(717) 948-846

4410-85-L-0036
Document ID 0177A

February 27, 1985

TMI Program Office
Attn: Dr. B. J. Snyder
       Program Director
US Nuclear Regulatory Commission
Washington, DC   20555

Dear Dr. Snyder:

> Three Mile Island Nuclear Station, Unit 2 (TMI-2)
> Operating License No. DPR-73
> Docket No. 50-320
> Fuel Canister Storage Racks Technical Evaluation Report

Attached for your review and approval is the Technical Evaluation Report
(TER) for the Fuel Canister Storage Racks. The Fuel Canister Storage
Racks will be utilized to provide storage for three (3) types of
canisters (i.e., fuel, filter, and knockout) which will be filled with
materials from the TMI-2 reactor core.

Per the requirements of 10 CFR 170, an application fee of $150.00 is
enclosed for review of this document.

Sincerely,

F. R. Standerfer
Vice President/Director, TMI-2

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P   PDR

FRS/RDW/jep

Attachment: GPU Nuclear Check No. 000 14685

cc: Deputy Program Director - TMI Program Office, Dr. W. D. Travers

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GPU Nuclear

☐ ITS
☒ NSR
☐ NITS

TMI-2
DIVISION
TECHNICAL EVALUATION REPORT

FOR

<u>Fuel Canister Storage Racks</u>

_____

_____

COG ENG   _C. L. Ril_   DATE _1/29/85_

RTR   _E. T. Smith_   DATE _1/29/85_

COG ENG MGR. _C. L. Ril fo- R.L.Ride_ DATE _1/29/85_

NO	DATE	REVISIONS	BY	CHECKED	GROUP SUPERVISOR	MGR DESIGN ENGINEERING
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				CHIEF ENGINEER		

EPD-33612 10-84

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NO.
15737-2-G03-113

Title
Technical Evaluation Report for Fuel Canister Storage Racks

PAGE 2
OF 19

Rev.	SUMMARY OF CHANGE
0	Issued For Use.

SHEET	LATEST REV.	SHEET	LATEST REV.	SHEET	LATEST REV.	SHEET	LATEST REV.	SHEET	LATEST REV.	SHEET	LATEST REV.	SHEET	LATEST REV.
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REVISION STATUS SHEET

BECHTEL

DOCUMENT TITLE: Technical Evaluation Report for Fuel Canister Storage Racks

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SPEC. NO. 2-G03-113

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GPD-33000-T 10/83

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1.0 INTRODUCTION

1.1 General/Purpose

The Fuel Canister Storage Racks (FCSR) will be utilized to provide storage for the three different types of canisters (fuel, filter and knockout) which will be filled with materials from the TMI Unit 2 reactor core. Storage for a total of 263 canisters will be available in the racks which will be located in spent fuel pool A and the deep end of the fuel transfer canal (FTC). The purpose of this Technical Evaluation Report (TER) is to evaluate the FCSR to assure they do not create an undue risk to the health and safety of the public.

1.2 Scope

The scope of this TER includes the design of the FCSR and the activities associated with the installation of the racks prior to defueling. Also included, is a discussion of structural and seismic concerns related to the FCSR.

The criticality analyses are not within the scope of this TER. These analyses will be addressed in the TER for Defueling Canisters, Reference 1.

2.0 RACK DESCRIPTION

2.1 Codes and Standards

The FCSR will be designed in accordance with the following:

A. ASME Code, Section III, Subsection NF, 1983 Edition.

B. USNRC Regulatory Guide 1.92, "Combination of Modes and Spatial Components in Seismic Response Analysis, "Rev. 1, February 1976.

C. USNRC Standard Review Plan (SRP), 9.1.2, "Spent Fuel Storage", July 1981.

D. USNRC "Position Paper for Review and Acceptance of Spent Fuel Storage and Handling Applications, "April 14, 1978 and Supplement, January 18, 1979.

E. AISC, Manual of Steel Construction, Eighth Edition, 1980.

F. AISI, Stainless Steel Cold-Formed Structural Design Manual, 1974 Edition.

G. USNRC SRP 3.8.4 - "Other Category I Structures", July 1981.

H. USNRC Regulatory Guide 1.61 "Damping Values for Seismic Design of Nuclear Power Plants", October 1973.

2.2 Rack Locations

Racks for storing the three types of defueling canisters will be installed at two locations in TMI-2, these locations are:

1. The deep end of the fuel transfer canal, within the containment, will contain 11 canister storage cells. The materials for these racks will be taken through the containment personnel air lock and assembled inside the containment. The rack arrangement is shown in figure 1.

2. Fuel pool "A" in the Fuel Handling Building (FHB) will contain an additional 252 fuel canister storage cells. These racks will be modular and transported to fuel pool 'A' as 4, 9 x 7 assemblies and lowered into place. The rack arrangement is shown in figure 2.

2.2.1 Fuel Transfer Canal

The FCSR in the deep end of the FTC are layed out in a C-shaped array, with 11 storage locations and will be seismically designed in order to protect the FCSR should long term storage of canisters become necessary. The racks are constructed of 14.4 inch square ID cells connected by means of tie plates welded intermittently along their entire heights. The cells are made of 0.12-inch thick 304L stainless steel sheets and are assembled in an 18.5-inch center to center spacing in the east-west direction, and 18-inch center to center spacing in the north-south direction. The rack includes a bottom support plate and swiveling, adjustable pads to contact the canal floor. The rack is designed to resist lateral loads by means of 10 support points that interlock the rack with the existing structural embedment bracket near the top of the south wall of the deep end of the fuel transfer canal. The overall height of the cells is 167.25 inches with an internal height of 150 inches, the tops of the canisters will be flush with the tops of the cells. Figure 3 shows a schematic drawing of the rack array. These racks are classified as Nuclear Safety Related (NSR).

2.2.2 Spent Fuel Pool

The FHB FCSR will be comprised of four free-standing 9 x 7 modules and will be seismically designed in order to protect the FCSR should long term storage of canisters become necessary. The racks are constructed from Type 304L stainless steel cells, 18.0-inch square nominal OD by 0.090-inch walls. The cells are connected by tie angles to form a continuous honeycomb structure which is rigid and dimensionally stable. The cell center to center spacing is maintained at a nominal 18.0 inches. The canisters are laterally supported at top and bottom by guide collars that are flared to facilitate insertion. Each storage chamber has

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an interior height of 150 inches to ensure that the tops of
the cells are flush with the tops of canisters when the
canisters are fully inserted. The bottom of each storage
cell sits on and is welded to the rack base plate. The rack
base plate has swiveling, adjustable support pads to contact
the pool floor. Sufficient space is provided between
adjacent racks and between racks and pool structures and
walls to preclude impact/collision in the event that the rack
assemblies slide on the fuel pool floor during a seismic
event. Figure 4 shows a schematic of a 9 x 7 rack. These
racks are classified as NSR.

3.0 TECHNICAL EVALUATION

The technical evaluation for the FCSR includes five separate areas:
structural and seismic, load drops, criticality, occupational exposure
and thermal loads. Each of these areas is addressed individually.

3.1 Structural and Seismic

Both structural and seismic analyses of the TMI-2 FCSR were
performed to verify the adequacy of the design to withstand the
loadings encountered during handling, shipping, installation, normal
operation, severe environmental conditions of Safe Shutdown
Earthquake (SSE) and Operating Basis Earthquake (OBE, herein equated
to 1/2 SSE).

The following is a summary of the results of the seismic, stress and
sliding analyses:

1) The results of the seismic and structural analyses indicate that
   the stresses in the rack structure resulting from the specified
   load cases are within allowable stress limits.

2) Sloshing of pool water during a seismic event has insignificant
   effects on the fuel storage racks.

3) The maximum rack cell displacement for the free standing 9 x 7
   modular rack (rack sliding plus cell top deflection) is less
   than the 8-inch minimum clearance provided between the pool
   walls and racks, and less than the 2-inch minimum clearance
   provided between adjacent racks. Therefore, it has been
   concluded that even if adjacent racks simultaneously slide and
   deflect toward each other the gaps provided are sufficient to
   preclude any collision during an SSE.

3.1.1 Load Conditions

The following load conditions are considered in the analysis
of the canister storage racks.

3.1.1.1 Load Definitions

    A. Normal Loads

        D = Dead load of racks and supporting framing
        L = Live load due to weight of fuel canister
        T_O = Thermal effect and loads during normal
            operating and shutdown conditions
            ($\Delta T = 54°F$)

    B. Severe Environmental Loads

        E = Loads generated by the OBE (including
            loads generated by wave action, i.e.,
            sloshing)

    C. Extreme Environmental Loads

        E' = Loads generated by the safe shutdown
            earthquake (SSE) (to include loads
            generated by wave action, i.e., sloshing)

    D. Abnormal Loads

        T_a = Thermal effects and loads generated by
            maximum pool temperature differential
        P_f = 6000 lb minimum net upward load at
            critical location of rack
        F_d = Fully loaded canister load drop
            (see Section 3.1.1.2 B.)

3.1.1.2 Load Combinations

    The fuel canister storage racks are proportioned to
    maintain elastic behavior. When subjected to
    various combinations of gravity, thermal, and
    accident loads, elastic behavior is considered
    limited by the yield stress (Sy) of the effective
    load-carrying structural members. Yield stresses
    for stainless steel are the values of "Sy" at the
    temperatures as outlined in ASME Section III,
    Subsection NF.

    The following load combinations are satisfied:

    A. For Elastic Analysis   Acceptance Limit

        1) D + L   Normal limits of
                          NF 3231.1a

        2) D + L + T_O Normal limits of
                          NF 3231.1a

3) $D + L + T_o + E$ Normal limits of
NF 3231.1a

4) $D + L + T_a + E$ Sy

5) $D + P_f$ Sy

6) $D + L + T_a + E'$ Faulted condition,
Limits of NF 3231.1c

7) $D + L + F_d$ The overall
structural integrity
of the racks shall be
demonstrated

B. For Limit Analysis

The following load combinations will be
subjected to the limits of ASME Code Section
III, Appendix XVII Paragraph 4000:

1) $1.7 (D + L)$

2) $1.7 (D + L + E)$

3) $1.3 (D + L + T_o)$

4) $1.3 (D + L + E + T_o)$

5) $1.1 (D + L + T_a + E')$

The fuel canister storage racks are designed to
withstand the impact energy of a postulated
defueling canister drop. The design drop height
from the canister transfer shield (CTS) is total of
6'-1.5" in air and 5'-9" in water. Damage to the
FCSR caused by such an accidental drop is limited to
the area of impact and does not cause a reduction in
the nominal 18 inch spacing of the canister.
Additionally, damage to the liner does not result as
the FCSR absorbs the energy from the impact of the
dropped canister and transmits that energy to the
liner plates via the support pads. In addition, the
storage racks are designed to preclude a canister
from falling between canister positions. The design
of the rack includes provisions to prevent a
canister which is dropped outside of the rack from
leaning against the rack or rolling against the rack
so that the side of the dropped canister is less
than 4 inches from the side of the nearest canister
in the rack.

3.1.2 Stress Analysis

3.1.2.1 Method of Analysis

The basic rack seismic stress analysis steps are
outlined below.

A. Detailed finite element models of all rack
    module types were developed using beam and plate
    elements with computer analysis using the ANSYS
    computer code.

B. Modal analysis was performed to determine
    maximum seismic response for the 3 and 4 cell
    FTC rack modules.

C. Three dimensional beam type non-linear models of
    the combined rack and contained canisters were
    developed using data from the detailed finite
    element models for the 9 x 7 modules.

D. Sliding analyses were performed on the
    non-linear models of step C assuming fully
    loaded and partially loaded 9 x 7 racks to
    determine pool floor loads and maximum rack
    displacement.

3.1.2.2 Detailed Finite Element Models

Detailed three dimensional finite element models of
the racks were used to provide the dynamic
characteristics used in the non-linear models and
for the detailed stress evaluation. In the vertical
direction the nodes are spaced closer together to
allow more detail in the higher stress areas.

3.1.2.3 Stress Analysis

The racks are designed to ensure that the stresses
resulting from the specified load cases are
maintained within allowable stress limits defined in
Section 3.1.1.2 above.

The analyses of the accidental load drops indicate
acceptable local structural damage to the storage
cells with no buckling or collapse, and thus no
significant effect on the cell spacing.

3.1.3 Sliding Analysis

The sliding and stability analysis for the 9 x 7 rack module
uses the 3-dimensional non-linear time-history analysis
method described below. For the Reactor Building storage
racks, the computations are based on energy principles
utilizing the results of the modal analysis.

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3.1.3.1 Method of Analysis

Detailed simultaneous, three directional non-linear time history seismic analyses were performed to evaluate the maximum sliding and tipping motions of the 9 x 7 canister racks and to determine the maximum frictional resistance load transmitted by the racks to the pool floor liner plate during an SSE.

In order to perform the non-linear time history seismic analysis of the canister spent fuel assembly/storage cell structure, a 9 x 7 spent fuel rack and the stored fuel assemblies were represented by a three dimensional beam type finite element model. Using computer analysis, the effects of impact, friction, and hydro-dynamic coupling are included in the step by step procedure of the code.

The canister cantilever beam consists of masses lumped at the nodal points interconnected by discrete beam elements. Each lumped mass represents the tributary weight of the canister mass. The stiffness characteristics of the beam elements are related to the effective flexural rigidity of the canisters.

The rack cantilever beam similarly consists of lumped masses interconnected by discrete elastic beam elements. Each lumped mass represents the tributary weight of the storage cells, water trapped inside the cells and the virtual water mass to account for the hydrodynamic effects. The stiffness characteristics of the storage rack beam elements are related to the dynamic characteristics (fundamental frequency of vibration) of the storage rack as determined by analysis.

In order to account for canister impact, adjacent masses of the canister beam and the spent fuel rack beam are laterally coupled by means of non-linear spring/gap elements. The non-linear spring/gap elements permit the adjacent masses to impact each other whenever the gap closes during a seismic event. The stiffness of the non-linear spring is taken as the local stiffness value of the canister/cell impact surface. An initial gap reflecting the lateral gap between the canister and the storage cell wall is provided. The non-linear spring/gap elements are effective for canister impact on either side of the storage cell.

The two cantilever beams representing the storage
cells and the canisters are attached to the pool
floor mass by means of the non-linear sliding
element to best represent the rack standing freely
on the pool floor. The sliding of the rack is
initiated when the lateral force in the sliding
element exceeds the frictional resistance force
which is equal to the coefficient of friction times
the vertical weight of the rack.

3.1.3.2 Sliding Analysis

The non-linear time history seismic analysis of the
Three Mile Island 2 free-standing fuel canister
storage racks was performed using the ANSYS computer
program.

The calculation of the maximum accumulated sliding
displacement of the rack relative to its initial
floor location assumes a coefficient of friction
value of 0.20. This maximum displacement represents
the accumulated spent fuel rack sliding response
during 24 seconds of applied time history.

The calculation of the maximum rack top deflection
assumes a coefficient of friction of 0.8 which is
the upper bound friction coefficient between two
stainless steel surfaces.

The maximum rack cell displacment (rack sliding plus
cell top deflection) is limited to less than the
8-inch minimum clearance provided between the pool
walls and racks, and less than the 2-inch minimum
clearance provided between adjacent racks.

3.2 Load Drops

The FCSR are designed to withstand the impact energy of a postulated
defueling canister drop. The maximum drop height from the CTS is a
total of 6'-1.5" in air and 5'-9" in water for a drop in the FTC,
for a drop in the fuel pool the design drop height is a total of
3'-1" in air and 5'-9" in water. Damage caused by such an
accidental drop is local in nature and does not cause a reduction in
the nominal 18 inch spacing of the canister. The dropping of the
CTS is not considered a credible event as the CTS is an integral
part of the canister handling bridge (CHB).

The FCSR and the CTS are configured in such a way as to prevent a
canister falling from the transfer shield to drop horizontally on
top of the FCSR. In addition, the storage racks are designed to
preclude a canister from falling between canister positions. The
design of the rack includes provisions to prevent a canister which
is dropped outside of the rack from leaning against the rack or
rolling against the rack so that the side of the dropped canister is
less than 4 inches from the side of the nearest canister in the rack.

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The dropping of heavy loads on the FCSR without canisters present (in either the fuel pool or the FTC) poses no safety concern as there is no opportunity for a criticality event, radiation release or uncovering of fuel. Furthermore, the FCSR are constructed in such a way that should damage occur, the damaged FCSR section could be removed and repaired or replaced.

During the installation of the FCSR the potential exists for dropping a section of the FCSR due to a load handling accident. In order to avoid creating any potential safety concerns due to a load handling accident the sections of the FCSR to be installed in containment will be handled within the limits set forth in Reference 2.

The handling of loads other than canisters over the FCSR in the fuel pool or deep end of the FTC, when canisters are in the racks, will be restricted to loads less than the design load drop for the FCSR (3355 pounds). In addition, the loads lift height will be limited such that the potential energy will be less than that of a suspended fuel canister. The following equations will be used to determine the maximum plant elevation (h, maximum plant elevation in feet) to which a given weight (W, where W is in pounds and less than 3355 lbs.) can be raised over the FCSR in the FHB or containment. Two equations are presented as the canister lift heights for the containment and FHB are different.

$$h_{FHB} = \frac{76,000}{W} + 308$$

$$h_{CONT} = \frac{85,600}{W} + 308$$

3.3 Criticality

This TER addresses only the design, including FCSR response to structural and seismic loads, and assembly of the FCSR. Criticality is not addressed in this TER as no fuel canisters or other fuel material will be present during the fabrication or installation of the FCSR in either the fuel pool or the deep end of the FTC. Criticality concerns with defueling canisters in the FCSR will be addressed in the TER for the Defueling Canisters, Reference 1.

3.4 Occupational Exposure

The occupational exposure attributable to the fuel racks would be that dose accumulated during their installation in and removal from the containment and FHB. In order to calculate the man-rem associated with the installation and removal a general area dose rate of 35 mR/hr will be used for in-containment man-hours. This dose rate is based on the current man millirem per man-hour for in-containment work. A dose rate of 0.3 mR/hr is assumed in the

man-rem estimates for the installation and removal of the FCSR in
the FHB. This dose rate is based upon the FHB being decontaminated
prior to the FCSR installation and the FCSR being decontaminated
prior to their removal if required. The following table provides an
estimate of the man-hours and man-rem associated with the
installation and removal (man-hours for removal are estimated to be
equal to 50% of those required for installation) of the
in-containment and FHB FCSR. These estimates are based upon current
man-hour projections for the in-containment work.

IN CONTAINMENT

Activity	Man-Hours	Dose Rate (mR/hr)	Man-Rem
Installation	100	35	3.50
Removal	50	35	1.75

FUEL HANDLING BUILDING

Activity	Man-Hours	Dose Rate (mR/hr)	Man-Rem
Installation	300	.3	.09
Removal	150	.3	.05

The total man-rem attributable to the installation and removal of
the FCSR is expected to be between 4.5 and 8.5 man-rem. This
estimate is based upon a total of 5.4 man-rem from the above,
increased by 20% for Health Physics coverage and allowing $\pm$ 30% due
to uncertainties.

3.5 Thermal Loads

The loaded defueling canisters when standing in the FCSR will be
cooled by the fuel pool water. The decay heat produced by the fuel
in each canister will be approximately 60 watts (this is based upon
the current decay heat load of 15KW being distributed amongst 250
canisters) and the surface area of the defueling canister exposed to
the fuel pool water is approximately 46 ft^2. The canister support
plate contains the necessary openings for adequate cooling flow past
the canisters.

4.0 10CFR50.59 EVALUATION

10CFR50, Paragraph 50.59, permits the holder of an operating licensing to
make changes to the facility or perform a test or experiment, provided
the change, test, or experiment is determined not to be an unreviewed
safety question and does not involve a modification of the plant
technical specifications.

A proposed change involves an unreviewed safety question if:

a) The possibility of occurrence or the consequences of an accident or
    malfunction of equipment important to safety previously evaluated in
    the safety analysis report may be increased; or

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b) The possibility for an accident or malfunction of a different type than any evaluated previously in the safety analysis report may be created; or

c) The margin of safety, as defined in the basis for any technical specification, is reduced.

The activities associated with the design, installation and use of the FCSR will not increase the probability of occurrence of the consequences of an accident or malfunction of equipment important to safety previously evaluated. The FCSR will be designed and used in accordance with this TER and its references in order to prevent an inadvertent criticality. In addition, the racks are seismically designed in order to prevent an inadvertent criticality during a seismic event.

Additionally, there are no safety concerns associated with the installation of the FCSR. Even if a section of the racks were dropped during their installation in the FTC/fuel pool resulting in damage to the liner plate, the liner plate could be repaired prior to the commencement of defueling. The planned activities will not create the possibility of an accident or malfunction of a different type than any evaluated previously and have been shown not to be an unreviewed safety question. Since the operation of systems and equipment will be in accordance with approved procedures to ensure compliance to technical specifications, the tasks included in this TER will not reduce the margin of safety as defined in the basis for any technical specification.

Therefore, it is concluded that the fuel canister storage racks do not involve any unreviewed safety question as defined in 10CFR Part 50, Paragraph 50.59.

5.0 REFERENCES

1. "Technical Evaluation Report for Defueling Canisters", 15737-2-G03-114.

2. "Safety Evaluation Report for Heavy Load Handling Inside Containment", 15737-2-G07-105, Rev. 0, October 29, 1984.
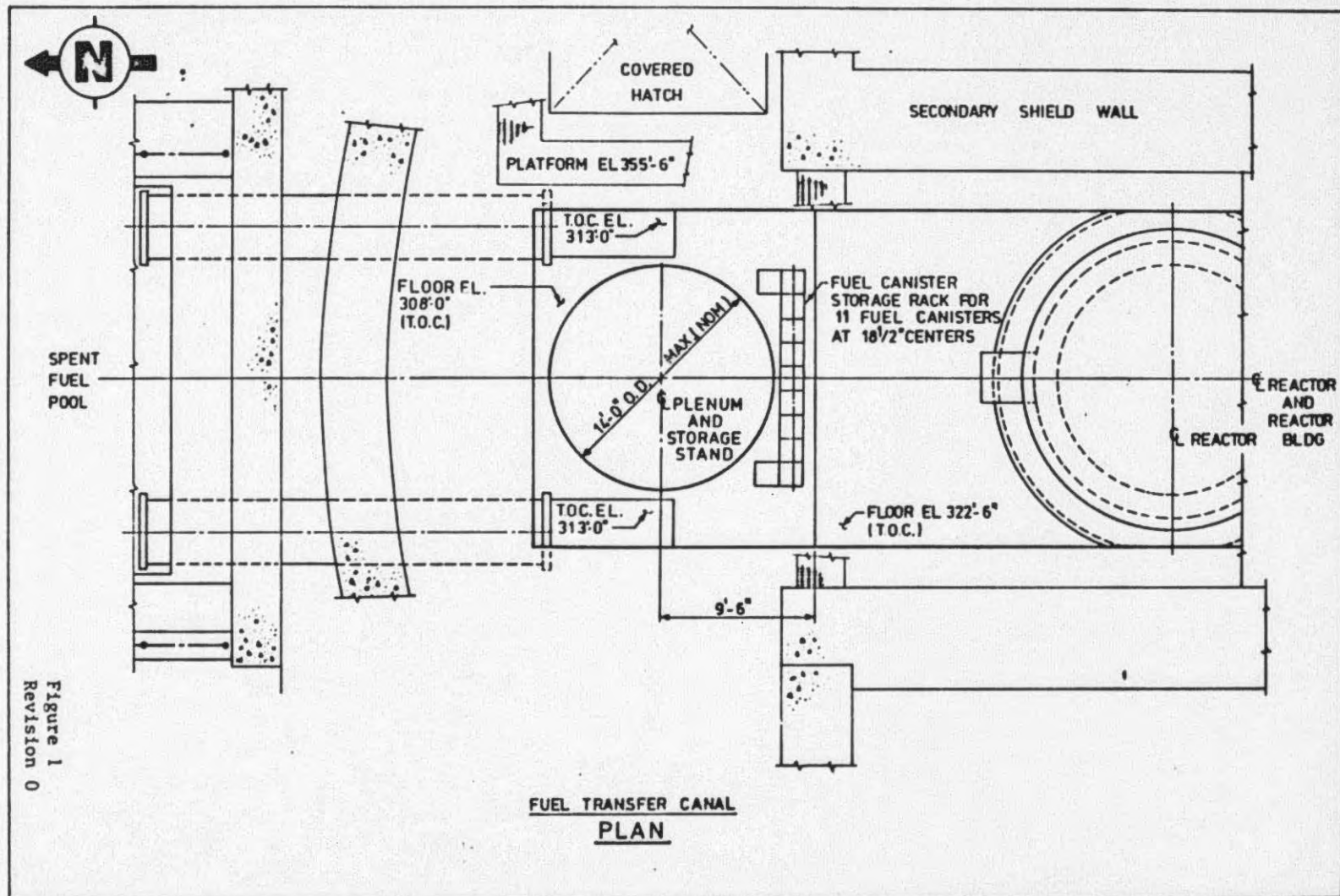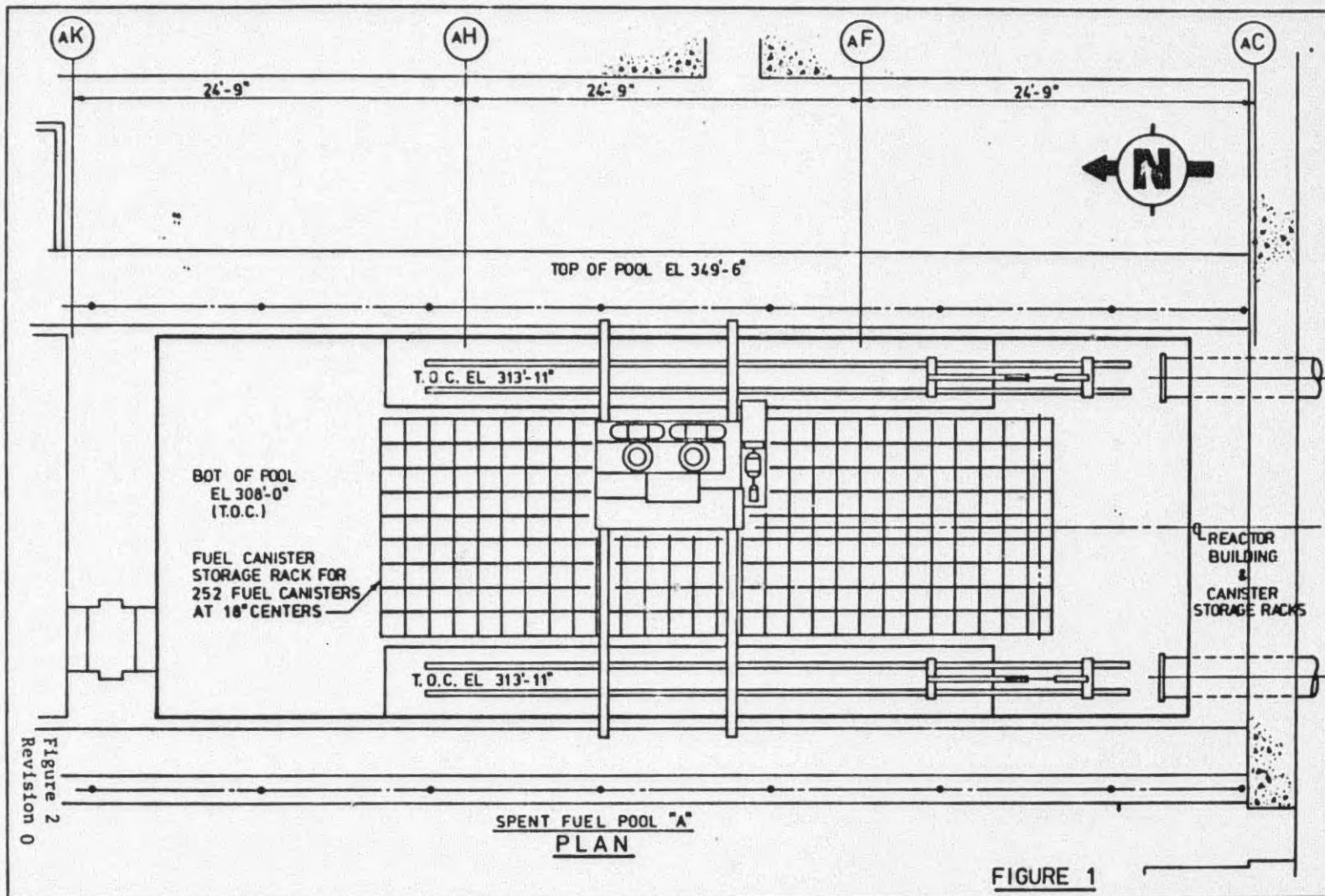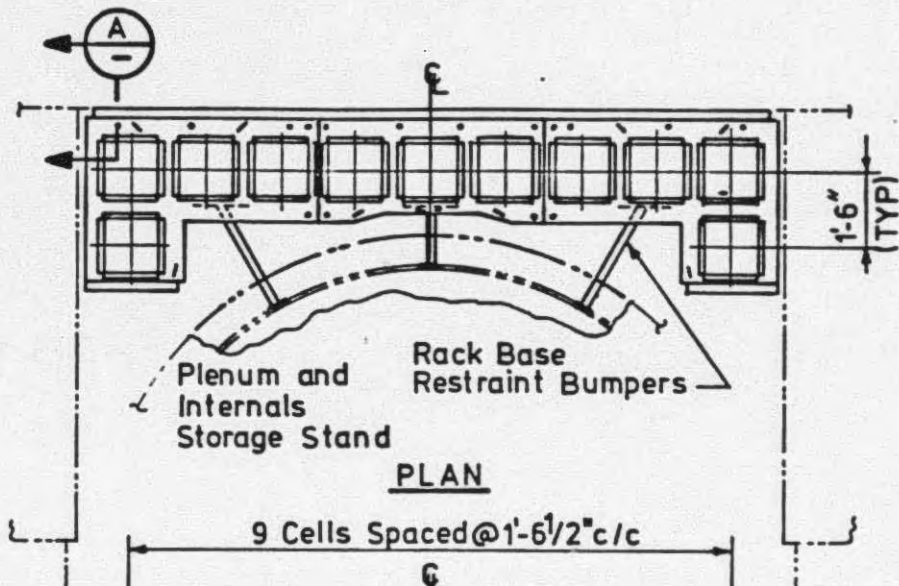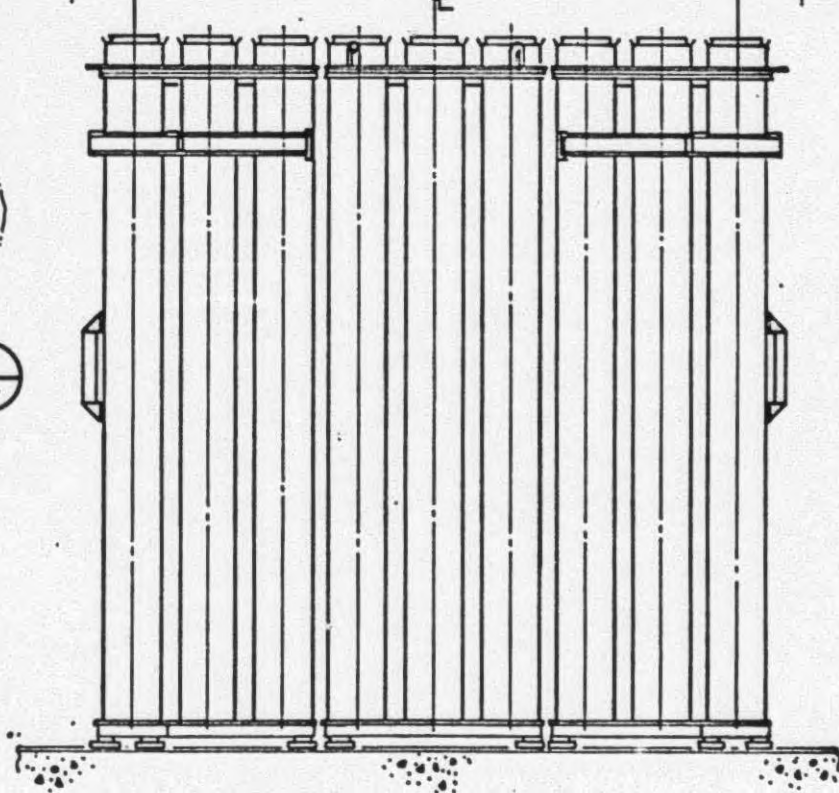
Figure 1
Revision 0

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COVERED
HATCH

PLATFORM EL 355'-6"

SECONDARY SHIELD WALL

T.O.C. EL.
313'-0"

FLOOR FL.
308'-0"
(T.O.C.)

FUEL CANISTER
STORAGE RACK FOR
11 FUEL CANISTERS
AT 18½" CENTERS

SPENT
FUEL
POOL

14'-0" O.D. MAX (NOM.)

℄ PLENUM
AND
STORAGE
STAND

℄ REACTOR
AND
REACTOR
BLDG

℄ REACTOR

T.O.C. EL.
313'-0"

FLOOR EL 322'-6"
(T.O.C.)

9'-6"

FUEL TRANSFER CANAL
PLAN

Figure 2
Revision 0

SPENT FUEL POOL "A"
PLAN

FIGURE 1

N

A

PLAN

Plenum and Internals Storage Stand

Rack Base Restraint Bumpers

1'-6" (TYP)

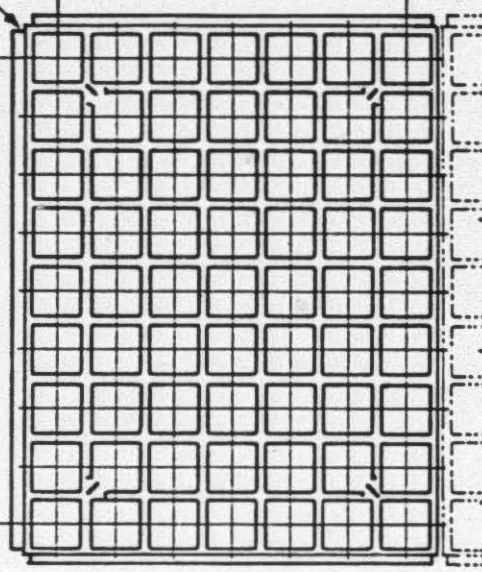9 Cells Spaced @ 1'-6½" c/c

Hold Down Nut

SECTION **A**

ELEVATION VIEW

(REACTOR BUILDING)

FUEL CANISTER STORAGE RACKS

Figure 3
Revision 0

7x9 Array Freestanding Rack Module (Typ 4 Places)

7 Cells Spaced @ 1'-6" c/c

9 Cells Spaced @ 1'-6" c/c

PLAN
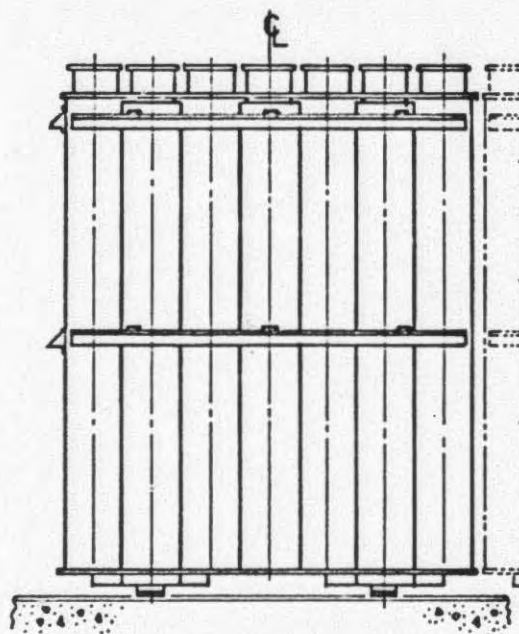
ELEVATION VIEW

(FUEL HANDLING BUILDING)

FUEL CANISTER STORAGE RACKS

Figure 4
Revision 0