration, accommodate pressure differential without collapse or permanent deformation during Design Events I through IV.

5.4.2 A subcritical configuration shall be maintained throughout packaging during Design Events I through IV.

5.4.3 The packaging equipment shall meet the following:

5.4.3.1 Perform normal process function under Design Event I.

5.4.3.2 Prevent Rod damage during Design Event I.

5.4.3.3 Preclude uncontrolled fuel Rod movement during Design Events I and II.

5.4.3.4 Prevent Rod damage due to loads, distortions, displacements, or deflections imposed on fuel Rods by equipment during Design Event II.

5.4.3.5 Provide for fuel removal and decontamination/decommissioning following Design Event II through IV.

5.4.3.6 To the extent required by the facility, provide for local Confinement of radioactive particulate during Design Events I and II.

5.5 **Nonfuel-Bearing Component Handling.** Equipment required for Nonfuel-Bearing Component handling which includes component cutting, shearing and compacting equipment, storage containers, tools, storage racks and equipment stands shall meet the following performance requirements:

5.5.1 Perform normal process function under Design Event I.

5.5.2 Provide for the Confinement of debris and free Nonfuel-Bearing Component hardware during cutting, shearing and compaction for Design Event I.

5.5.3 To the extent required by the facility, provide for local Confinement of radioactive particulate during Design Events I and II.

5.5.4 Maintain the capability of storage racks and equipment stands to receive and allow withdrawal of components, containers or equipment following Design Event II. but not III and IV

5.6 **Off-Normal Rod Handling.**

Off-normal Rod handling includes the capability to retrieve, transfer and prepare for storage; Damaged, Stray and portions of broken Rods. Equipment provided for off-normal Rod handling shall meet the following performance requirements:

5.6.1 Remove and retrieve fuel Rod sections and associated debris from fuel assemblies or work area following Design Event II.

5.6.2 Transfer fuel Rods and associated debris to an to an appropriate storage container following Design Event II.

5.6.3 Provide for and maintain subcriticality during Design Events I through IV.

5.6.4 To the extent required by the facility, provide for local Confinement of radioactive particulate during Design Events I and II.

5.6.5 See Section 5.4.1 for applicable performance requirements for off-normal Rods storage containers.

5.7 **Auxiliary Operations.** Equipment, tools, and fixtures required to support Rod Consolidation operations shall perform their function during the Design Events that are applicable to the particular operation they support.

5.8 **Facility or Installation Interfaces.**

5.8.1 Structural design of the Canister and mating clearances with stands, racks, casks and other supporting structures shall be such to preclude overstressing of supporting structures during Design Events I through IV.

5.8.2 Maintain subcriticality in the event of physical and nuclear interactions with adjacent subfunctions for Design Events I through IV.

6.0 DESIGN REQUIREMENTS

The design requirements for the Rod Consolidation system are presented separately by subfunction. The Design Events to which these requirements apply are presented in Section 5.0.

6.1 End Fitting Removal

6.1.1 Codes and Standards. The End Fitting removal equipment shall be designated non-nuclear safety (NNS)(1) and shall be designed in accordance with commercial codes and standards. The following codes and standards represent an acceptable level of design and construction for components providing structural support.

1) ASME Boiler and Pressure Vessel Code Section VIII Division 1,[4]

2) Materials shall conform to Section III subsystem NF of the ASME Code[5], or AISC-5326 1978 Specifications for Design, Fabrication and Erection of Structural Steel for Buildings [6].

3) Cranes and hoists used for handling Spent Fuel Assemblies and Rods shall meet the requirements for the auxiliary handling crane in ANSI/ANS-57.1, 1980[7].

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(1) As defined in ANSI/ANS-51.1 1983 - Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants [3]

6.1.2 Conditions of Design

6.1.2.1 Design of the End Fitting Removal equipment shall provide adequate clearances when cutting to remove the End Fitting such that fuel Rod are not damaged.

6.1.2.2 All surfaces contacting fuel Rods shall be free of burrs, sharp corners, edges and weld beads that could breach the fuel Rod cladding.

6.1.2.3 All materials of construction shall be capable of withstanding cumulative radiation exposures anticipated in the intended service.

6.1.2.4 Placement of controls for any system shall be such as to enable the operator to use the controls while observing operations or instruments monitoring the functioning of the equipment being controlled.

6.1.2.5 All operator controls in systems for use in wet environments shall be designed for manipulation with gloved hands.

6.1.2.6 The following requirements apply to components normally underwater:

a) Lubricants and hydraulic fluids shall be compatible with water chemistry requirements.

b) Rust inhibitive coatings shall be compatible with wear conditions and water chemistry requirements.

c) Components, such as wheels, bearings and cables shall be capable of dry operation for limited periods for functional checkout and testing.

d) Materials shall be compatible with the wetted materials of the primary reactor coolant system. For example: avoid the use of sulfur, mercury and their compounds and alloys, or lead, cadmium, halogens and their compounds and alloys unless encapsulated or otherwise prevented from coming into contact with the pool water.

6.1.2.7 The equipment shall be designed to permit removal and replacement, or repair of functional components. Underwater actuating components should be capable of being removed and installed without lowering the pool water level.

6.1.2.8 Suitable fastener locking devices, e.g., bent metal tabs, or lock wires shall be used to prevent parts from falling from the equipment.

6.1.2.9 Commercial components, assemblies, and sub-assemblies should be selected to facilitate repair, replacement and interchangeability.

6.1.2.10 Galvanic and chemical corrosion shall be evaluated as part of the material selection process.

6.1.2.11 Means should be provided for the local collection of debris resulting from cutting operations.

6.1.2.12 Lubricants, sealants and protective coatings shall be compatible with their intended service and environment.

6.1.3 Interfaces. The End Fitting removal equipment should interface with the Rod Removal equipment and NFBC equipment.

6.1.4 Testing, Inspection and Maintenance

6.1.4.1 Provision shall be made in the design of the equipment to permit functional testing.

6.1.4.2 Provision shall be made to permit routine maintenance and inspection of components to assure that acceptable performance levels are maintained.

6.1.5 Design Documentation. Documentation shall be maintained to substantiate conformance with applicable standards and with applicable federal, state and local requirements. Design documentation, (drawings, specifications, and calculations) shall be checked in accordance with the quality assurance plan of Section 6.14.

6.2 **Rod Removal**

6.2.1 Codes and Standards. The Rod Removal equipment shall be designated non-nuclear safety (NNS)(1) and shall be designed in accordance with commercial codes and standards. The following codes and standards represent an acceptable level of design and construction for components providing structural support.

1) ASME Boiler and Pressure Vessel Code Section VIII Division 1[4],

2) Materials shall conform to Section III subsystem NF of the ASME Code[5], or AISC-5326 1978 Specifications for Design, Fabrication and Erection of Structural Steel for Buildings [6].

3) Cranes and hoists used for handling Spent Fuel Assemblies and Rods shall meet the requirements for the auxiliary fuel handling crane in ANSI/ANS-57.1 1980[7].

6.2.2 Conditions of Design

6.2.2.1 The Rod Removal equipment shall be designed to

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(1) As defined in ANSI/ANS-51.1 1983 - Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants[3]

maintain subcriticality in accordance with Section 6.9.1.

6.2.2.2 Fail safe latches should be utilized for moving and lifting mechanisms.

6.2.2.3 All surfaces contacting fuel Rods shall be free of burrs, sharp corners, edges and weld beads that could breach the fuel Rod cladding.

6.2.2.4 Devices for fuel Rod Removal shall be designed not to breach fuel cladding or damage Rods.

6.2.2.5 Means shall be provided to preclude inadvertent release of a fuel Rod by the handling equipment. Loss of power shall not result in dropping of fuel Rods.

6.2.2.6 Placement of controls for any system shall be such as to enable the operator to use the controls while observing operations or instruments monitoring the functioning of the equipment being controlled.

6.2.2.7 All operator controls for systems used in wet environments shall be designed for manipulation with gloved hands.

6.2.2.8 The following requirements apply to components normally underwater:

a) Lubricants and hydraulic fluids shall be compatible with water chemistry requirements.

b) Rust inhibitive coatings shall be compatible with wear conditions and water chemistry requirements.

c) Components such as wheels, bearings and cables shall be capable of dry operation for limited periods for functional check-out and testing.

d) Materials in contact with the pool water shall be compatible with the wetted materials of the primary reactor coolant system. For example: avoid the use of sulfur, mercury and their compounds and alloys or lead, cadmium, halogens and their compounds and alloys or unless encapsulated or otherwise prevented from coming into contact with the pool water.

6.2.2.9 Controls, interlocks or other features shall be provided to minimize the potential for dropping or jamming fuel Rods during handling operations.

6.2.2.10 The equipment shall be designed to permit removal and replacement, or repair of functional components. Underwater components should be capable of being removed and installed without lowering the pool water level.

6.2.2.11 Suitable fastener locking devices; e.g., bent metal tabs, or lock wires shall be used to prevent parts from falling from the equipment.

6.2.2.12 Commercial Components, assemblies, and sub-assemblies should be selected to facilitate repair, replacement and interchangeability.

6.2.2.13 Galvanic and chemical corrosion shall be evaluated as part of the material selection process.

6.2.2.14 Lubricants, sealants and protective coatings shall be compatible with their intended service and environment.

6.2.2.15 Means shall be provided to restrict movement of the fuel assembly during Rod Removal without damage to the Spent Fuel Assembly structure that would preclude further Rod Removal.

6.2.2.16 During the Rod Removal, means shall be provided within the operational envelope for the collection of the particulate matter released from the operation.

6.2.2.17 All materials of construction shall be capable of withstanding cumulative radiation exposures anticipated in the intended service.

6.2.3 Interfaces. The Rod Removal equipment should interface with the End Fitting removal equipment and the fuel Rod array reconfiguration equipment.

6.2.4 Testing, Inspection and Maintenance.

6.2.4.1 Provision shall be made in the design of the equipment to permit functional testing.

6.2.4.2 Provision shall be made to permit routine maintenance and inspection of components to assure that acceptable performance levels are maintained.

6.2.5 Design Documentation. Documentation shall be maintained to substantiate conformance with the applicable standards and with applicable federal, state and local requirements. Design documentation, (drawings, specifications, and calculations) shall be checked in accordance with the quality assurance plan of Section 6.14.

6.3 **Rod Array Reconfiguration.**

6.3.1 Codes and Standards. The Rod array reconfiguration equipment shall be designated non-nuclear safety (NNS)(1) and shall be designed in accordance with commercial codes and standards. The following codes and standards represent an acceptable level of design and construction for components providing structural

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(1) As defined in ANSI/ANS-51.1 1983 - Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants[3]

support:

1) ASME Boiler and Pressure Vessel Code Section VIII Division 1[4],

2) Materials shall conform to Section III subsystem NF of the ASME Code[5], or AISC-5326 Specifications for Design, Fabrication and Erection of Structural Steel for Buildings 1978[6].

3) Cranes and hoists used for handling Spent Fuel Assemblies and Rods shall meet the requirements for the auxiliary fuel handling crane in ANSI/ANS-57.1 1980[7].

6.3.2 Conditions of Design

6.3.2.1 The Rod array reconfiguration equipment shall be designed to maintain subcriticality in accordance with Section 6.9.1.

6.3.2.3 All surfaces contacting fuel Rods shall be free of burrs, sharp corners, edges and weld beads that could breach the fuel Rod cladding.

6.3.2.4 Means shall be provided to preclude inadvertent release of the fuel Rod by the handling equipment. Loss of power shall not result in dropping of fuel Rod.

6.3.2.5 Placement of controls for any system shall be such as to enable the operator to use the controls while observing operations or instruments monitoring the functioning of the equipment being controlled.

6.3.2.6 All operator controls for wet systems shall be designed for manipulation with gloved hands.

6.3.2.7 The following requirements apply to components normally underwater:

a) Lubricants and hydraulic fluids shall be compatible with water chemistry requirements.

b) Rust inhibitive coatings shall be compatible with wear conditions and water chemistry requirements.

c) Components, such as wheels, bearings and cables shall be capable of dry operation for limited periods for functional check-out and testing.

d) Materials shall be compatible with the wetted materials of the primary reactor coolant system. For example: avoid the use of sulfur, mercury and their compounds and alloys, or lead, cadmium, halogens and their compounds and alloys unless encapsulated or otherwise prevented from coming into contact with the pool water.

6.3.2.8 Controls, interlocks or other features shall be provided to minimize the potential for dropping or jamming fuel Rods during handling operations.

6.3.2.9 The equipment shall be designed to permit removal and replacement, or repair of functional components. Underwater components should be capable of being removed and installed without lowering the pool water level.

6.3.2.10 Suitable fastener locking devices, e.g., bent metal tabs or lock wires shall be used to prevent parts from falling from the equipment.

6.3.2.11 Commercial Components, assemblies, and sub-assemblies should be selected to facilitate repair, replacement and interchangeability.

6.3.2.12 Galvanic and chemical corrosion shall be evaluated as part of the material selection process.

6.3.2.13 Lubricants, sealants and protective coatings shall be compatible with their intended service and environment.

6.3.2.14 During the Rod array reconfiguration means shall be provided within the operational envelope for the collection of the particulate matter released from this operation.

6.3.2.15 All materials of construction shall be capable of withstanding cumulative radiation exposures anticipated in the intended service.

6.3.3 Interfaces. The Rod array reconfiguration equipment should interface with the Rod Removal and Rod packaging equipment.

6.3.4 Testing, Inspection and Maintenance.

6.3.4.1 Provision shall be made in the design of the equipment to permit functional testing.

6.3.4.2 Provision shall be made to permit routine maintenance and inspection of components to assure that acceptable performance levels are maintained.

6.3.5 Design Documentation. Documentation shall be maintained to substantiate conformance with the applicable standards and with applicable federal, state and local requirements. Design documentation (drawings, specifications, and calculations) shall be checked in accordance with the quality assurance plan of Section 6.14.

6.4 Consolidated Rod Packaging

6.4.1 Codes and Standards. The Canister provided for packaging of reconfigured Rods shall be designated as non-nuclear safety (NNS)(1) and shall be designed in accordance with commercial codes and standards. The following code represents an acceptable level of design: ASME Boiler and Pressure Vessel Code, Section III, Division 1, Part NF[5].

6.4.2 Conditions of Design

6.4.2.1 The design shall maintain fuel Rod cladding temperature in accordance with Section 6.11 when the Canister is loaded with fuel Rods.

6.4.2.2 The consolidated Rod packaging equipment shall be designed to maintain subcriticality in accordance with Section 6.9.1.

6.4.2.3 Allowable design stresses used in the design of the Canister shall be in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Part NF[5] for loads and methods specified in Section 6.10.

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(1) As defined in ANSI/ANS-51.1 1983 - Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants[3].

6.4.2.4 Galvanic and chemical corrosion shall be evaluated as part of the material selection process.

6.4.2.5 Provisions shall be made in the Canister to allow for drainage or vacuation.

6.4.3 Interfaces. The Canister shall be dimensionally compatible with the Rods, the consolidation packaging, and spent fuel handling equipment. The Canister shall also be compatible with the immediate storage system beyond the Rod Consolidation equipment.

6.4.4 Testing, Inspection and Maintenance.

6.4.4.1 Provision shall be made in the design of the equipment to permit functional testing.

6.4.4.2 Provision shall be made to permit routine maintenance and inspection of components to assure that acceptable performance levels are maintained.

6.4.5 Design Documentation. Documentation shall be maintained to substantiate conformance with the applicable standards and with applicable federal, state and local requirements. Design documentation (drawings, specificationns and calculations) shall be checked in accordance with Section 6.14.

6.5 **Nonfuel-Bearing Components Handling System**

6.5.1 Codes and Standards. The Nonfuel Bearing Component handling equipment shall be designated as non-nuclear safety (NNS)(1) and shall be designed in accordance with commercial codes and standards. The following codes represent an acceptable level of design for the structural components of the Nonfuel Bearing Component handling system;

1) ASME Boiler and Pressure Vessel Code, Section VIII, Division 1[4],

2) Materials shall conform to the ASME Code Section III Subsection NF[5] or AISC-S326 1978, Specifications for Design, Fabrication and Erection of Structural Steel for Buildings[6].

3) Cranes and hoists used for handling Spent Fuel Assemblies and Rods shall meet the requirements for the auxiliary fuel handling crane in ANSI/ANS-57.1 1980[7].

6.5.2 Conditions of Design

6.5.2.1 All operator controls for wetted systems shall be designed for manipulation with gloved hands.

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(1) As defined in ANSI/ANS-51.1 1983 - Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants[3].

6.5.2.2 Placement of controls shall be such as to enable the operator to use the controls while observing operations or instruments monitoring the functioning of the equipment being controlled.

6.5.2.3 Fail safe latches should be utilized for moving and lifting mechanisms.

6.5.2.4 The following requirements apply to components normally underwater:

a) Lubricants and hydraulic fluids shall be compatible with water chemistry requirements.

b) Rust inhibitive coatings shall be compatible with wear conditions and water chemistry requirements.

c) Components such as wheels, bearings and cables shall be capable of dry operation for limited periods for purposes of functional check-out and testing.

d) Materials shall be compatible with the wetted materials of the primary reactor coolant system. For example; avoid the use of sulfur, mercury and their compounds and alloys, or lead, cadmium, halogens and their compounds and alloys unless encapsulated or otherwise prevented from coming into contact with the pool water.

6.5.2.5 The equipment shall be designed to permit removal and replacement, or repair of functional components. Underwater actuating components should be removable and installable without lowering the pool water level.

6.5.2.6 Suitable fastener locking devices, e.g., bent metal tabs, or lock wires shall be used to prevent parts from falling from the equipment.

6.5.2.7 Commercial Components, assemblies, and subassemblies should be selected to facilitate repair, replacement or interchangeability.

6.5.2.8 Galvanic and chemical corrosion shall be evaluated as part of the material selection process.

6.5.2.9 Lubricants, sealants and protective coatings shall be compatible with their intended service and environment.

6.5.2.10 During the Nonfuel-Bearing Component handling means shall be provided within the operational envelope for the collection of the particulate material released from this operation.

6.5.2.11 Consideration should be given to prevention of pyrophoric conditions in sheared NFBC during dry storage and transport.

6.5.2.12 Provisions shall be made in the NFBC container to allow for drainage or vacuation.

6.5.2.13 Provision shall be made for permanent identification of the NFBC container which is discernable during storage.

6.5.3 Interfaces. The Nonfuel-Bearing Component handling equipment should interface with the Rod Consolidation and Spent Fuel Assembly handling systems. The Nonfuel-Bearing Component disposal container shall be compatible with the immediate storage system beyond the Rod Consolidation system.

6.5.4 Testing, Inspection and Maintenance. Provisions shall be made in the design of the equipment to permit functional testing, routine maintenance and inspection of components to assure that acceptable performance levels are maintained.

6.5.5 Design Documentation. Documentatiion shall be maintained to substantiate conformance with applicable standards and with applicable federal, state and local requirements. Design documentation (drawings, specifications, and calculations) shall be checked in accordance with the quality assurance plan in Section 6.14.

6.6 **Off-Normal Rod Handling**

6.6.1 Codes and Standards. The off-normal Rod handling equipment shall be designated as non-nuclear safety (NNS)(1) and shall be designed in accordance with commercial codes and standards. The following codes represents an acceptable level of design: ASME Boiler and Pressure Vessel Code, Section VIII, Division 1[4].

6.6.2 Conditions of Design

6.6.2.1 The Off-normal Rod handling equipment and containers shall be designed to maintain subcriticality in accordance with Section 6.9.1.

6.6.2.2 Means shall be provided to preclude inadvertent release of the Damaged, Stray, or broken Rod sections by the handling device during loss of power.

6.6.2.3 Placement of controls shall be such as to enable the operator to use the controls while observing operations or instruments monitoring the functioning of the equipment being controlled.

6.6.2.4 All operator controls for wetted systems shall be designed for manipulation with gloved hands.

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[1] As defined in ANSI/ANS-51.1 1983 - Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants[3].

6.6.2.5 The following requirements apply to components normally underwater:

a) Lubricants and hydraulic fluids shall be compatible with water chemistry requirements.

b) Rust inhibitive coatings shall be compatible with wear conditions and water chemistry requirements.

c) Components, such as wheels, bearings, and cables shall be capable of dry operation for limited periods for functional check-out and testing.

d) Materials in contact with the pool water shall be compatible with wetted materials of the primary reactor coolant system. For example: avoid the use of sulfur, mercury and their compounds and alloys or lead, cadmium, halogens and their compounds and alloys unless encapsulated or otherwise prevented from coming into contact with the pool water.

6.6.2.6 Controls, interlocks or other features should be provided to minimize the potential for dropping or jamming broken fuel Rods during handling operations.

6.6.2.7 The equipment shall be designed to permit removal and replacement, or repair of functional components. Underwater components should be removable and installable without lowering the pool water level.

6.6.2.8 Suitable fastener locking devices, e.g., bent metal tabs or lock wires shall be used to prevent parts from falling from the equipment.

6.6.2.9 Commercial Components, assemblies, and subassemblies should be selected to facilitate repair, replacement, or interchangeability.

6.6.2.10 Galvanic and chemical corrosion shall be evaluated as part of the material selection process.

6.6.2.11 Lubricants, sealants and protective coatings shall be compatible with their intended service and environments.

6.6.2.12 All materials of construction shall be capable of withstanding cumulative radiation exposure anticipated in the intended service.

6.6.2.13 Indicators showing the force being applied to remove broken or Stray Rods shall be provided.

6.6.2.14 During off-normal Rod handling means shall be provided within the operational envelope for the collection of particulate material released from this operation.

6.6.3 Interfaces. The off-normal Rod handling equipment should interface with each of the other subfunctions of the Rod Consolidation process. Use of the off-normal Rod handling equipment should not require disassembly of the Rod Consolidation system. The off-normal Canister shall be dimensionally compatible with the immediate storage system.

6.6.4 Testing, Inspection and Maintenance

6.6.4.1 Provision shall be made in the design of the equipment to permit functional testing.

6.6.4.2 Provision shall be made to permit routine maintenance and inspection of components to assure that acceptable performance levels are maintained.

6.6.5 Design Documentation. Documentation shall be maintained to substantiate conformance with applicable standards and with applicable federal, state, and local requirements. Design documentation (drawings, specifications and calculations) shall be checked in accordance with the quality assurance plan of Section 6.14.

6.7 Auxiliary Operations

6.7.1 Codes and Standards. Auxiliary equipment shall be designed in accordance with commercial codes and standards.

6.7.2 Conditions of Design

6.7.2.1 Placement of controls shall be such as to enable the operator to use the controls while observing operations or instruments monitoring the functioning of the tools being controlled.

6.7.2.2 All operator controls for systems used in wet environments shall be designed for manipulation with gloved hands.

6.7.2.3 The following shall apply to components normally underwater:

a) Lubricants and hydraulic fluids for immersed components shall be compatible with water chemistry requirements.

b) Rust inhibitive coatings shall be compatible with wear conditions and water chemistry requirements.

c) Components such as wheels, bearings and cables shall be capable of dry operation for limited periods for functional check-out and testing.

d) Material in contact with pool water shall be compatible with wetted materials of the primary reactor coolant system. For example: avoid the use of sulfur, mercury, and their compounds and alloys or lead, cadmium, halogens and their compounds and alloys unless encapsulated or otherwise prevented from coming in contact with the pool water.

6.7.2.4 The equipment should be designed to permit removal and replacement, or repair of functional components. Underwater actuating components shall be removable and reinstallable without lowering the pool water level.

6.7.2.5 Suitable fastener locking devices, e.g., bent metal tabs, or lock wires shall be used to prevent parts from falling from the tools.

6.7.2.6 Commercial Components, assemblies, and subassemblies should be selected to facilitate repair, replacement, or interchangeability.

6.7.2.7 Galvanic and chemical corrosion shall be evaluated as part of the material selection process.

6.7.2.8 Lubricants, sealants and protective coatings shall be compatible with their intended service and environment.

6.7.3 Interface. The auxiliary equipment should interface with each of the other subfunctions of the Rod Consolidation process.

6.7.4 Testing, Inspection and Maintenance

6.7.4.1 Provisions should be made in the design of auxiliary tools and equipment to permit functional testing.

6.7.4.2 Provisions should be made to permit routine maintenance and inspection of components to assure that acceptable performance levels are maintained.

6.7.5 Design Documentation. Documentation shall be maintained to substantiate conformance with applicable standards and with applicable federal, state, and local requirements. Design documentation (drawings, specifications, and calculations) shall be in accordance with the quality assurance plan of Section 6.14.

6.8 **Facility or Installation Interfaces**

Various services, systems, or components of the host facility or installation interface with the Rod Consolidation process. Design reviews and analysis of the host facility or installation systems shall be performed to assure they have sufficient capacity, with suitable margins, to meet the additional requirements imposed by the Rod Consolidation process. In particular the following considerations shall be addressed;

6.8.1 Materials Compatibility. Evaluate all materials introduced into the facility or installation operating environment such as hydraulic fluids and structural components to assure compatability.

6.8.2 Radioactive Particulate Control. Evaluate the existing facility or installation systems such as spent fuel pool cleaning or hotcell HVAC to assure these systems can accommodate any radioactive particulate released during the Rod Consolidation operation.

6.8.3 Thermal Loads. Evaluate the heat removal systems such as spent fuel pool cooling and hotcell HVAC to assure these systems can accommodate the heat load from the increased concentration of fuel in storage.

6.8.4 Structural Loads. Evaluate systems and structures such as fuel handling equipment, storage racks, and the spent fuel storage area to assure the additional loads from full Canisters and NFBC containers can be accommodated.

6.8.5 Criticality. Evaluate existing facility systems to assure continued subcritically in accordance with the facility subcriticality criteria.

6.8.6 Shielding. Evaluate the facility or installation shielding features which limit radiological dose to operating personnel such as minimum pool water operating depth or shielding walls to assure that Spent Fuel Assembly handling, the Rod Consolidation process, and the subsequent handling of full Canisters and NFBC container do not result in exposures above the design basis or criteria.

6.8.7 Decontamination. Evaluate the existing decontamination systems to assure the adequate decontamination of the Rod Consolidation tools, equipment, and fixtures.

6.8.8 Radwaste Handling. Evaluate the existing liquid and solid radwaste systems to assure they can accommodate the additional waste generated from the Rod Consolidation process.

6.8.9 Maintenance. Evaluate existing maintenance areas and equipment to assure that the equipment of the Rod Consolidation process can be properly maintained.

6.8.10 Operational Impacts. Evaluate the Rod Consolidation process, its operation and physical location to assure that the safety of the existing facility or installation is not adversely affected.

6.8.11 Auxiliary Equipment Storage. Auxiliary equipment should be provided with restraints for use during storage periods that are compatible with requirements of the storage area.

6.9 **Nuclear Safety**

6.9.1 Nuclear Criticality Safety

6.9.1.1 Codes and Standards. Nuclear criticality safety of Rod Consolidation process shall be in accordance with applicable American National Standards developed by ANS Subcommittee 8.

6.9.1.2 Conditions of Design

6.9.1.2.1 Prior to first use and before implementing design changes to Rod Consolidation, a criticality safety analysis shall be performed in accordance with ANSI/ANS-8.17 1983[10].

6.9.1.2.2 General criteria applicable to Rod Consolidation process are contained in ANSI/ANS-8.17 1983[10].

6.9.1.2.3 Methods used to calculate subcriticality shall be validated in accordance with ANSI/ANS 8.1 1983[8] and ANSI/ANS-8.17 1983[10].

6.9.1.2.4 Credit taken for fuel burnup shall be in accordance with ANSI/ANS-8.17 1983[10].

6.9.1.2.5 No credit shall be taken for soluble poison.

6.9.1.2.6 The analysis shall demonstrate that fuel will be handled, stored, and transported in a manner providing a sufficient factor of safety to require at least two unlikely, independent, and concurrent changes in conditions before a criticality accident is possible.

6.9.1.2.7 The analysis shall demonstrate that damaged fuel Canisters, or spilled Rods, if credible will remain subcritical.

6.9.1.2.8 The analysis shall demonstrate that during the Canister loading operation, partially loaded Canisters remain subcritical.

6.9.1.2.9 The analysis shall demonstrate that broken Rods, pellets, and debris in Canisters, containers, basin areas and filters, remain subcritical.

6.9.1.2.10 Guidance to determine the need for and use of a criticality alarm system shall be in accordance with ANSI/ANS-8.3 1979[9].

6.9.2 Radiological Protection. This section presents the radiological protection requirements for the Rod Consolidation process.

6.9.2.1 Conditions of Design

6.9.2.1.1 Structures, systems and components for which operation, maintenance, and required inspections may involve exposure to radiation shall be designed, fabricated, located, shielded, controlled, and tested so as to control external and internal radiation exposure to on-site personnel and the public to levels which are consistent with the principles of ALARA.

6.9.2.1.2 The system design shall consider personnel safety and the confinement of radioactive particulate under conditions of system failure and misoperation.

6.9.2.1.3 All releases of radioactive particulate in liquid or airborne effluents to unrestricted areas shall meet the requirements defined in the facility or installation Safety Analysis Report.

6.9.2.1.4 Design provisions shall be incorporated in the Rod Consolidation process to prevent or minimize the accumulation of radioactive particulate in normally occupied areas. For systems that require nonroutine access, decontamination capability should be provided.

6.9.2.1.5 The Rod Consolidation process design should incorporate provisions to reduce, to the extent practicable, the time required to perform work (including maintenance) in radioactive environments.

6.9.2.1.6 Provision shall be made in the design to limit the spread of radioactive particulate, and control radiation levels.

6.9.2.1.7 Estimates of dose rates which would arise because of a buildup of contamination within the Rod Consolidation process shall be based on least favorable radiation and contamination conditions that can be anticipated during the lifetime of the process.

6.9.2.1.8 Special precautions shall be taken in the design of shielding and equipment to avoid high doses to the extremities of operationing personnel during access to and manipulation of Rod Consolidation equipment.

6.9.2.1.9 Design of the Rod Consolidation process shall provide for control of radioactive particulate by appropriate confinement and suitably designed cleanup systems.

6.9.2.1.10 The background environment shall be considered in determining audio and light intensity levels to be specified for radiation alarms and access control devices.

6.9.2.1.11 Rod Consolidation equipment should be designed to permit ease of decontamination; i.e., minimize crevices where contaminants could accumulate. Where crevices are unavoidable, parts should be designed to be disassembled to facilitate decontamination.

6.9.2.1.12 Flow of water or air when used for contamination control in the Rod Consolidation process shall be from areas of lower radioactive contamination to areas of higher contamination.

6.9.2.1.13 In water shielded systems, Rod Removal travel shall be controlled to prevent loss of adequate shielding in the event of sudden fuel Rod release.

6.10 Structural Analysis

Load combinations and design limits for steel structures are provided in this section. Seismic loads to be used are based on the standard designation of the safe shutdown earthquake (SSE). Seismic excitation along three orthogonal directions shall be applied simultaneously. The square root of the sum of the squares method may be used to combine the three spatial components of the earthquake. Seismic calculations shall be based on plant specific earthquake response curves or time-history data.

Seismic loading effects on free-standing systems shall be considered. Minimum required factors of safety shall be 1.1 against both overturning and sliding. These minimum requirements on factors of safety need not be met, provided that any one of the following conditions is met:

1) It can be shown by detailed nonlinear dynamic analyses that the amplitudes of sliding motion are minimal and impact between adjacent equipment or structures is prevented. In addition, minimum requirement for the factor of safety against overturning is satisfied.

2) It can be shown that any sliding or tilting motion will be contained within suitable geometric constraints such that any impact forces are incorporated.

6.10.1 Loads

6.10.1.1 Normal Operating Loads (For Design Events I thru IV). All permanent and transient loads that could exist or be developed during normal operation of the system shall be included.

D - Dead load of the structure

L - Live load of the structure

T - Thermal loads

6.10.1.2 Natural Phenomena Loads (For Design Event IV).

E - Loads generated by the SSE

6.10.1.3 Abnormal Operating Loads (For Design Events II and III).

Ta - Loads due to a temperature rise resulting from loss of auxiliary cooling systems for extended periods of time

A - Loads due to dropped components that impact system

6.10.2 Design Limits

6.10 2.1 Strength

S - Required strength of a section, member or connection computed in accordance with

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6″

1

IMAGE EVALUATION TEST TARGET (MT-3)

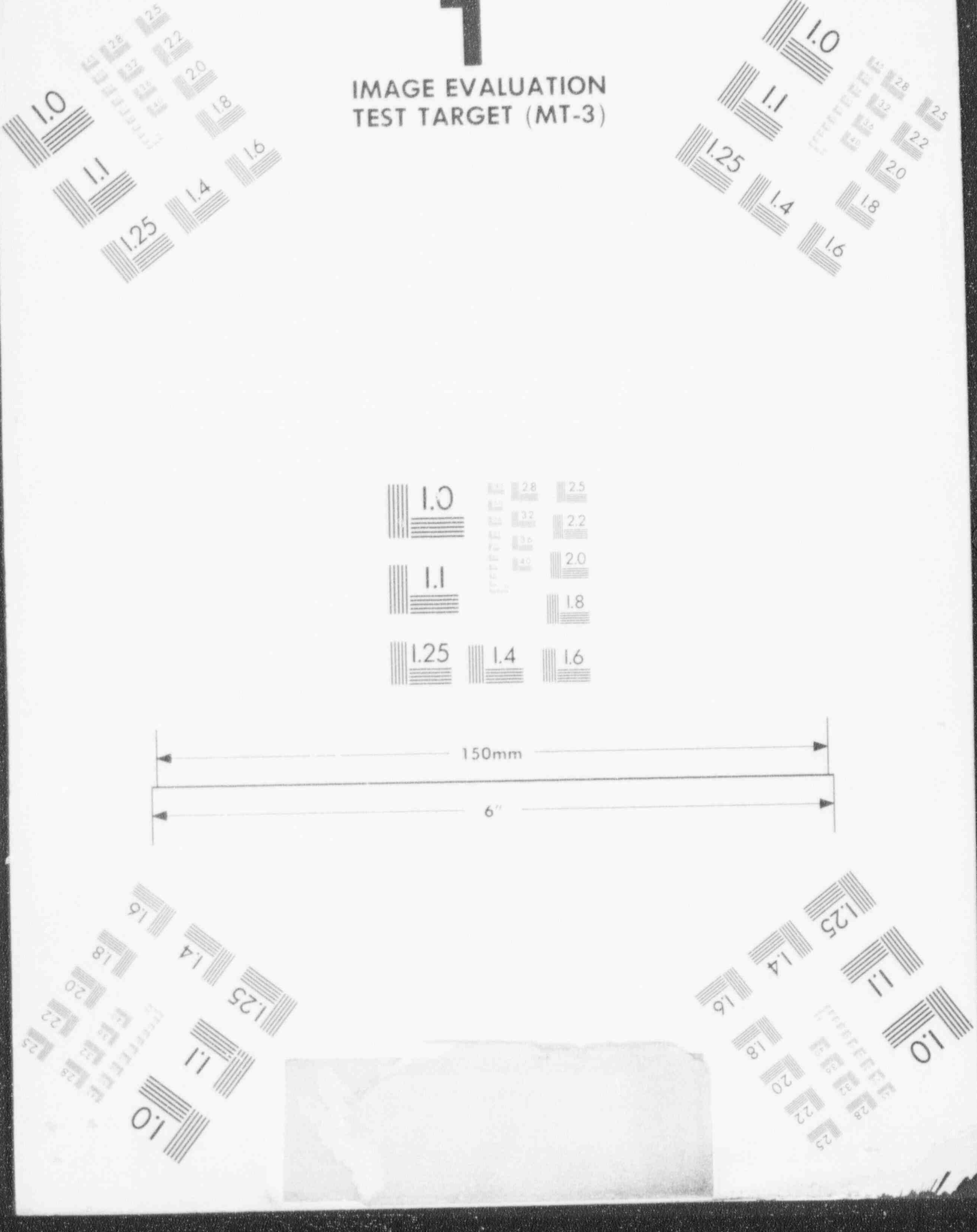
1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2 3.6 4.0

150mm

6"

1

IMAGE EVALUATION
TEST TARGET (MT-3)



1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

"Allowable Stress Design Method" of Part I of AISC Specifications-1978[6]. The one-third increase in allowable stresses for wind and seismic loading conditions is not permitted.

Y - Required strength of a section, member or connection computed in accordance with the "Plastic Design Method" of Part II of the AISC Specification-1978[6]. In evaluating the effects of localized stresses caused by the postulated natural phenomena and abnormal operating loads, elasto-plastic behavior of the structures may be considered with appropriate ductility ratios, provided the accompanying deformations would not result in loss of function of the affected structures, systems, and components.

6.10.2.2 Materials. Carbon steel materials and properties used shall be in accordance with approved standards such as the ASTM standards[12] approved for use with the AISC Specification[6] and Appendix I of ASME Boiler and Pressure Vessel Codes, Section III[5].

6.10.2.3 Deformation. The deformations of structures and structural components under design load conditions shall be computed to assure that other structures, systems, and components affected by these deformations multiplied by the appropriate load factor as required in the following sections.

6.10.3 Load Combinations. The designated loads shall be combined to simulate the most adverse load conditions considering the possible variations in their magnitude and direction.

6.10.3.1 Allowable Stress Design Method. When the allowable stress design method is used, the following relationship between the load combinations and the allowable stresses S shall be satisfied:

a) $S > D + L$

b) $1.5S > D + L + T$

c) $1.6S > D + L + T + E$

d) $1.7S > D + L + Ta + E$

e) $1.7S > D + L + A$

In no case shall the required shear strength exceed 1.4S. For determining the flexural strength under load combinations d) and e) above, the plastic section moduli of steel shapes may be used; however, the required strength shall not exceed 1.9S.

The Rod Consolidation equipment may undergo local plastic deformation when subjected to load combinations e) and d) above, as long as the system maintains subcriticality in accordance with Section 6.9. Thermal loads may be neglected when it can be shown that they are secondary and self-limiting in nature, the design shall provide a sufficient redundancy to prevent collapse due to the formation of plastic hinges and when the material is ductile.

6.10.3.2 Plastic Strength Design. When the plastic design method is used, the following relationship between the required strength Y and the load combinations shall be satisfied.

a) $Y > 1.7\ (D + L)$

b) $Y > 1.3\ (D + L + T)$

c) $Y > 1.2\ (D + L + T + E)$

d) $Y > 1.1\ (D + L + Ta + E)$

e) $Y > 1.1\ (D + L + A)$

The Rod Consolidation equipment may undergo plastic deformation when subjected to load combinations e) and d) above, as long as the system maintains subcriticality in accordance with Section 6.9. Thermal loads may be neglected when it can be shown that they are secondary and self-limiting in nature, the design shall provide sufficient redundancy to prevent collapse due to the formation of plastic hinges and when the material is ductile.

6.11 **Thermal Criteria**

The section presents the design temperature limits for the cladding of the fuel Rods during the Rod Consolidation process.

6.11.1 For Rod Consolidation performed in water, the maximum Rod cladding temperatures under normal conditions shall not exceed that temperature which would produce localized boiling throughout the process. This limiting temperature can be conservatively defined as the boiling temperature of the pool water at the depth which corresponds to the uppermost possible position of the Spent Fuel Assembly. Rod temperatures shall be calculated assuming the worst expected conditions considering factors such as Rod geometry in the Canister, cooling flow through the Canister, maximum pool water temperature, etc.

6.11.2 For Rod Consolidation performed in a dry air environment. The maximum fuel Rod cladding temperature shall not exceed temperature limits as defined in ANSI/ANS-57.9[2]. Thermal design objectives should be met by extending the required minimum cooling time of the fuel or by providing engineered systems that enhance Rod cooling or by use of an inert gas blanket. In calculating the maximum Rod cladding temperature in the dry environment, the worst expected conditions shall be assumed including factors such as the number and geometry of the Rods in the Canister, air flow through and around the Canister, contact area and contact resistance between Rods, ambient air temperature, etc.

6.12 **Accountability and Safeguards**

The Rod Consolidation process and associated equipment shall be designed to accommodate accountability and safeguard considerations as presented in this section.

6.12.1 The Canister and cover shall each be identifiable by means of a unique permanent alphanumeric code(s). This identification shall be readily visible when the Canister is in the consolidation work area and in the storage area.

6.12.2 Tamper-indicating seals shall be provided for the Canister closure. Provisions shall be incorporated in the design of the Canister to facilitate installation and checking of these seals.

6.12.3 Provisions for Canister identification shall be consistent with the facility or installation safeguards and accountability requirements.

6.12.4 Accountability procedures and records shall be consistent with the facility or installation accountability requirements.

6.12.4.1 Canisters should contain integral Spent Fuel Assemblies whenever possible and SNM accounting may be based on whole numbers of fuel assemblies.

6.12.4.2 Where an integral number of Spent Fuel Assemblies is not achieved and the Canister contains Rods of the same nominal initial enrichment, accountability shall be effected by a count of the number of Rods placed in the Canister. In this case, SNM material amounts may be calculated by multiplying the fraction of each Spent Fuel Assembly Rods placed in the Canister times the total Spent Fuel Assembly SNM content.

6.12.4.3 Where Rods from a non-integral number of Spent Fuel Assemblies which contain Rods of differing nominal initial enrichments, througho[illegible] the Spent Fuel Assembly are to be placed in more than one Canister, a records system shall be devised to ascertain the SNM contents of those Canisters.

6.12.5 Packaging and accounting arrangements shall be provided for individual Stray or Damaged Rods which result from the Rod Consolidation process. Canisters for broken or Damaged Rods and miscellaneous associated SNM shall follow the same identification and sealing requirements as whole Rod Canisters.

6.12.6 Physical protection requirements for the Rod Consolidation process shall be dictated by the requirements of the facility or installation in which the operation is conducted.

6.13 **Decomissioning**

The Rod Consolidation equipment shall be designed to facilitate decommissioning either as part of the facility or installation decommissioning or as a separate system. Provisions may be made to facilitate decontamination of structures and equipment, minimize the quantity of radioactive wastes and contaminated equipment, and facilitate the removal of radioactive wastes and contaminated material. Examples of such design features may include the following:

a) Large or very long components made in sections to facilitate easy removal, packaging, and shipment.

b) Crevices or cavities be minimized where contaminants could accumulate.

c) Materials that minimize activation product formation or facilitate decontamination be selected.

d) Exposed surfaces be coated with strippable materials to ease decontamination.

6.14 **Quality Assurance**

6.14.1 As a minimum, the following equipment,

a) End Fitting removal,

b) Rod Removal,

c) Rod array reconfiguration,

d) Consolidated Rod packaging,

e) Off-normal Rod handling

shall be designed and fabricated commensurate with the quality assurance requirements of the facility, or installation, with a quality assurance program developed from the applicable sections of ANSI/ASME NQA-1 1983, Quality Assurance Program Requirements for Nuclear Power Plants[3] that meet the facility or installation safety requirements.

6.14.2 All other equipment and components of the Rod Consolidation process shall be designed and fabricated commensurate with safety requirements of the facility or installation and in accordance with the quality assurance requirements of the facility or installation in which the Rod Consolidation process is located.

7.0 REFERENCES

[1] ANSI/ANS-57.7 Design Criteria for and Independent Spent Fuel Storage Installation (Water Pool Type)

[2] ANSI/ANS-57.9 Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Types)

[3] ANSI/ANS-51.1 Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants, 1983

[4] ASME Boiler and Pressure Vessel Code Section VIII Division 1

[5] ASME Boiler and Pressure Vessel Code Section III Subsystem NF and Appendix 1

[6] AISC-5326 Specifications for Design, Fabrication and Erection of Structural Steel for Buildings

[7] ANSI/ANS-57.1 Design Criteria for LWR Spent Fuel Handling Equipment, 1980

[8] ANSI/ANS-8.1 Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors, 1983

[9] ANSI/ANS-8.3 Criticality Alarm Systems, 1979

[10] ANSI/ANS-8.17 Criticality Safety Criteria for Handling, Storage, and Transportation of LWR Fuel Outside Reactors, 1983

[11] ANSI/ANS-8.19 Administrative Practices for Nuclear Criticality Safety, 1983

[12] ASTM Carbon Steel Standards

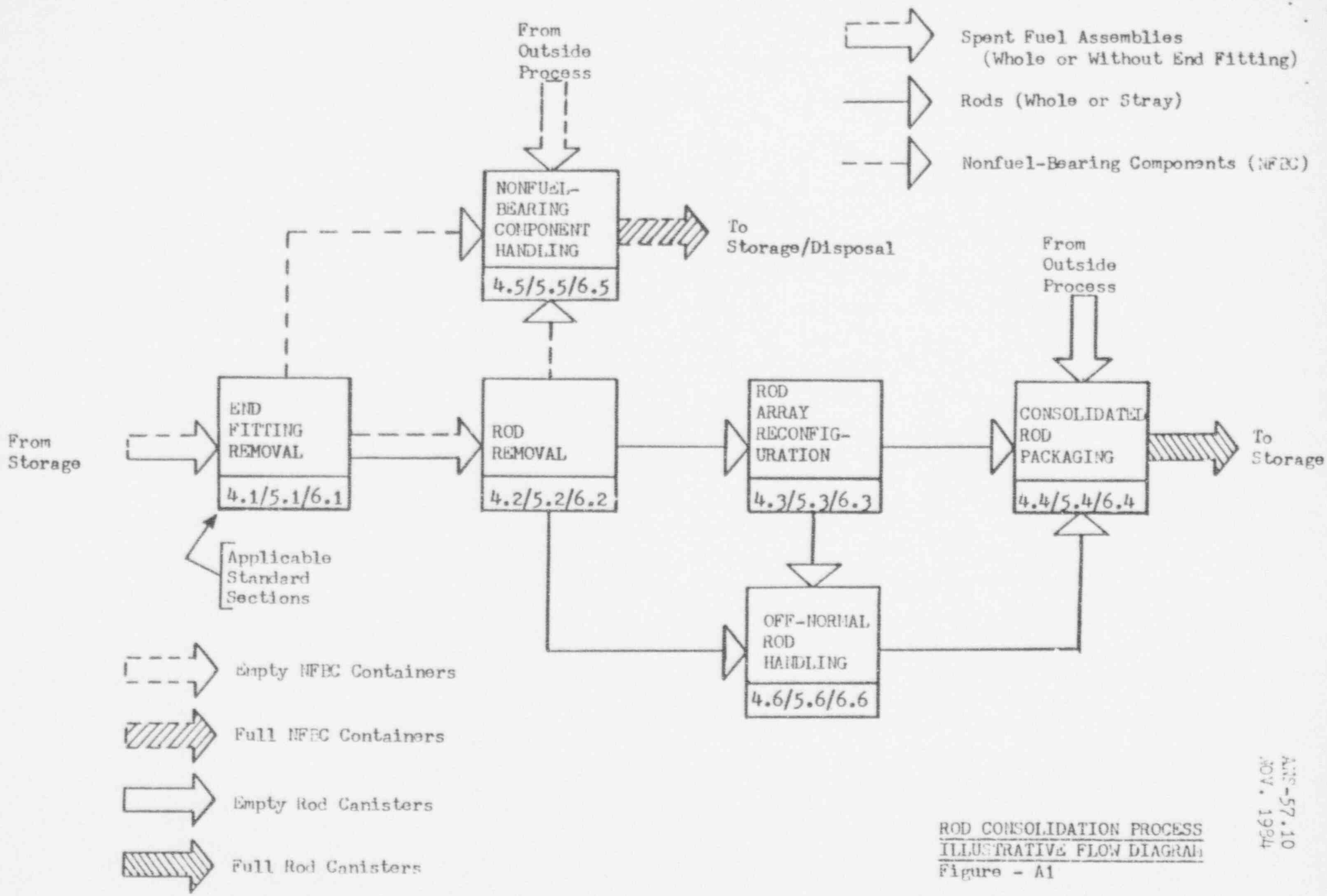
[13] ANSI/ASME NQA-1 Quality Assurance Program Requirements for Nuclear Power Plants, 1983

APPENDIX A

(This Appendix is not a part of this standard, Design Criteria for the Consolidation of LWR Spent Fuel, ANS-57.10, but is included for information purposes only.)

ILLUSTRATIVE DIAGRAM

The following diagram depicts the Rod Consolidation process flow. Also shown are the applicable sections of this standard.



ROD CONSOLIDATION PROCESS ILLUSTRATIVE FLOW DIAGRAM
Figure - A1

APPENDIX B

(This Appendix is not a part of this standard, Design Criteria for the Consolidation of LWR Spent Fuel, ANS-57.10, but is included for information purposes only.)

NUCLEAR CRITICALITY SAFETY

B-1.0

The purpose of this Appendix is to point out special characteristics of the rod consolidation operation that impact on the nuclear criticality safety analysis. Observations are also made that should help in selecting design features to help ensure criticality safety.

B-2.0

The discussion and examples in the Appendix will assume fuel assemblies and rod systems that are nonirradiated and fully moderated with water. The standard provides an option to take credit for fuel burnup and fission products. Also, rod consolidation could be carried out in a dry facility recognizing the fact that unmoderated uranium enriched to less than 5 wt% U235 cannot sustain a neutron chain reaction regardless of the number of fuel rods (i.e., k_{∞} is less than unity).

B-3.0

For Light Water Reactor (LWR) fuel assembly handling and storage, criticality safety is usually controlled by spacing. Compact storage systems may include a neutron poison between assemblies. At the optimum spacing for criticality, the number of assemblies required for criticality is 7 to 10 for Boiling Water Reactors (BWR) and 3 to 5 for Pressurized Water Reactors (PWR). The reason for these relatively high numbers is that the rods within the assemblies are significantly undermoderated.

B-4.0

When fuel rods are removed from the assembly structure, or are otherwise released from confinement and allowed to spread apart, the number of fuel rods required for criticality significantly drops, for the BWR fuel.

B-4.1

For BWR assemblies, there is an insufficient number of rods in one assembly for criticality. A 7x7 assembly contains 49 rods. For 2 to 3 wt% U235 enriched fuel with 0.5 in. diameter rods, the minimum critical number of rods is in the range of 110 to 230 (see Tables 1 and 2).

B-4.2

For PWR assemblies, the situation is different. One PWR assembly alone contains a sufficient number of fuel rods for criticality. Subcriticality is maintained by the close packed, undermoderated arrangement of rods in the assembly. A 17x17 rod assembly contains 289 rods. For 4 wt% U235 enriched fuel with 0.4 in. diameter rods, the minimum critical number of rods is in the range of 110 to 140 (see Tables 1 thru 3).

B-4.3

Because of sensitivity of the spacing between the rods to the critical number of rods, special attention should be given in the rod consolidation systems to number of rods present and the potential spacing between rods, e.g., accidental spreading.

B-5.0

It may be beneficial to recognize that there is a canister size for each characteristic fuel assembly that is geometrically favorable. Within this confined geometry, the fuel will remain subcritical, regardless of the number or spacing between the fuel rods. Two examples are given below on how to estimate "minimum critical" size.

B-5.1

Consider square canisters that are to contain 0.4 in. diameter fuel rods. Figure 1 shows canister capacity (number of rods) as a function of water-to-fuel volume ratio (Vw/Vf) for several canister sizes. Superimposed on these curves is a line representing the minimum cirtical number of 3 wt% U235 enriched rods as a function of Vw/Vf. Note that the "critical number" line is tangent to a canister line at a canister size of about 11x11 in. Thus, below an 11x11 in. canister size, a critical rod configuration in a single isolated canister is not possible for 0.4 in. diameter rods enriched to 3 wt% U235, regardless of the number of rods or the pitch.

B-5.2

For cylindrical canisters, a similar approach may be used to find the minimum critical canister size. Figure 2 shows a series of curves giving canister capacity as a function of the spacing between rods (Vw/Vf). Superimposed on these curves is the curve giving critical number of rods as a function of spacing between the rods. Note that the critical curve is tangential to the curve representing a canister diameter of about 11.1 in.

B-5.3

Survey calculations have been performed to estimate the minimum critical cylindrical and square canister sizes for LWR fuel rods at 3 wt% and 5 wt% U235 enrichment (see Figures 3 thru 8). For cylinders, the diameters are 11.3 in. and 9.2 in., respectively. For square canisters, the dimensions are about 10x10 in. and 8x8 in., respectively.

B-6.0

Rod consolidation operations carried out using canisters not subcritical by virtue of geometry for all credible numbers of rods and spacing between rods may require special design features to ensure subcriticality. Examples are as follows:

a) Mechanically holding close-packed rods together while the canister is loaded

b) Bundling the loose rods together before adding the bundle to

c) a canister

Preventing water addition to the canister.

TABLE I

Critical Number of Rods in Water

As a Function of Lattice Pitch

(2 wt% Enriched UO_2)

Lattice Pitch, in.	Critical Number Rods	Effective Cylinder Diameter, in.
0.3 in. Dia. Rods		
.498	780	14.61 (Min.)
.538	679	14.72
.575	633	15.20
.610	613	15.87
.643	617	16.77
.675	633	17.83
.705	663	19.06
.761	780	22.32
.814	1013	27.20
0.4 in. Dia. Rods		
.506	1380	19.74
.574	659	15.47
.635	470	14.45
.717	376	14.61
.742	363	14.84
.767	354	15.16
.813	351	15.98
.858	356	17.01
.900	374	18.27
.940	401	19.76
0.6 in. Dia. Rods		
.759	560	18.86
.908	227	14.37
1.076	170	14.72
1.114	167	15.12
1.150	167	15.59
1.220	172	16.81
1.280	185	18.35

TABLE 2
Critical Number of Rods in Water
As a Function of Lattice Pitch
(3 wt% Enriched UO_2)

Lattice Pitch, in.	Critical Number Rods	Effective Cylinder Diameter, in.
0.3 in. Dia. Rods		
.538	408	11.42 (Min.)
.575	365	11.54
.643	320	12.09
.675	308	12.44
.705	304	12.91
.734	302	13.39
.761	306	13.98
.814	316	15.20
.910	383	18.70
.997	547	24.49
0.4 in. Dia. Rods		
.541	572	13.58
.664	266	11.38
.767	205	11.54
.858	186	12.28
.900	182	12.76
.940	183	13.35
.978	185	13.98
1.086	205	16.34
1.214	274	21.10
1.330	487	30.83
0.6 in. Dia. Rods		
.812	235	13.07
.996	118	11.34
1.150	96.3	11.85
1.220	93.7	12.40
1.286	93.6	13.07
1.350	96.2	13.90
1.410	100.0	14.80
1.467	106.6	15.91
1.727	127	20.43
1.821	324	34.41

TABLE 3

Critical Number of Rods in Water
As a Function of Lattice Pitch
(5 wt% Enriched UO_2)

Lattice Pitch, in.	Critical Number Rods	Effective Cylinder Diameter, in.
0.3 in. Dia. Rods		
.454	443	10.04
.575	233	9.21
.643	191	9.41
.705	173	9.72
.761	161	10.16
.814	156	10.67
.864	154	11.26
.910	156	11.93
.955	161	12.72
1.038	177	14.49
1.255	374	25.47
0.4 in. Dia. Rods		
.606	241	9.88
.664	182	9.41
.767	132	9.25
.858	113	9.57
.940	104	10.04
1.015	99.4	10.63
1.085	99.0	11.34
1.151	101.3	12.17
1.214	106	13.15
1.273	114	14.29
0.6 in. Dia. Rods		
.908	105	9.76
1.150	62.7	9.57
1.220	59.0	9.84
1.286	57.0	10.20
1.410	56.3	11.10
1.523	58.3	12.20
1.628	63.1	13.58
1.727	71.3	15.31
1.821	84.4	17.56

TABLE 4

CRITICALITY BOUNDARIES AND LOADING CAPACITY OF CYLINDRICAL STORAGE CANS FILLED WITH 3% AND 5% ENRICHED UO_2 FUEL RODS

FUEL ROD ENRICH. (%)	FUEL ROD DIAMETER (IN)	CRITICAL VALUES: BASELINE VALUES* NUMBER OF RODS	BASELINE VALUES* V_W/V_F ⊛	TANGENTIAL VALUES ǂ LATTICE PITCH (IN)	CAN DIAM (IN)	NUMBER OF RODS AND SAFE LIMITS		MAX ROD CAPACITY	NO OF ASSEMBLIES: 7×7 ASSEMB.	8×8 ASSEMB.	14×14 ASSEMB.	17×17 ASSEMB.
3.0												
	0.3	300	5.6	0.54	11.3	400	+10 −20	1286	—	—	6.6	4.5
	0.4	182	4.6	0.72	11.4	225	+40 −15	736	15.0	11.5	3.8	2.6
	0.5	125	4.2	0.88	11.5	155	+20 −10	479	9.8	7.5	—	—
	0.6	93	37	098	11.5	125	+10 −15	333	—	—	—	—
5.0												
	0.3	155	8.2	0.52	9.2	280	+15 −25	852	—	—	4.4	3.0
	0.4	98	6.7	0.75	9.3	140	+10 −15	490	10.0	7.7	2.5	1.7
	0.5	69	5.6	0.93	9.3	90	+10 −5	313	6.4	4.9	—	—
	0.6	55	4.8	1.05	9.4	72	+10 −5	222	—	—	—	—

* CRITICAL VALUE POSSIBLE AT OPTIMUM LATTICE SPACING AND ROD NUMBER OUTSIDE OF CAN.

ǂ CRITICAL VALUE POSSIBLE WITH OPTIMUM LATTICE SPACING INSIDE OF CAN.

⊛ VOLUME RATIO (MODERATOR (WATER) TO FUEL)

FIGURE 1. Number of Rods Vs Lattice Pitch For Square Canisters

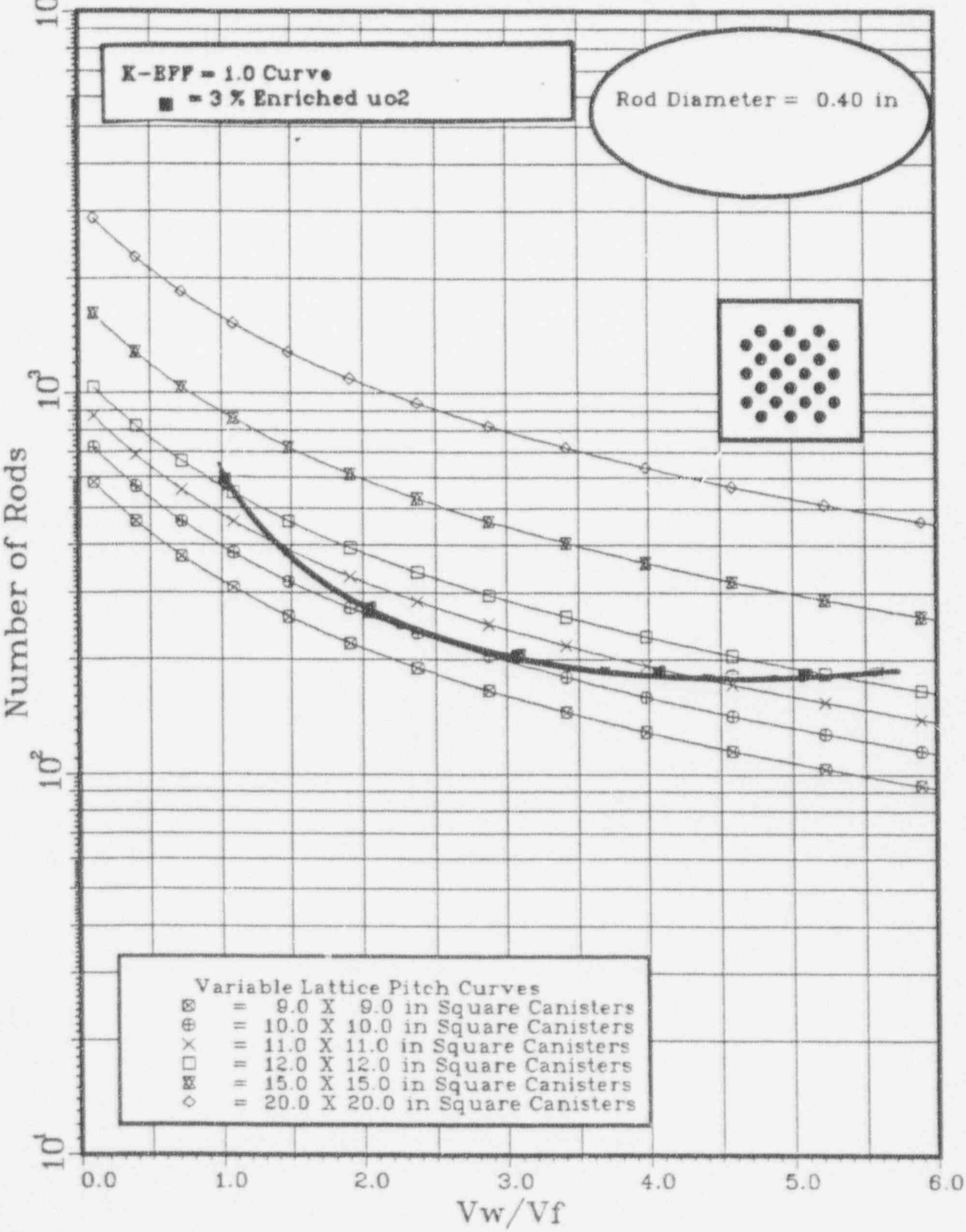


FIGURE 2. Number of Rods Vs Lattice Pitch For Cylinders

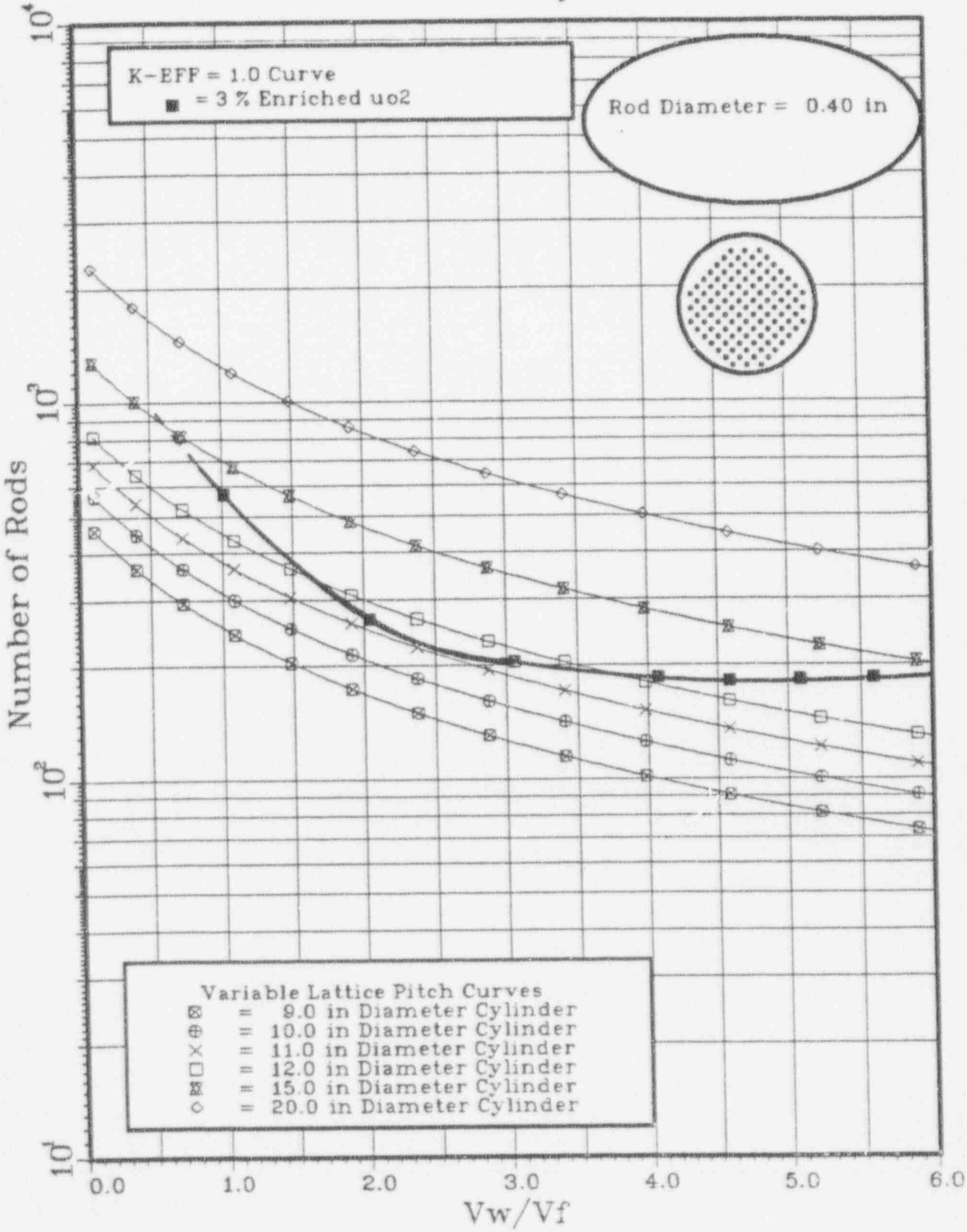


FIGURE 3

CANISTER CAPACITY FOR LWR FUEL RODS

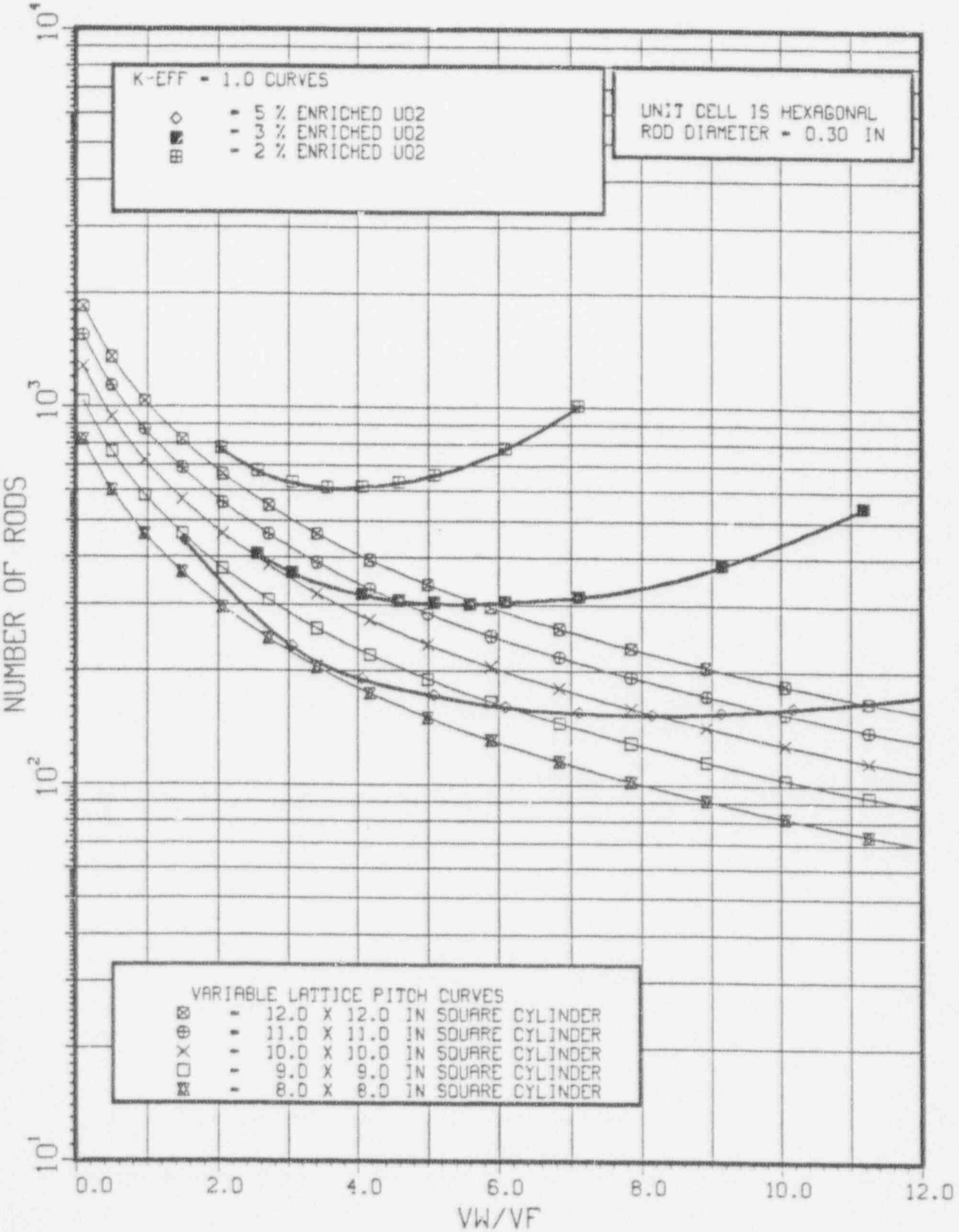
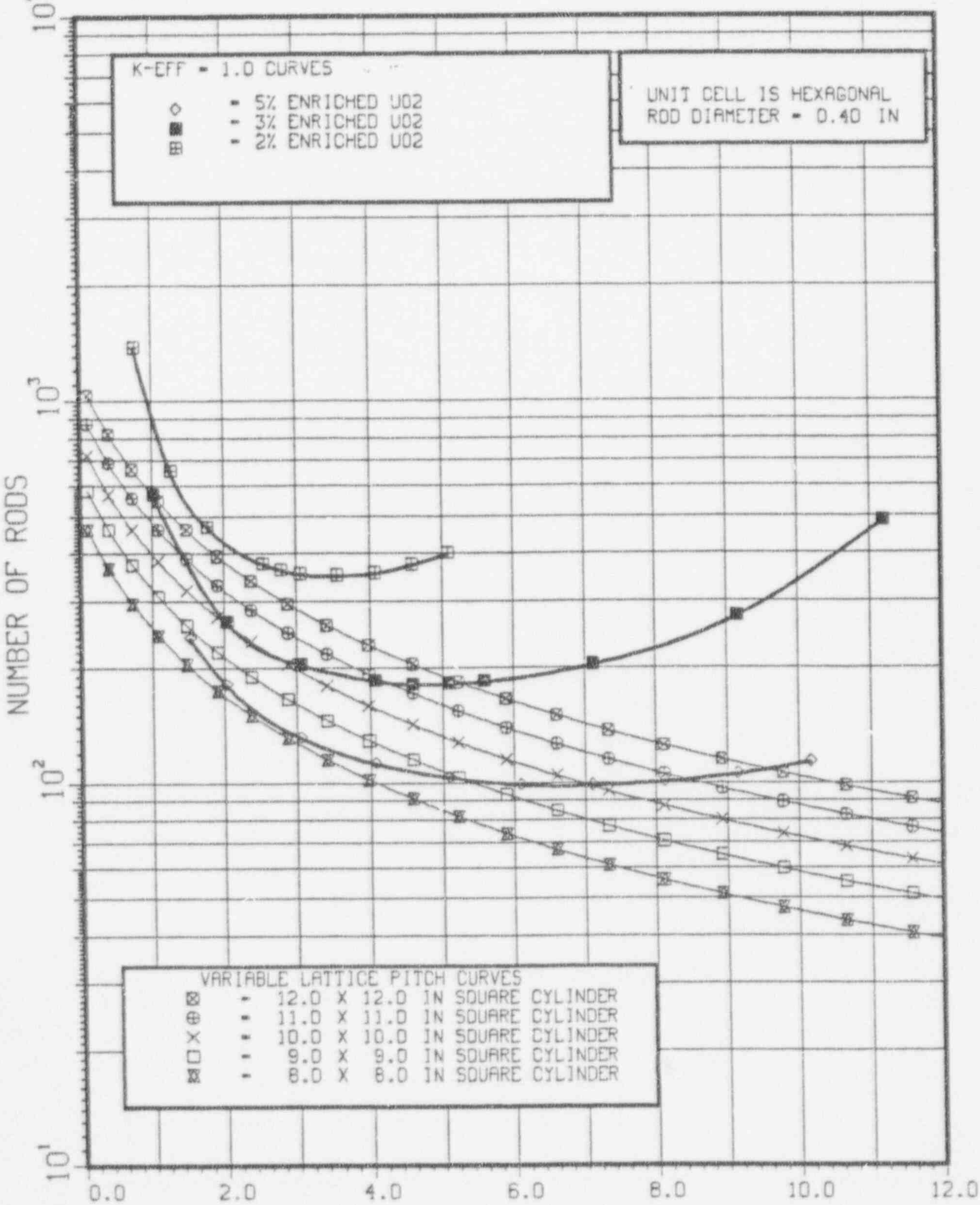


FIGURE 4

CANISTER CAPACITY FOR LWR FUEL RODS



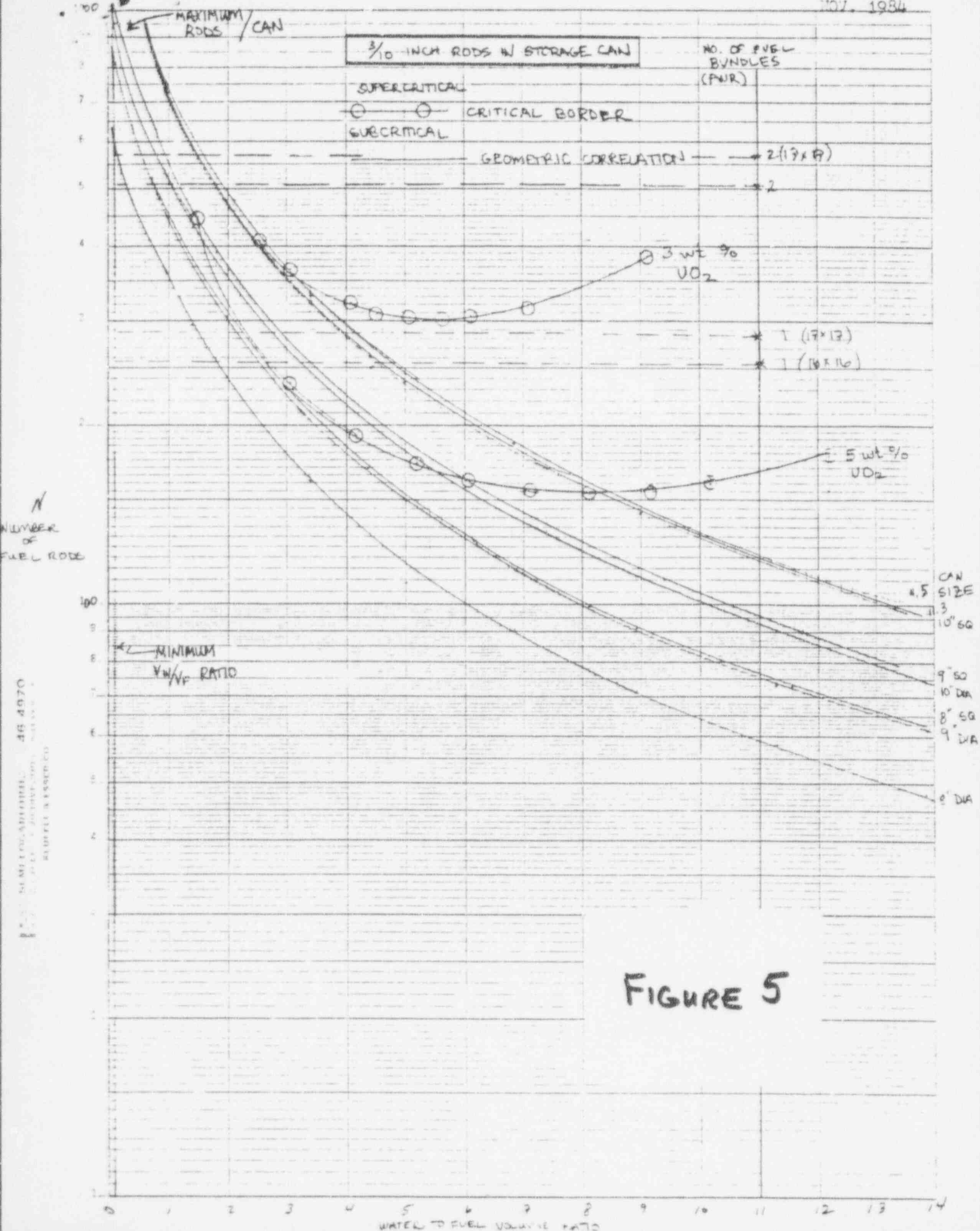

MAXIMUM RODS/CAN
3/10 INCH RODS IN STORAGE CAN
NO. OF FUEL BUNDLES (PWR)
SUPERCRITICAL
CRITICAL BORDER
SUBCRITICAL
GEOMETRIC CORRELATION
2 (17x17)
2
3 wt % UO2
1 (17x17)
1 (16x16)
5 wt % UO2
N
NUMBER OF FUEL RODS
MINIMUM Vw/Vf RATIO
CAN SIZE
10" SQ
9" SQ
10" DIA
8" SQ
9" DIA
8" DIA
WATER TO FUEL VOLUME RATIO

FIGURE 5

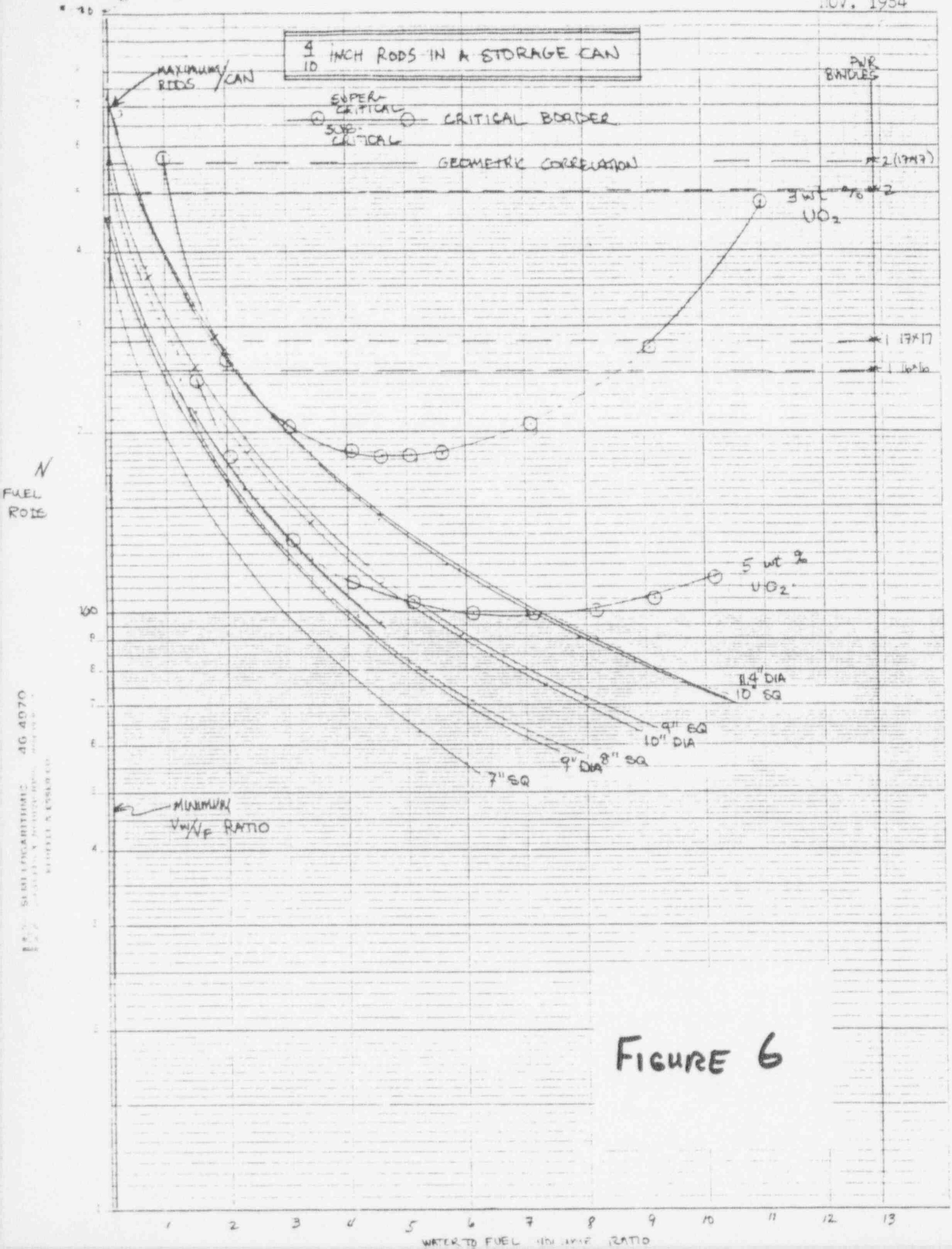

4/10 INCH RODS IN A STORAGE CAN
MAXIMUM RODS/CAN
SUPER-CRITICAL
SUB-CRITICAL
CRITICAL BORDER
GEOMETRIC CORRELATION
PWR BUNDLES
2(17x17)
2
1 17x17
1 16x16
3 wt % UO2
5 wt % UO2
14" DIA
10" SQ
9" SQ
10" DIA
9" DIA
8" SQ
7" SQ
MINIMUM VW/VF RATIO
N
FUEL RODS
100
1
2
3
4
5
6
7
8
9
10
11
12
13
WATER TO FUEL VOLUME RATIO

FIGURE 6

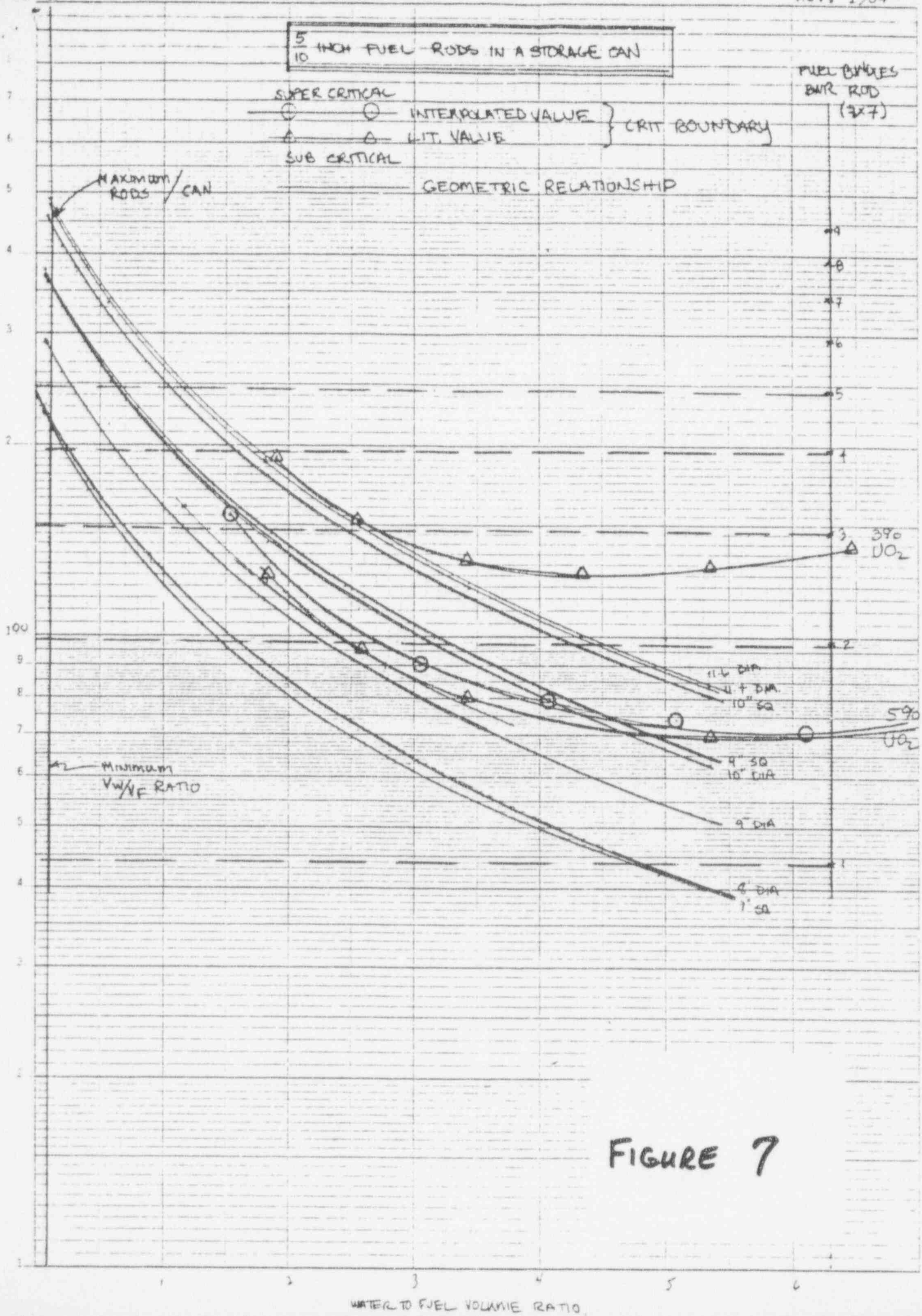

5/10 INCH FUEL RODS IN A STORAGE CAN
SUPER CRITICAL
INTERPOLATED VALUE
LIT. VALUE
CRIT BOUNDARY
SUB CRITICAL
GEOMETRIC RELATIONSHIP
FUEL BUNDLES BWR ROD (7x7)
MAXIMUM RODS/CAN
MINIMUM VW/VF RATIO
N FUEL RODS
WATER TO FUEL VOLUME RATIO
11.6 DIA
11.4 DIA
10" SQ
9" SQ
10" DIA
9" DIA
8" DIA
7" SQ
3% UO2
5% UO2
SEMI-LOGARITHMIC 46 4970
KEUFFEL & ESSER CO.

FIGURE 7

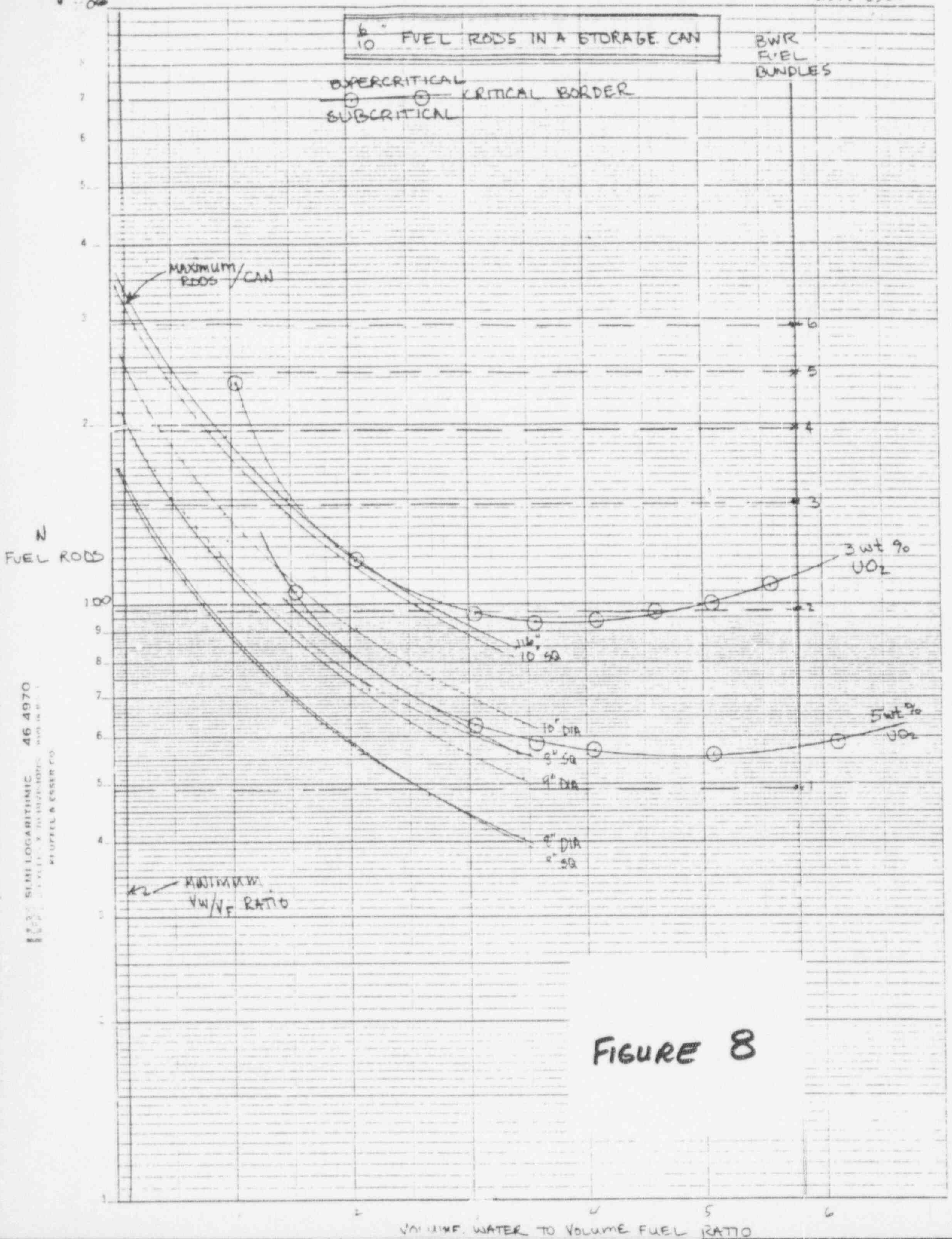

6" 10 FUEL RODS IN A STORAGE CAN
SUPERCRITICAL
CRITICAL BORDER
SUBCRITICAL
BWR FUEL BUNDLES
MAXIMUM RODS / CAN
N FUEL RODS
3 wt % UO2
5 wt % UO2
10" SQ
10" DIA
9" SQ
9" DIA
8" DIA
8" SQ
MINIMUM VW/VF RATIO
VOLUME WATER TO VOLUME FUEL RATIO

FIGURE 8