

SUPPLEMENTARY
TECHNICAL EVALUATION REPORT

NRC DOCKET NO. 50-331

FRC PROJECT C5506

NRC TAC NO. --

FRC ASSIGNMENT 12

NRC CONTRACT NO. NRC-03-81-130

FRC TASK 322

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

IOWA ELECTRIC LIGHT AND POWER COMPANY
DUANE ARNOLD ENERGY CENTER

TER-C5506-322

Prepared for

Nuclear Regulatory Commission
Washington, D.C. 20555

FRC Group Leader: V. N. Con
NRC Lead Engineer: H. Shaw

July 17, 1986

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Prepared by:

Reviewed by:

Approved by:

Stephen J. Trish
Principal Author

V. N. Con

J. P. Carfagna
Department Director

Date: 7/10/86

Date: 7/16/86

Date: 7-16-86

FRANKLIN RESEARCH CENTER
DIVISION OF ARVIN/CALSPAN
20th & RACE STREETS, PHILADELPHIA, PA 19105

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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 Duane Arnold 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.

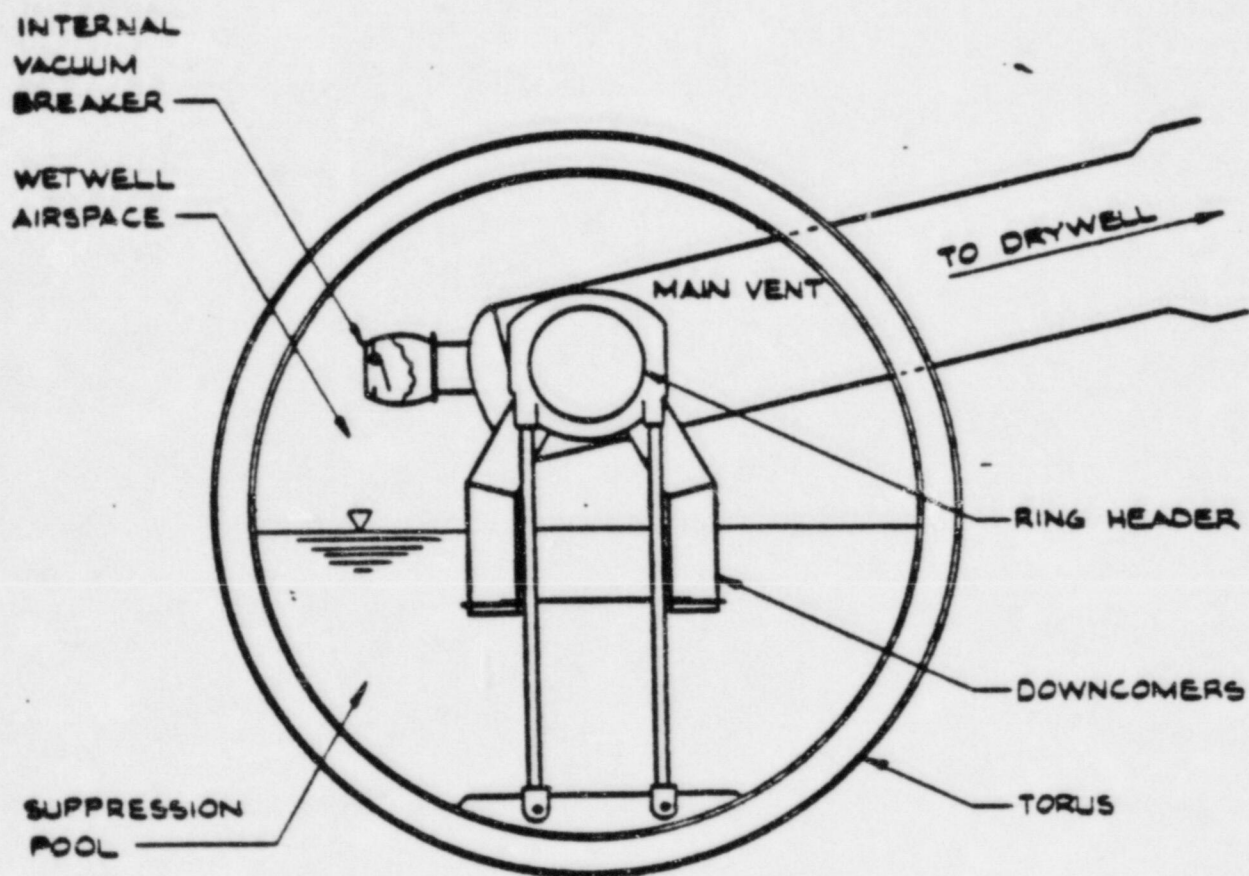


Figure 1. Internal Vacuum Breaker

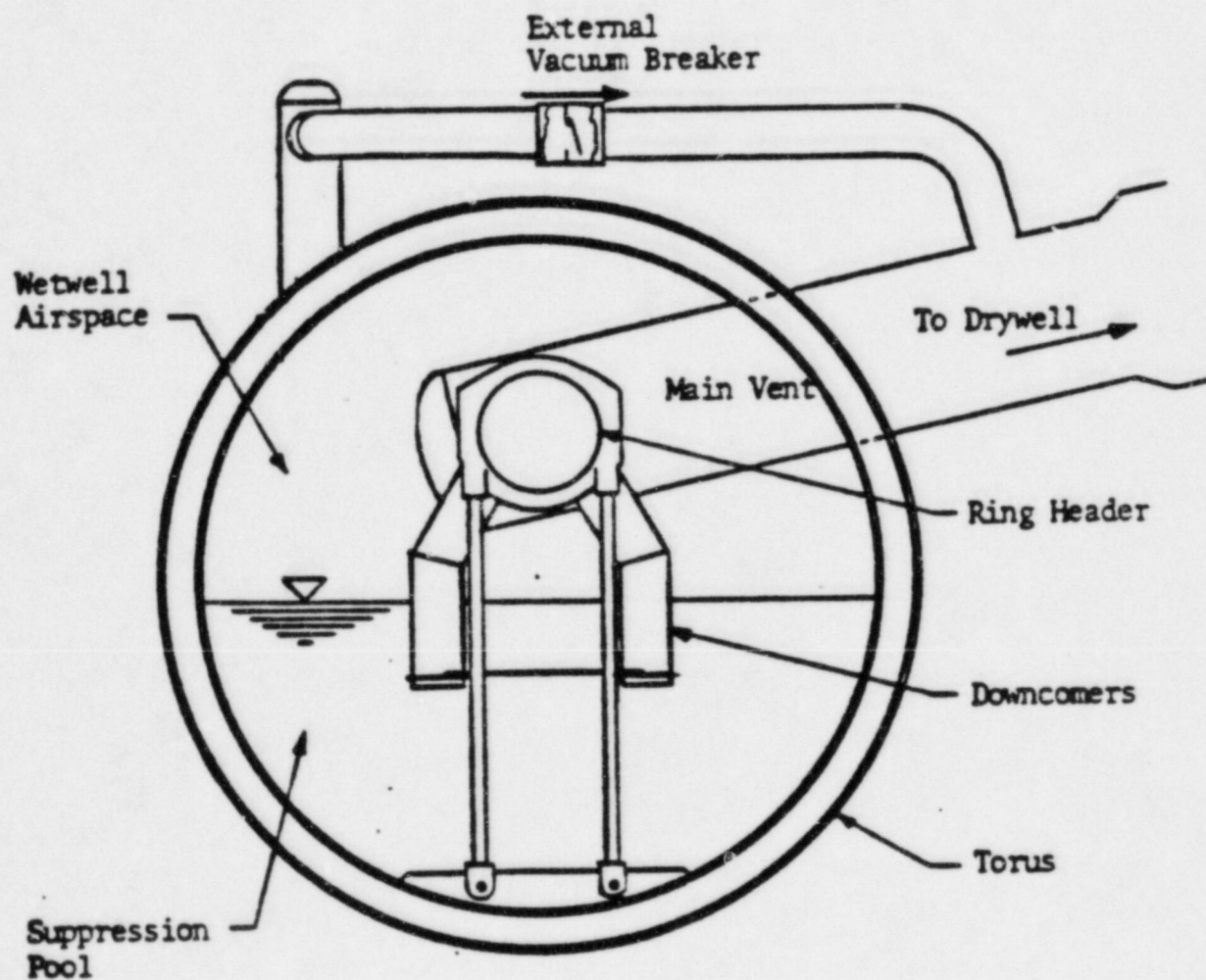


Figure 2. External Vacuum Breaker

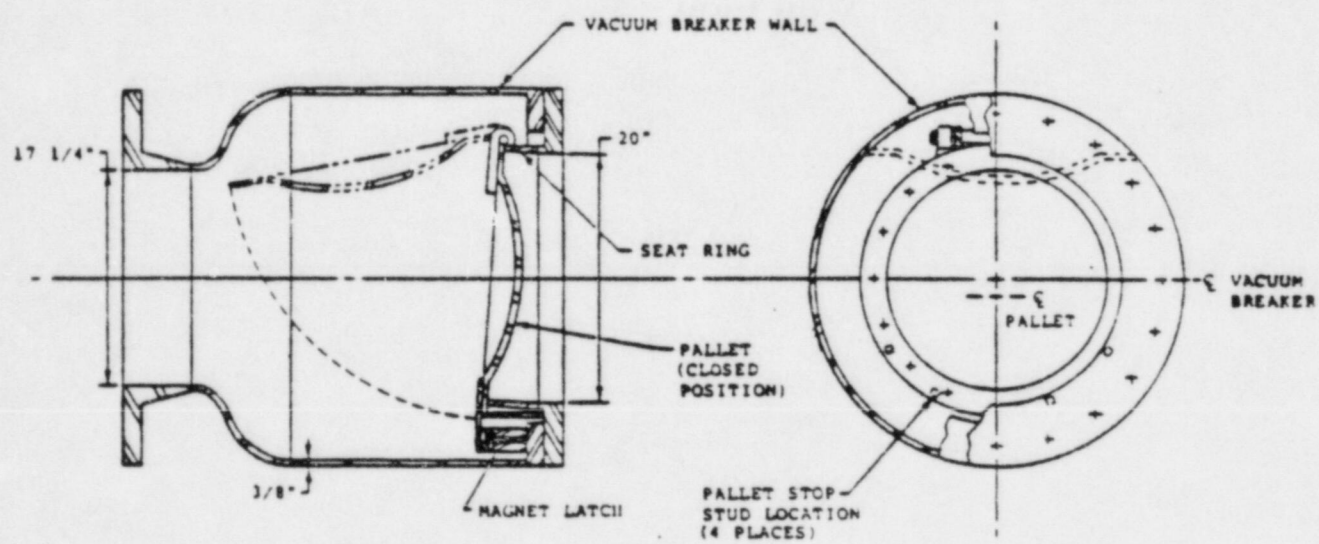


Figure 3. GPE Vacuum Breaker

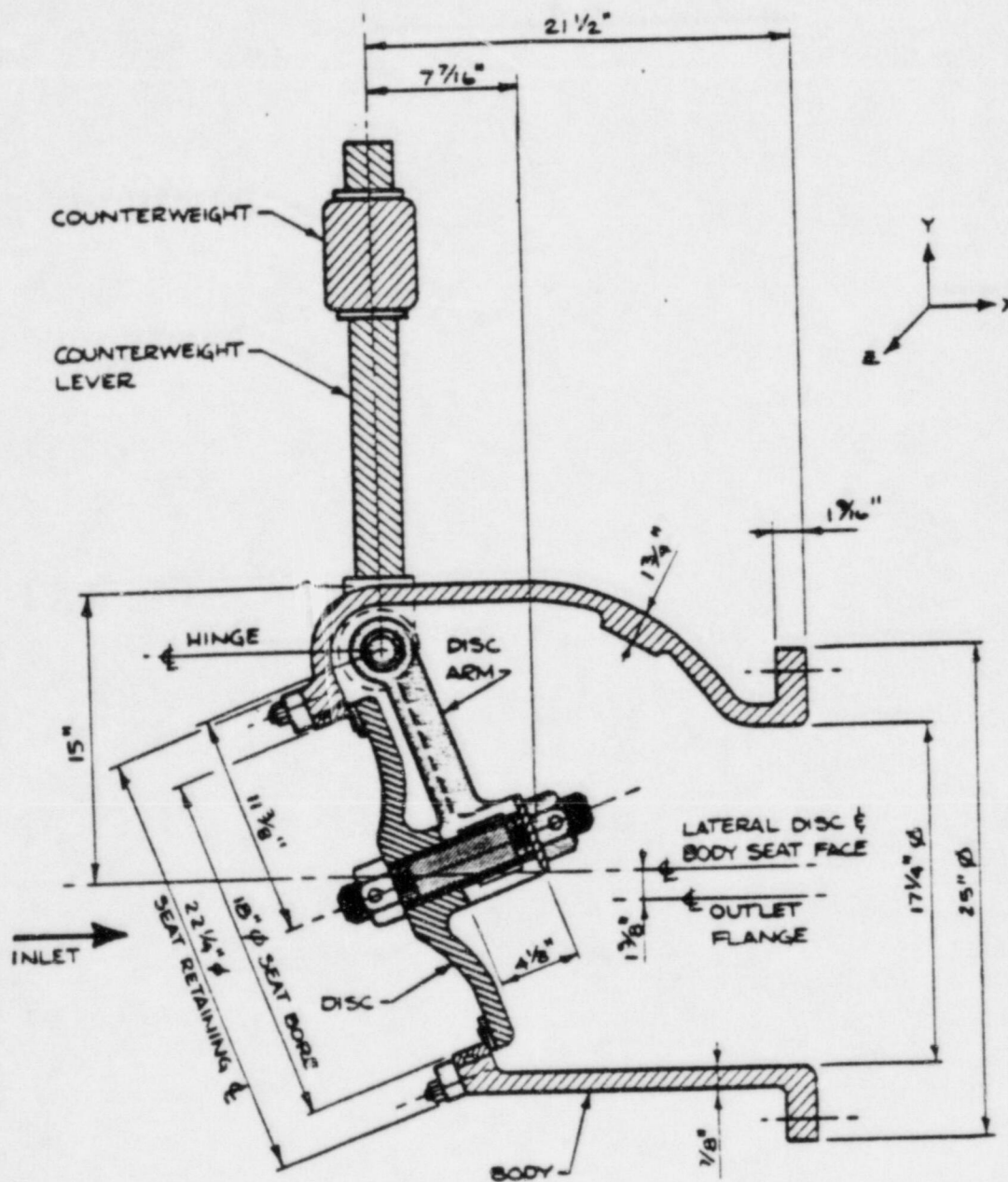


Figure 4. Atwood-Morrill Vacuum Breaker

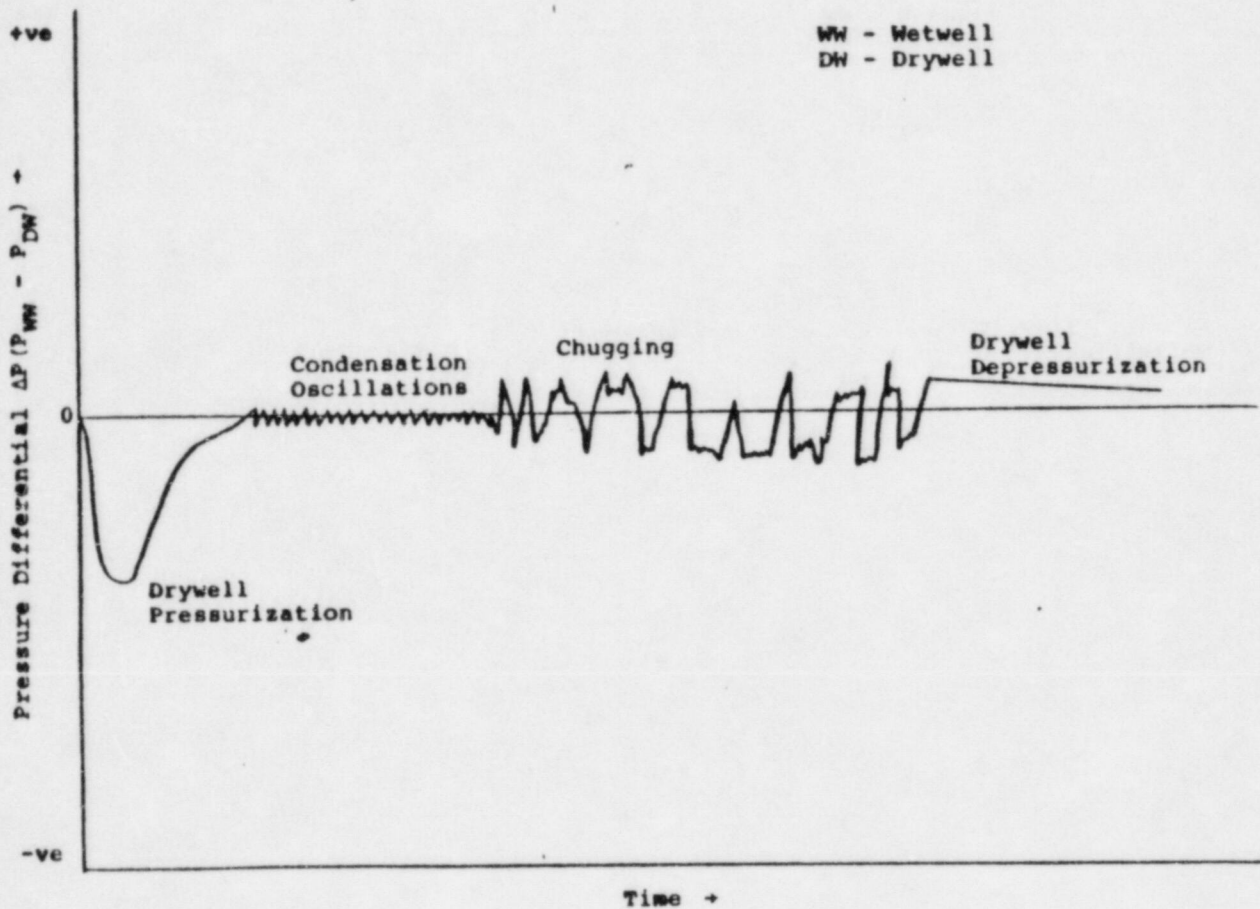


Figure 5. Typical DW/WW Vacuum Breaker Pressure Differential Due to LOCA

Table 1. Vacuum Breaker Types and Affected Plants

<u>Vacuum Breaker</u>	<u>Plant</u>
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.

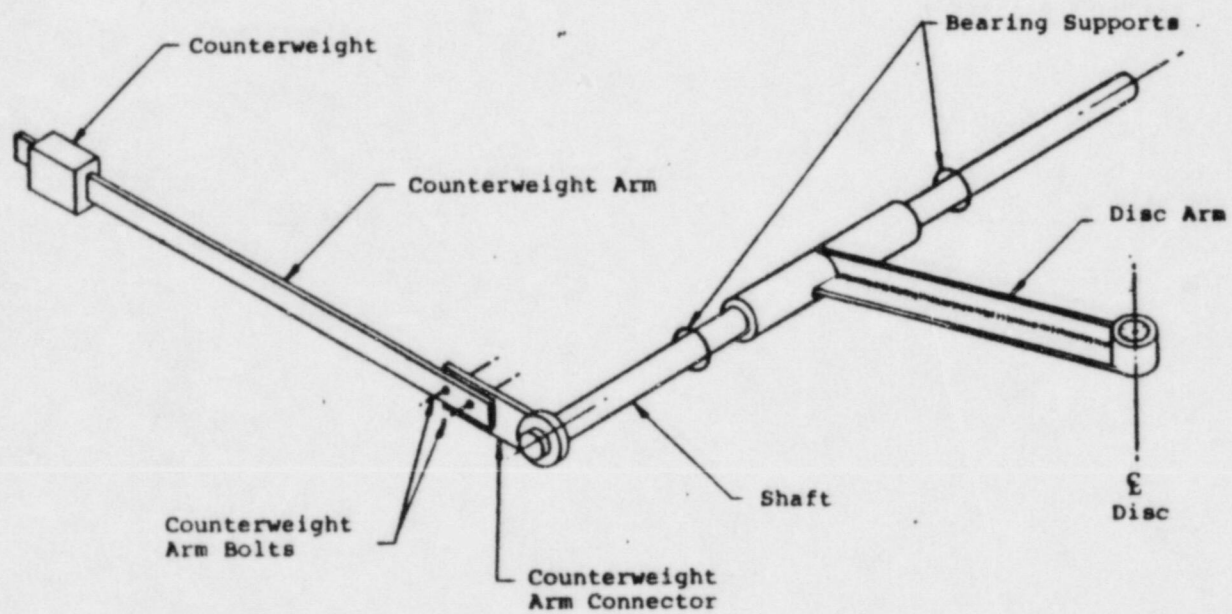


Figure 6. Detailed Valve Internal Model

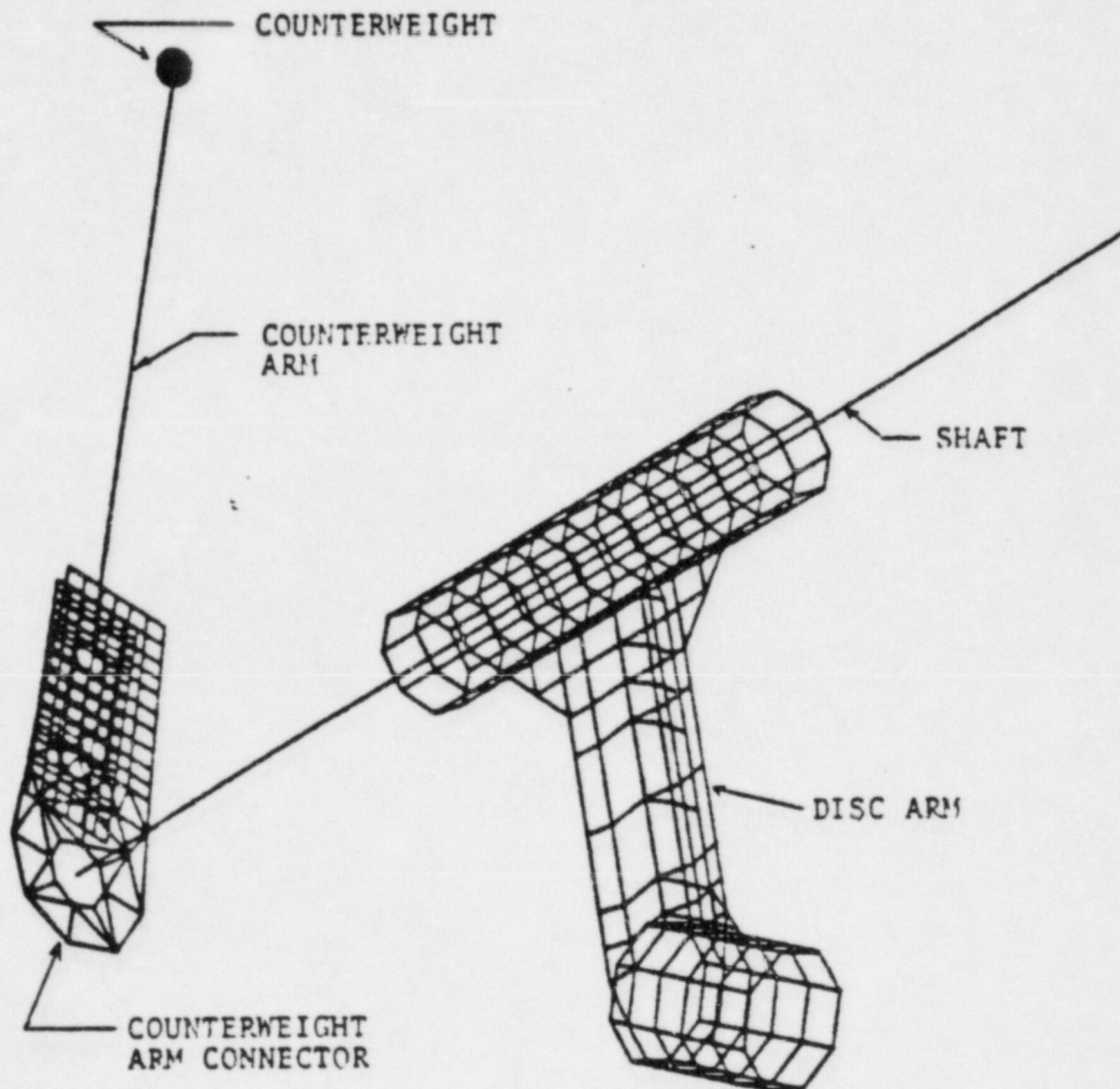


Figure 7. Finite Element Model of Valve Internals

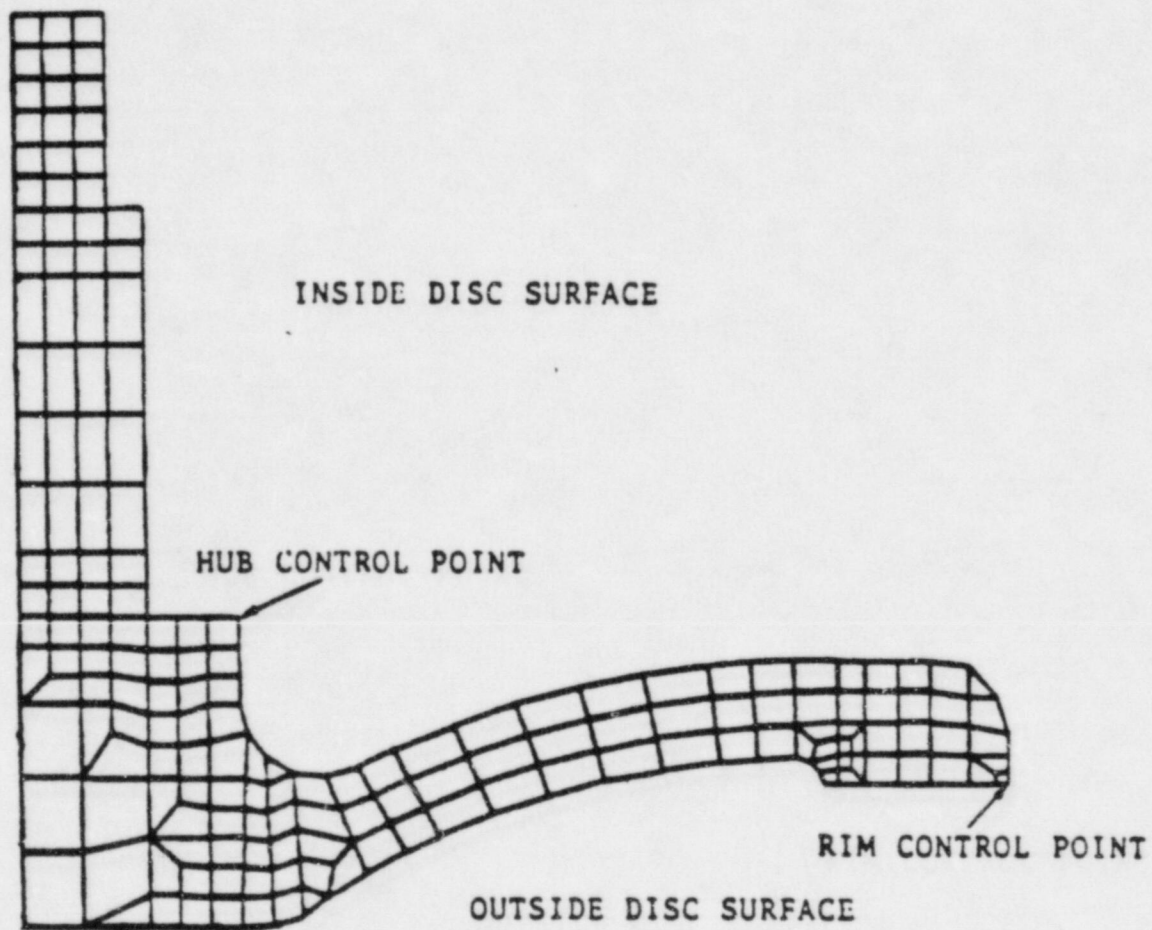


Figure 8. Valve Detailed Disc Model Geometry

5. PLANT-SPECIFIC REVIEW: DUANE ARNOLD

5.1 BACKGROUND INFORMATION

- o Vacuum breaker type: 18-inch GPE (internal)
- o Vacuum breakers extend 3 ft, 4 1/2 in from mounting flanges which are attached to 1 ft, 6 in diameter, 1-inch-thick nozzles.
- o Nozzles penetrate vent header at eight vent line/vent header intersections.

5.2 STRESS ANALYSIS RESULTS

Vacuum breakers were analyzed using a finite element model and the ANSYS computer program. Stress levels of critical components were calculated for various pallet impact velocities (see Table 2). A hydrodynamic model of the vent system was evaluated to determine the impact velocity of the Duane Arnold plant. The design impact velocity for vacuum breakers was calculated to be 5.72 radians/sec. Because stress is proportional to impact velocity, Table 2 indicates a potential for overstress with an impact velocity of 5.72 radians/sec. In order to increase the integrity of the vacuum breaker assemblies and to restore the original margin of safety, the following modifications were scheduled [7]:

Replacement of the W/D vacuum breaker pallet (SA-516 Gr 70) with SA-705 Gr 630 (age hardened at 1100°F)

Replacement of the W/D vacuum breaker hinge shafts (SA-320 B8 with SA-564 Gr 630 (age hardened at 1100°F)

Replacement of the W/D vacuum hinge arms (SA-516 Gr 70) with SA-564 Gr 630 (age hardened at 1100°F)

Replacement of the W/D vacuum hinge arm studs (SA-320 B8 with SA-564 Gr 630 (age hardened at 1100°F)

These new materials have an allowable stress of 70 ksi.

Table 2. Stress Levels by Component for 18-inch GPE Vacuum Breaker

<u>Component</u>	<u>Existing Material</u>	<u>ASME Allowable Stress (ksi)</u>	<u>Stress (ksi) for Various Pallet Impact Velocities</u>		
			<u>3.0</u>	<u>4.5</u> (rad/sec)	<u>9.3</u>
Pallet	SA-516 Gr 70	35.0	21.6	32.4	67.0
Hinge Arm	SA-516 Gr 70	35.0	11.8	17.7	36.6
Hinge Shaft	SA-320 B8	30.0	19.1	28.6	59.2
Hinge Arm Stud	SA-320 B8	30.0	12.5	18.8	38.8

6. CONCLUSIONS

A review has been conducted to determine the structural integrity of the vacuum breakers of the Duane Arnold 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:

- o 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 material of the pallet, hinge shaft, hinge arm, and hinge arm stud as described in Section 5.2. This modification approach has been reviewed and found to be adequate.

7. REFERENCES

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7. R. W. McGraughy
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Iowa Electric Light and Power Company
July 29, 1983