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TECHNICAL EVALUATION REPORT

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STRUCTURAL EVALUATION OF THE VACUUM BREAKERS
(MARK I CONTAINMENT PROGRAM)

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT

TER-C5506-323

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FOREWORD

This Technical Evaluation Report was prepared by Franklin Research Center under a contract with the U.S. Nuclear Regulatory Commission (Office of Nuclear Reactor Regulation, Division of Operating Reactors) for technical assistance in support of NRC operating reactor licensing actions. The technical evaluation was conducted in accordance with criteria established by the NRC.

1. INTRODUCTION

In a latter state of the generic resolution of the suppression pool dynamic load definition of the Mark I Containment Long-Term Program, a potential failure mode of the vacuum breakers was identified during the chugging and condensation phases of hydrodynamic loadings. To resolve this issue, two vacuum breaker owner groups were formed, one for those with General Precision Engineering (GPE) vacuum breakers, the other for those with Atwood-Morrill (AM) vacuum breakers.

The issue was not part of the original scope of the Mark I Containment Long-Term Program as described in NUREG-0661 [1]. However, vacuum breakers have the function of maintaining containment integrity and, therefore, are subject to Nuclear Regulatory Commission (NRC) review. In a generic letter dated February 2, 1983 [2], the NRC requested all affected plants either to submit the results of the plant-unique calculations which formed the bases for modifications to the vacuum breakers or to provide the justification for the as-built acceptability of the vacuum breakers.

Franklin Research Center (FRC) has been retained by the NRC to evaluate the acceptability of the structural analysis techniques and design criteria used in the plant-unique analysis (PUA) reports of 16 plants. As a part of this review, the structural analysis of the vacuum breakers has been reviewed and documented in this report.

The first part of this report (Sections 1 through 4) consists of generic information that is applicable to all affected plants. The second part of the report (Sections 5 and 6) provides a plant-specific review, which pertains to the Browns Ferry plant.

1.1 GENERIC BACKGROUND

In 1980, the Mark I owners and the NRC became aware of the vacuum breaker damage during full-scale test facility testing and of the potential for damage during actual LOCAs. Two vacuum breaker owner groups, General Precision Engineering (GPE) and Atwood-Morrill (AM), were formed to develop action plan for resolving this issue. In February 1983, the NRC issued Generic Letter 83-08 [2], requesting commitments from affected utilities to provide analytical results. The licensees responded to the NRC request by developing appropriate force functions simulating the anticipated hydrodynamic loads, and then performing stress analyses that used these loads. With respect to loading, the NRC has reviewed and issued a staff position as indicated in Section 3. FRC's function is to review the stress analysis submitted by a licensee.

1.2 VACUUM BREAKER FUNCTION

During steam condensation tests on BWR Mark I containments, the wetwell-to-drywell vacuum breakers cycled repeatedly during the transient phase of steam blowdown. This load was not included in the original load combinations used in the design of the vacuum breakers. Consequently, the repeated impact of the pallet on the valve seat and body created stresses that may impair its capability to remain functional.

A vacuum breaker is a check valve installed between the wetwell and the drywell. Its primary function is to prevent the formation of a negative pressure on the drywell containment during rapid condensation of steam in the drywell and in the final stages of a LOCA. The vacuum breaker maintains a wetwell pressure less than or equal to the drywell pressure by permitting air flow from the wetwell to the drywell when the wetwell is pressurized and the drywell is depressurized slowly.

A vacuum breaker can be internally or externally mounted. Figures 1 and 2 illustrate locations of vacuum breakers.

Schematics of typical GPE and AM vacuum breakers are illustrated in Figures 3 and 4.

A typical pressure differential vacuum breaker during a LOCA is provided in Figure 5.

Table 1 lists the various vacuum breaker types and the plants affected by them.

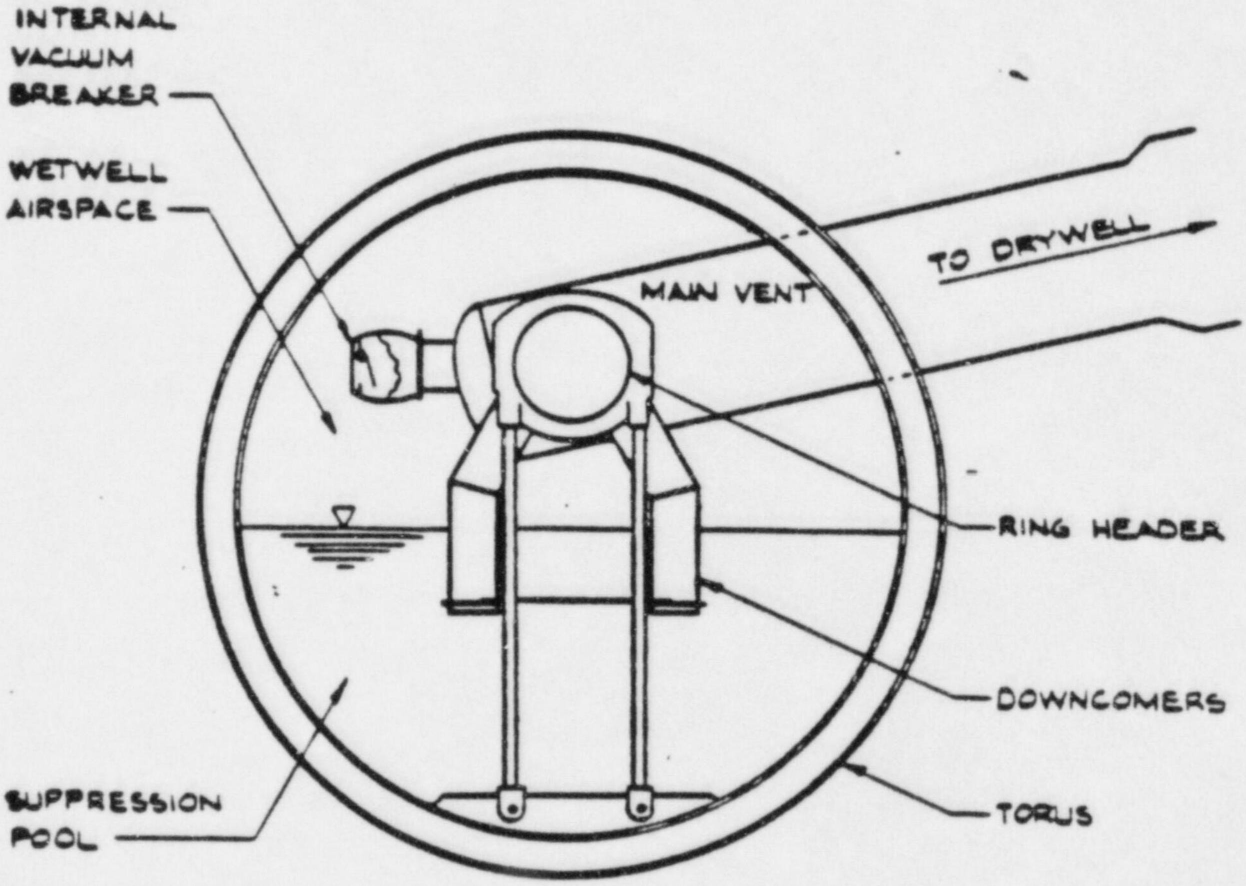

Figure 1. Internal Vacuum Breaker

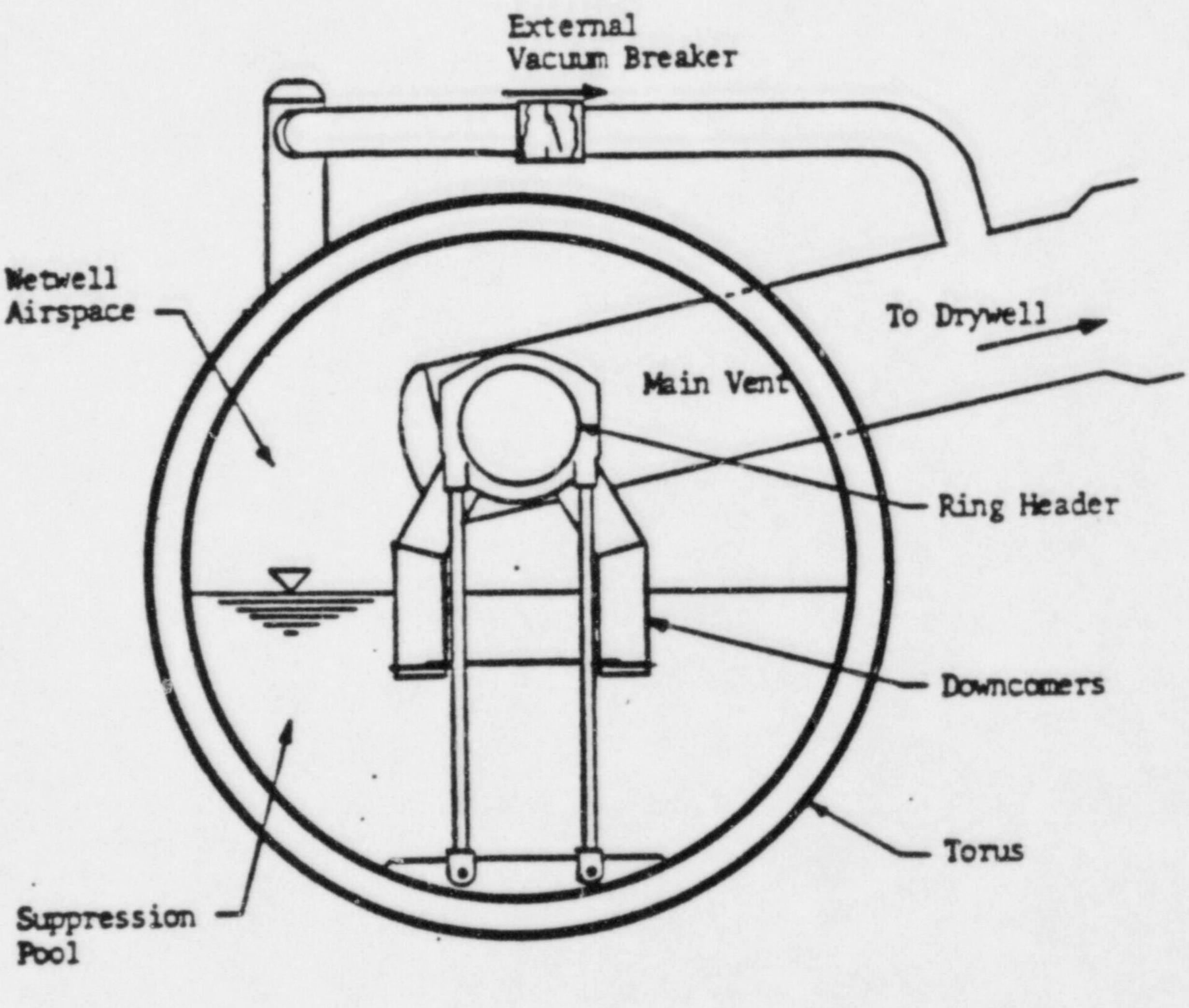

Figure 2. External Vacuum Breaker

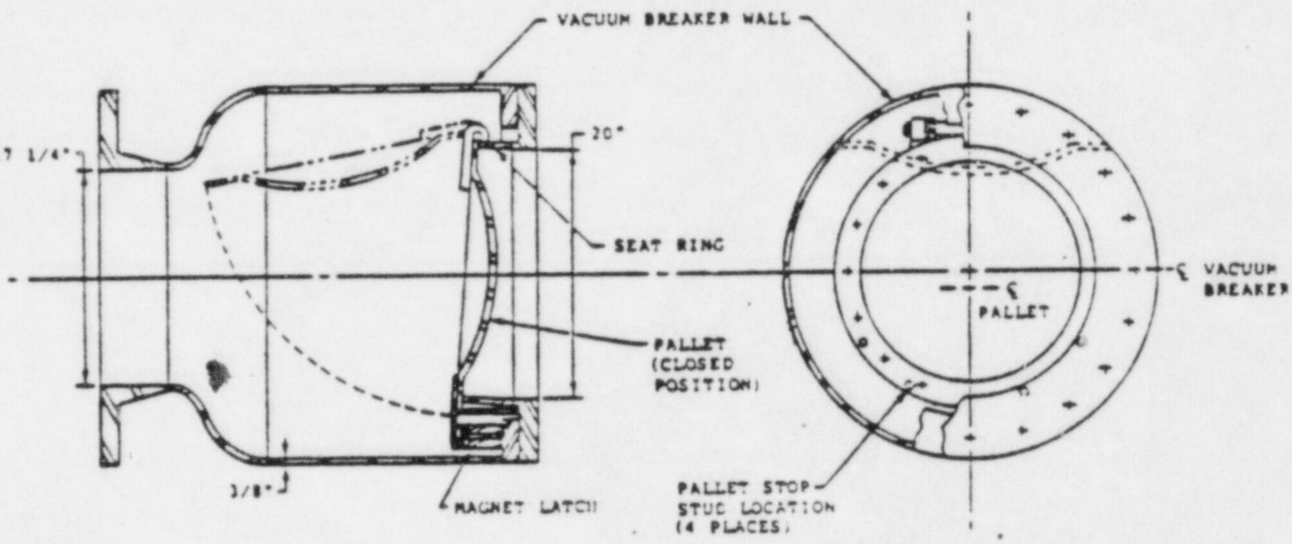

Figure 3. GPE Vacuum Breaker

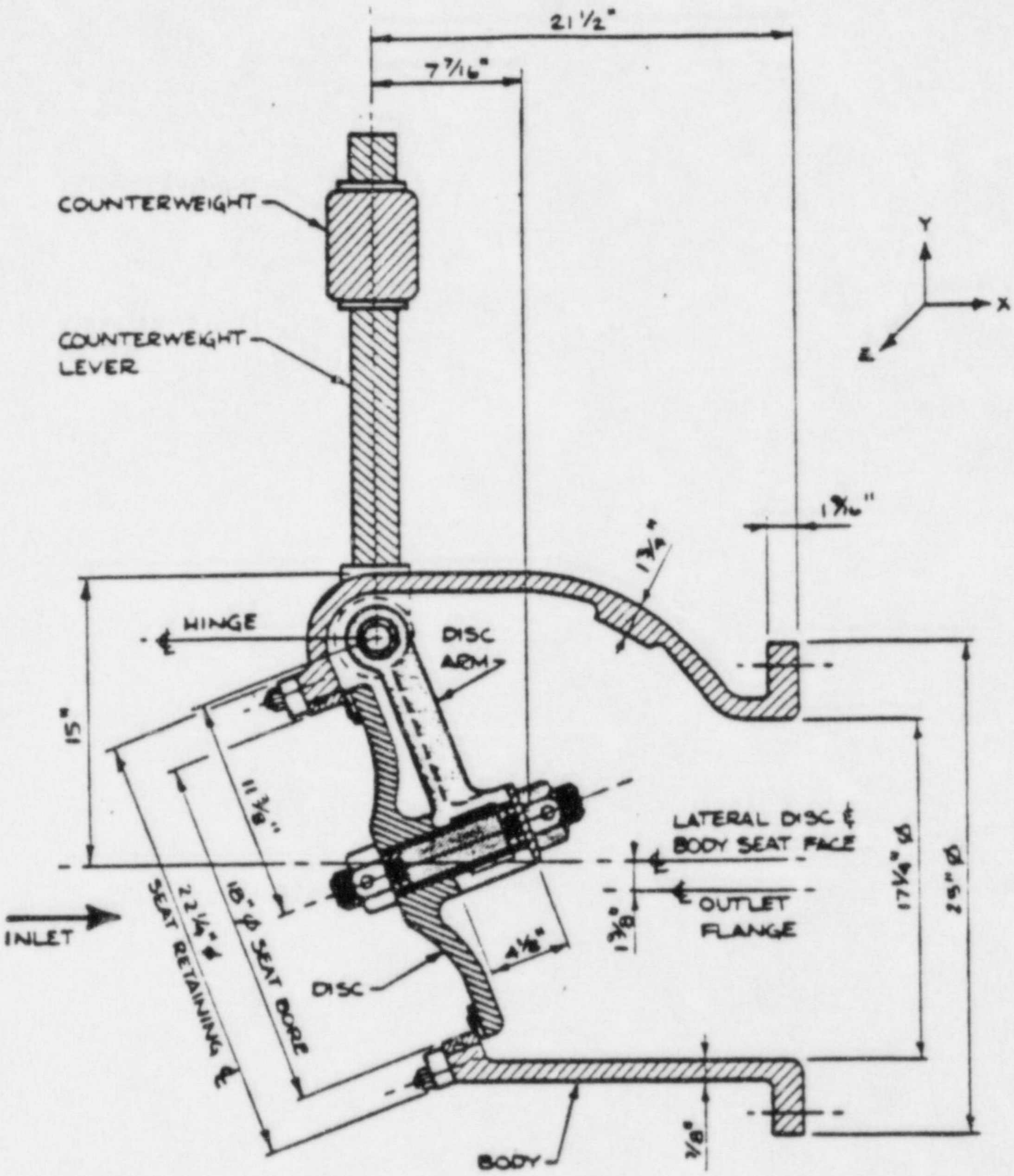

Figure 4. Atwood-Morrill Vacuum Breaker

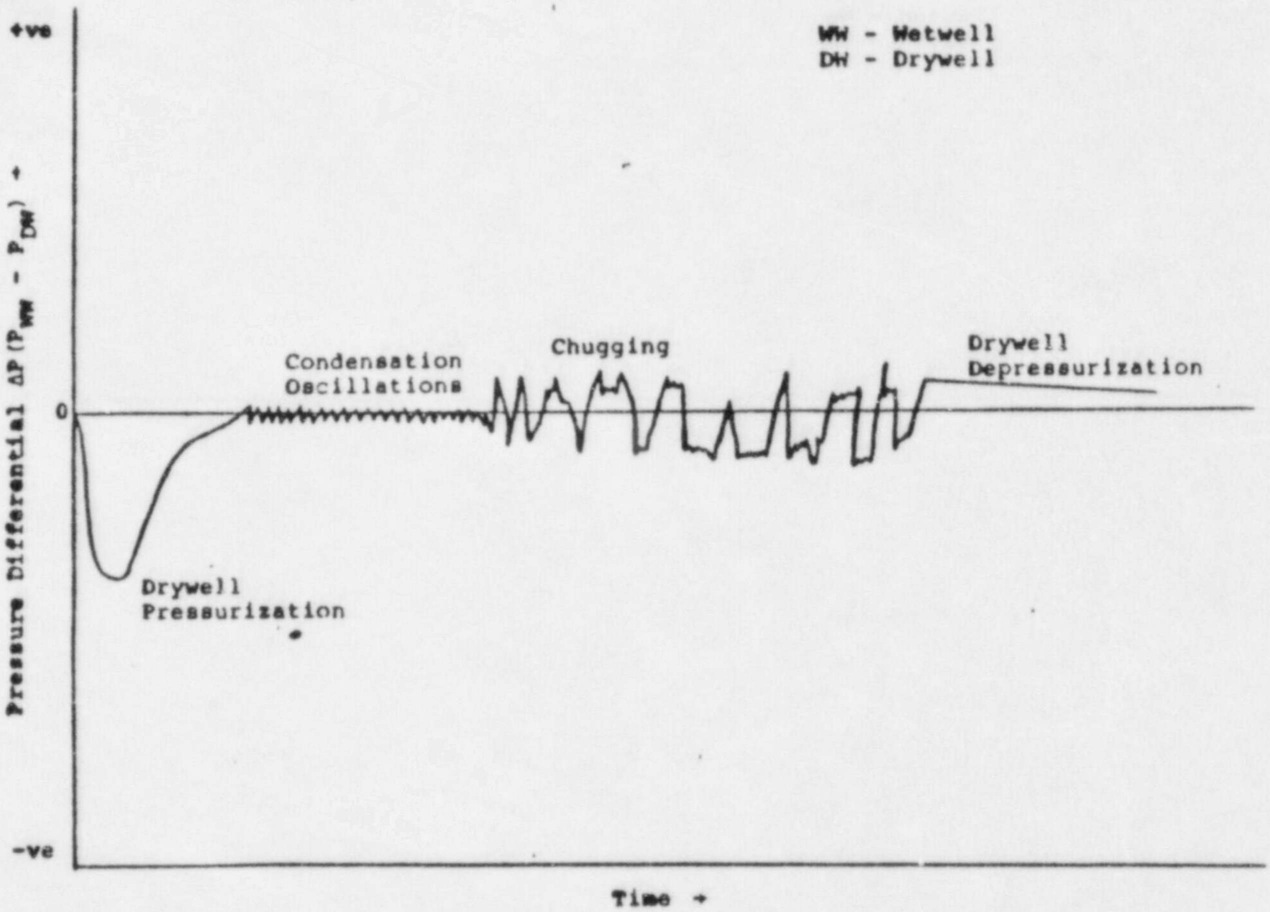

Figure 5. Typical DW/WW Vacuum Breaker Pressure Differential Due to LOCA

Table 1. Vacuum Breaker Types and Affected Plants

Vacuum Breaker	Plant
GPE 18 In (Internal)	Brown Ferry Units 1, 2, and 3 Pilgrim Unit 1 Brunswick Units 1 and 2 Cooper Hatch Units 1 and 2 Peach Bottom Units 2 and 3 Duane Arnold Fermi Unit 2
GPE 24 in (Internal)	Hope Creek
AM 18 in (Internal)	Monticello Quad Cities Units 1 and 2
AM 18 in (External)	Dresden Units 2 and 3 Millstone Unit 1 Oyster Creek Vermont Yankee
AM 18 in (External)	FitzPatrick Nine Mile Point Unit 1

2. EVALUATION CRITERIA

To evaluate the design of the vacuum breakers, the affected licensees follow the general requirements of NUREG-0661 [1] and those of "Mark I Containment Program Structural Acceptance Criteria Plant Unique Analysis Application Guide" [3]. Specifically, the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NC for Class 2 Components, 1977 Edition, including the summer 1977 addenda [4], have been used to evaluate the structural integrity of the vacuum breakers.

3. DESIGN LOADS

The loads acting on the Mark I structures and on the vacuum breaker are based upon the Mark I Program Load Definition Report [5] and the NRC Acceptance Criteria [1]. The loads acting on the vacuum breaker include gravity, seismic, and hydrodynamic loads. The hydrodynamic forcing functions were developed by Continuum Dynamics, Inc, (CDI). CDI used a dynamic model of a Mark I pressure suppression system, which was capable of predicting pressure transients at specified locations in the vent system. With this dynamic model and the full-scale test facility data, load definition resulting in pressure differential across the vacuum breaker disc was quantified as a function of time. This issue has been reviewed and addressed by the NRC [6].

4. STRESS EVALUATION

To determine structural integrity of the vacuum breaker, the licensees have employed standard analytical techniques, including the finite element method, to calculate stresses of critical components of the vacuum breaker under various design loadings. Loads resulting from the hydrodynamic phenomenon were compared with those values specified in the ASME Codes [4].

For illustration purposes, a schematic drawing of the moving parts of all components other than the actual disc of the Atwood-Morrill valve and of the corresponding finite element model are shown in Figures 6 and 7, respectively. The model in Figure 7 was used to investigate the dynamic response following impact.

A typical model for stress analysis of the vacuum breaker disc is shown in Figure 8. Loading inputs to this model are the displacement time histories that were obtained from the impact model analysis.

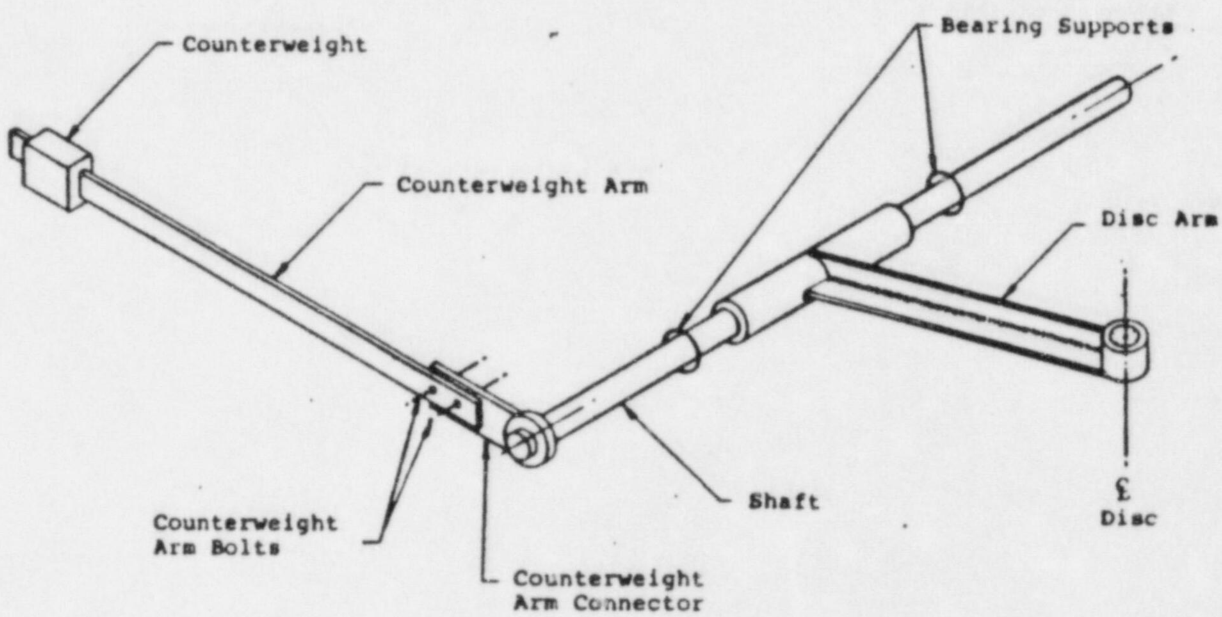

Figure 6. Detailed Valve Internal Model

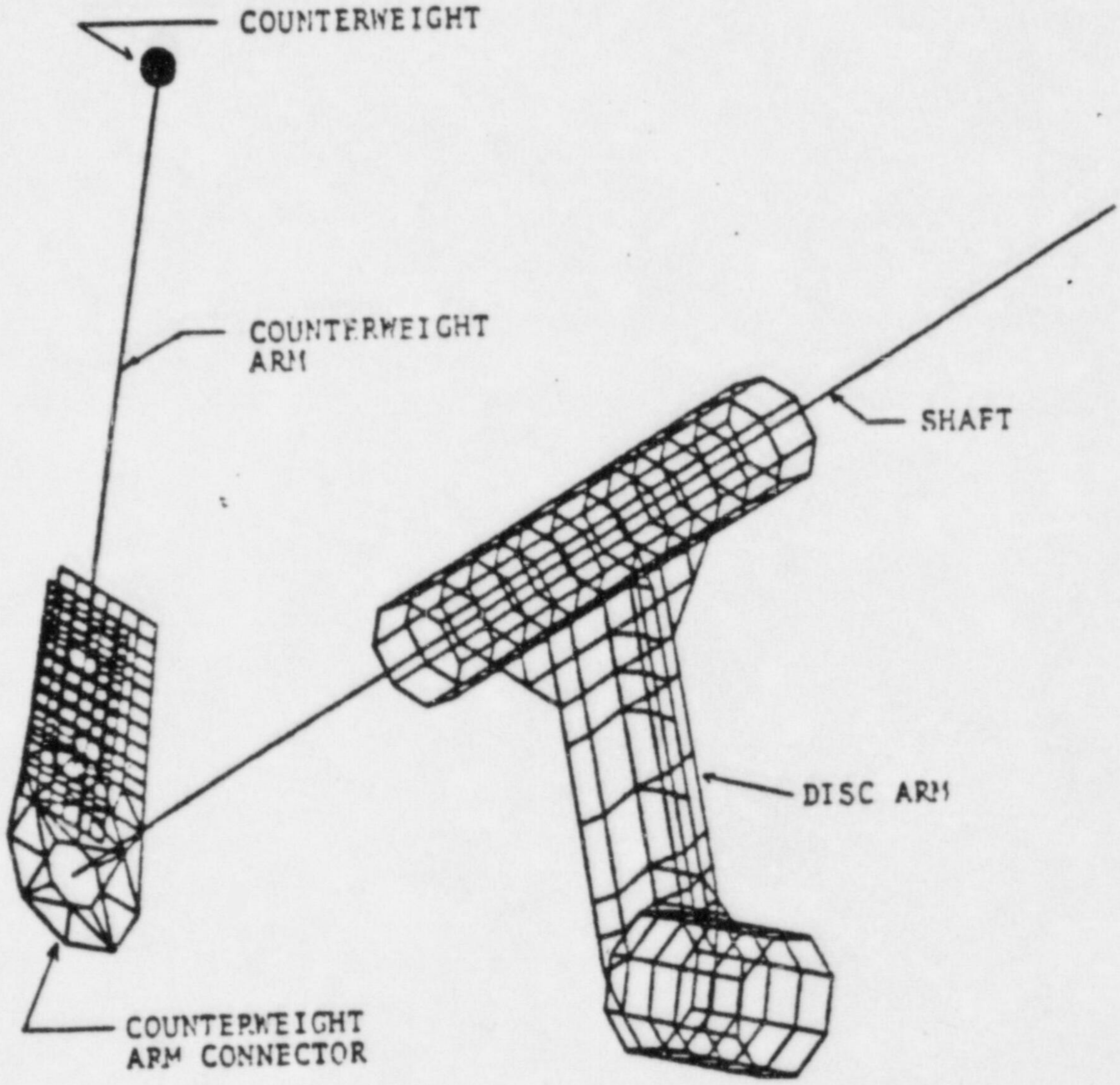

Figure 7. Finite Element Model of Valve Internals

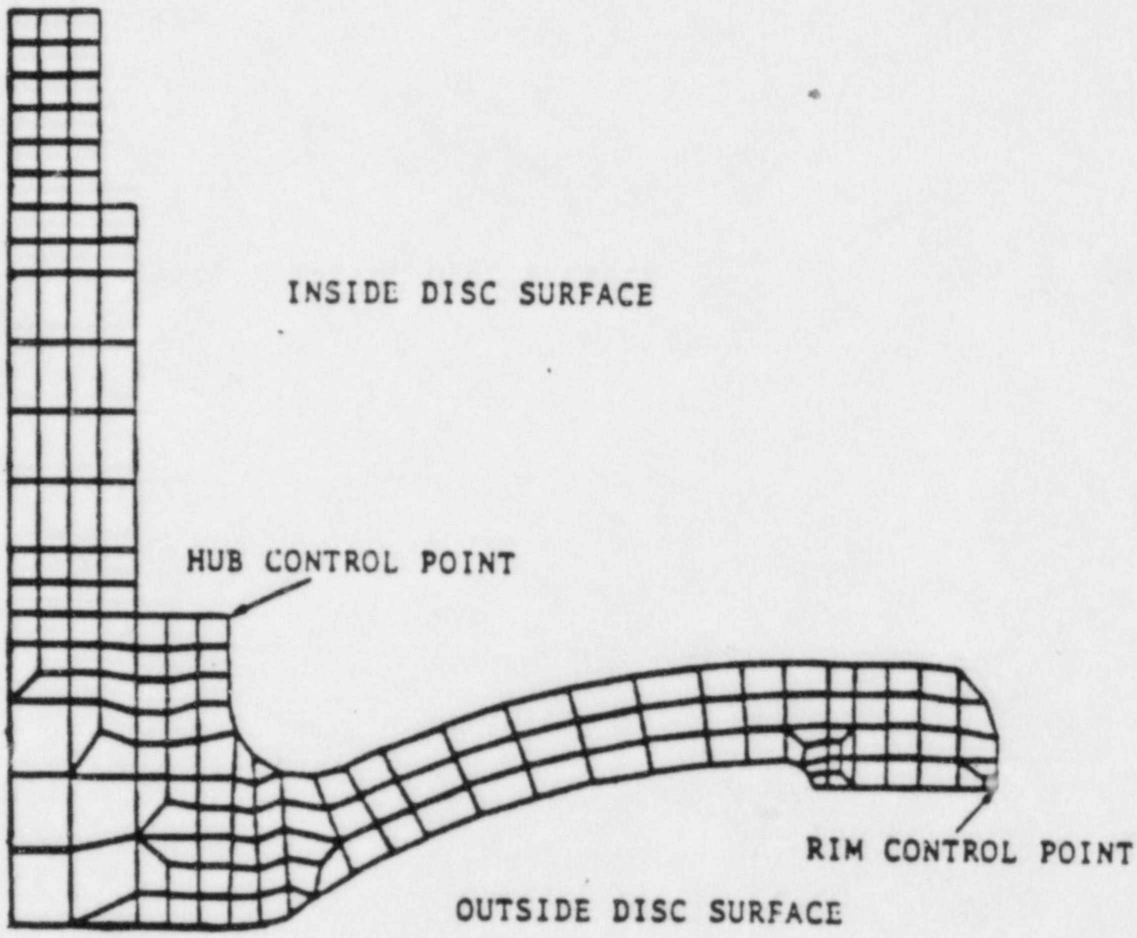

Figure 8. Valve Detailed Disc Model Geometry

5. PLANT-SPECIFIC REVIEW: BROWNS FERRY PLANT

5.1 BACKGROUND INFORMATION

- Vacuum breaker type: 18-inch GPE (internal)
- Vacuum breaker nozzles are located on the vent header/main vent intersection.
- There are 12 wetwell-to-drywell vacuum breakers: two in each of six wetwell bays.

5.2 STRESS ANALYSIS RESULTS

A unique structural analysis of the Browns Ferry vacuum breakers was performed using a classical approach that equates strain energy to kinetic energy of pallet prior to impact. This impact/stress analysis included the pallet, hinge arm, hinge arm bolts, hinge shaft, and shaft ear attachment. Hinge assembly components were evaluated for loads from the pallet impact. Stress levels and original material selection were evaluated for a design impact velocity of 6.89 radians/sec. As a result of this analysis, the Licensee determined that certain components should be upgraded to higher strength materials. The design modifications are summarized as follows [7]:

Hinge Arms

Each existing nodular iron hinge arm was replaced with one made of type 316 stainless steel. This material was chosen for its enhanced corrosion resistance characteristics as well as increased strength and ductility.

Hinge Pins

The existing 303 stainless steel pins were replaced with 410 stainless steel in order to provide greater strength and hardness.

Hinge Bushing

The existing teflon sleeved eccentric aluminum bushing was replaced with a concentric solid brass bushing. This material was chosen for its self-lubricating and corrosion resistance properties. Also, the pin-bushing combination affords maximum resistance to galling. The alignment adjustment capability afforded by the eccentric bushing is now provided by shimming under the hinge arm to obtain pallet-to-seat alignment within 0.003 inch.

Hinge Arm to Pallet Bolts

The existing mild carbon steel bolts were replaced with bolts made of ASTM A193 GR B6, which is a 410 stainless steel material.

Pallet Gasket

The existing gasket-retaining ring-threaded fasteners were secured after assembly by staking the threads. In addition to this, existing assembly procedures require that the gasket be secured to the pallet using plant approved gasket cement.

Stresses for the modified components were evaluated by the Licensee and found to be within allowable limits.

6. CONCLUSIONS

A review has been conducted to determine the structural integrity of the vacuum breakers of the Browns Ferry plant. The design loads associated with the hydrodynamic phenomena have been reviewed and addressed by the NRC in Reference 6. This review covered only the structural analysis of the vacuum breaker, and the following conclusion is drawn from the review:

- The analytical methods used to evaluate stresses of critical components have been reviewed and judged to be adequate; however, the stress results indicate a potential for overstressing of critical vacuum breaker components. The Licensee has decided to modify the vacuum breakers by upgrading the hinge arms, hinge pins, hinge bushing, hinge arm to pallet bolts, and pallet gasket as described in Section 5.2. This modification approach has been reviewed and found to be adequate.

7. REFERENCES

1. NUREG-0661
"Safety Evaluation Report, Mark I Containment Long-Term Program Resolution of Generic Technical Activity A-7," Office of Nuclear Reactor Regulation, USNRC
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2. D. G. Eisenhut
"USNRC Generic Letter 83-80, Modification of Vacuum Breakers on Mark I Containment"
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3. NEDO-24583-1
"Mark I Containment Program Structural Acceptance Criteria Plant Unique Analysis Application Guide," General Electric Co., San Jose, CA
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4. American Society of Mechanical Engineers
Boiler and Pressure Vessel Code, Section III, Division 1, "Nuclear Power Plant Components," New York, 1977 Edition and Addenda up to Summer 1977

5. NEDO-21888 Revision 2
"Mark I Containment Program Load Definition Report," General Electric Co., San Jose, CA
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6. D. B. Vassallo, NRC
Letter with Attachment to H. C. Pfefferlen, BWR Licensing Programs, GE
"Evaluation of Model for Predicting Drywell to Wetwell Vacuum Breaker Valve Dynamics"
December 24, 1984

7. J. A. Domer
Letter with Attachment to H. R. Denton (NRC)
Subject: Modification of Vacuum Breakers on Mark I Containment, Tennessee Valley Authority
November 5, 1984