EPRI

BWR Vessel and Internals Project Internal Core Spray Piping and Sparger Replacement Design Criteria (BWRVIP-16NP)

NON-PROPRIETARY INFORMATION

NOTICE: This report contains the non-proprietary information that is included in the proprietary version of this report. The proprietary version of this report contains proprietary information that is the intellectual property of BWRVIP utility members and EPRI. Accordingly, the proprietary report is available only under license from EPRI and may not be reproduced or disclosed, wholly or in part, by any Licensee to any other person or organization.

REPORT SUMMARY

The Boiling Water Reactor Vessel and Internals Project (BWRVIP), formed in June, 1994, is an association of utilities focused exclusively on BWR vessel and internals issues. This BWRVIP report documents criteria that can be used to design a replacement for core spray piping which has been known to crack in some BWRs.

BACKGROUND
A number of BWR plants have experienced stress corrosion cracking in the core spray piping which is located internal to the reactor pressure vessel. A variety of mechanical and welded techniques have been proposed to repair the cracks. An additional option is to replace all or portions of the piping. Since a large number of criteria need to be met in making such a replacement, it is useful to have these criteria set down in a comprehensive document.

OBJECTIVES
To compile the appropriate design criteria for replacement of core spray piping and spargers into a document which can be used by utility personnel performing the design and which could be submitted to appropriate regulatory agencies for approval of the generic design process.

APPROACH
The project team assembled a draft document which discussed all elements which need to be considered in designing a replacement to the core spray piping or spargers. These items include design objectives; structural evaluation; system evaluation, materials, fabrication and installation consideration; and required inspection and testing. The resulting draft was reviewed by BWRVIP utility representatives and third party contractors. The final report incorporates comments received during that review.

RESULTS
The document provides general design acceptance criteria for the replacement of core spray piping and spargers. Replacements designed to meet these criteria will maintain the structural integrity of the core spray system under normal operation as well as under postulated transient and design basis accident conditions.

EPRI PERSPECTIVE
The criteria listed in the report define a standard set of considerations which are important in designing a core spray piping replacement. These criteria will be submitted to the USNRC, and possibly non,US regulators, for approval. Regulatory acceptance of these generic criteria will significantly reduce the utility effort required to obtain approval for plant,specific replacements.

TR-106708NP

Keywords

Boiling water reactor
Core spray internals Repair
Replacement
Stress corrosion cracking
Vessel and internals

BWR Vessel and Internals Project

Internal Core Spray Piping and Sparger Replacement Design Criteria (BWRVIP-16NP)

TR-106708NP
Research Project B501
Final Report, February 2000

Prepared by:

BWRVIP Repair Committee

Sargent & Lundy LLC

Prepared for
BOILING WATER REACTOR VESSEL & INTERNALS PROJECT and
EPRI
3412 Hillview Ave.
Palo Alto, California 94304

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

This report was prepared by the organization(s) named below as an account of work sponsored or cosponsored by the BWR Vessel and Internals Project (BWRVIP) and the Electric Power Research Institute, Inc. (EPRI). Neither BWRVIP, EPRI, any member of EPRI, any cosponsor, the organization(s) named below, nor any person acting on behalf of any of them:

(a) makes any warranty or representation whatsoever, express or implied, (i) with respect to the use of any information, apparatus, method, process or similar item disclosed in this report, including mechantability and fitness for a particular purpose, or (ii) that such use does not infringe on or interfere with privately owned rights, including any party's intellectual property, or (iii) that this report is suitable to any particular user's circumstance, or

(b) assumes any responsibility for any damages or other liability whatsoever (including any consequential damages, even if BWRVIP, EPRI or any EPRI representative has been advised of the possibility of such damages) resulting from your selection or use of this report or any information, apparatus, method, process or similar item disclosed in this report.

Organization(s) that prepared this report:

BWRVIP REPAIR COMMITTEE

SARGENT & LUNDY LLC

ORDERING INFORMATION

Requests for copies of this report should be directed to the BWRVIP Program Manager, 3412 Ave., Palo Alto, Ca. 94304, (650) 855-2340.

Abstract

The Boiling Water Reactor Vessel and Internals Project (BWRVIP) was formed in June 1994 as a utility-directed initiative to address BWR vessel and internals issues. This criteria document was developed by the Repair Technical Subcommittee of the BWRVIP.

This document provides the general design acceptance criteria for full and/or partial replacement of internal core spray piping, spargers and supports. It is provided to assist BWR owners in designing replacements which maintain the structural integrity and system functionality of the internal core spray piping and spargers during normal operation and under postulated transient and design basis accident conditions for the remaining plant life or other service life as specified by the plant owner.

Replacement of internal core spray piping and spargers is only one of several options that are available for resolving cracking of internal core spray piping and spargers and should be considered where repairs may be either too extensive (and costly) or impractical. Partial pipe replacement in combination with repairs is permitted by this design criteria document. Due to variation in the material, fabrication, environment and as-found condition of individual internal core spray piping and spargers, the action to be taken for individual plants will need to be evaluated on a case-by-case basis by the plant licensee.

TABLE OF CONTENTS

LIST OF FIGURES

1. Introduction

1.1 Background

Core spray line/sparger cracking was first detected in 1978 during routine in-vessel visual inspections. As the cracking was found to be more widespread in subsequent years, and recognizing the nature of stress corrosion cracking, the NRC issued IE Bulletin 80-13, requiring that augmented visual inspections be performed in addition to the examinations required by ASME XI. Plants have been performing inspections to the IE Bulletin 80-13 requirements for many years, and have continued to find and address core spray line/sparger cracking.

Recently, the BWRVIP prepared a safety assessment of BWR internals as a follow-on to the activities completed on shroud cracking. In the evaluation of internal core spray piping and spargers and the consequences of internal core spray pipe cracking, it was clear that inspection is an important part of assessing internal core spray piping integrity, and thus the ability to achieve safe shutdown for worst case scenarios. As a result, the BWRVIP made development of the core spray inspection and evaluation guidelines a high priority for 1996 (see Reference 17).

In parallel, field cracking at creviced locations was found by visual inspection of the outside surfaces of internal core spray piping in the shroud annulus. Supplemental ultrasonic examination showed that actual cracking could be considerably more severe than was shown by the outside visual indications. This field experience raised the priority of BWRVIP internal core spray piping and sparger assessment and repair activities culminating in the requirements set forth in two criteria documents. One criteria document for the design of repairs (Internal Core Spray Piping and Sparger Repair Design Criteria, BWRVIP-19) and this document for the design of replacement of core spray piping, spargers, and supports. The guidance provided in these design criteria documents is consistent and thus facilitates implementation of partial or full pipe replacement in combination with repairs.

1.2 Purpose

The purpose of this document is to provide general design guidance and acceptance criteria for replacement of 300 series stainless steel (SS) internal core spray piping, spargers and supports. It is expected that individual licensees and vendors will adhere to these criteria in the development of plant-specific replacement designs.

The issuance of this document is not intended to imply that replacement of internal core spray piping, spargers and supports is the only viable approach to resolution of the cracking issue. .

1.3 Scope

This document is applicable to General Electric BWR 2, BWR 3-5, and BWR/6 plants which plan to implement replacement of the 300 series SS internal core spray piping and

spargers (including their supports) that are subject to cracking. The interface with other RPV internals and repairs of internal core spray piping and spargers is also addressed within the scope of this document.

2. Definitions

Replacement	Replacement as used in the context of this document constitutes removal or structural replacement of all or portions of the piping, spargers and/or supports that are subject to cracking and installation of new piping, spargers and/or supports in their place. The material and design shall be resistant to the cracking mechanisms that have been experienced in these components.
Repair	Repair as used in the context of this document is a broad term that applies to actions taken to design, analyze, fabricate and install hardware that restores the structural and functional integrity of all or a portion of the internal core spray piping, spargers, and supports. Repairs differ from replacement primarily in that the flaws are left in place. Weld overlay, without removal of the defect, is also considered a repair in the context of this criteria document.
Internal Core Spray Piping	Internal Core Spray Piping is defined to include the core spray piping internal to the reactor vessel including: the core spray nozzle thermal sleeve (but not including the nozzle safe end), and the piping which runs from the thermal sleeve to the shroud (including the connection to the core shroud) sometimes referred to as the core spray line (CSL).
Core Spray Sparger	For the purpose of this criteria, the core spray spargers are taken to be either the upper or lower core spray spargers which are entirely within the core shroud. The upper and lower sparger consists of two sparger halves each of which extend approximately 180 degrees around the inside of the shroud.

The original manufacturing drawing nomenclature (titles) differs from the above definitions in that the sparger, as shown on the sparger or shroud drawing, extends through the shroud, includes an upward directed elbow, a short vertical spool section and female coupling which are located in the annulus. The decision to use the shroud wall as the dividing line between Internal Core Spray Piping and Core Spray Sparger was made to simplify the definition of replacement criteria, and to provide consistency between related BWRVIP documents.

3. Internal Core Spray Piping and Sparger Characteristics and Safety Function

3.1 Generic Physical Description

The internal core spray piping and sparger assemblies are constructed of austenitic stainless steel. The internal core spray piping provides the flow path for core cooling water from the vessel nozzle, through the shroud or top guide (BWR 6) to the core spray spargers that provide distribution of core spray flow over the core to assure long-term cooling when the core cannot be reflooded. The assembly consists of junction or T-box connections that route flow to different piping runs, welded joints needed to construct the individual piping segments in the assembly, and spray nozzles in the spargers that provide the spray distribution over the core. Internal brackets are used to support internal core spray piping and spargers at different locations along the piping runs. Figures 1 through 3 show the overall configuration of the internal core spray piping assembly for each of the main categories of plants: BWR 2, BWR 3-5 and BWR 6. Figures 4 and 5 show a typical core spray sparger configuration.

3.2 Safety Design Bases

Content Deleted -
EPRI Proprietary Information

3.3 Event Analyses

As previously stated, the purpose of this document is to provide general design criteria for replacement of 300 series SS internal core spray piping and spargers susceptible to cracking. Accordingly, various events and operational conditions must be considered to ensure that the replacement does not inhibit the ability of the internal core spray piping and core spray spargers to perform their basic safety functions. The following general load cases shall be considered in design of the proposed replacement.

3.3.1 Normal Operation

Content Deleted -
EPRI Proprietary Information

3.3.2 Anticipated Operational Occurrences (Upset Conditions)

Content Deleted -
EPRI Proprietary Information

Content Deleted -
EPRI Proprietary Information

3.3.3 Design Basis Accidents (Emergency/Faulted Conditions)

Content Deleted -
EPRI Proprietary Information

3.3.4 Loading Combinations

Content Deleted -
EPRI Proprietary Information

4. Scope of Replacement

Internal core spray piping, sparger and support replacements address cracking by removing or structurally replacing portions of the Intergranlar Stress Corrosion Cracking (IGSCC) components and installing new components of resistant material and design in their place. Replacement includes the hardware necessary to connect the new components into the existing piping elements and replacement of internal piping supports (on the vessel wall or the shroud). It is acceptable to either replace or abandon in place the existing components provided all of the requirements of this document are satisfied. For both approaches, all of the applicable requirements related to loose parts, vibration analysis, inspection, etc. shall be evaluated and satisfied.

When either the vessel nozzle safe end or a weld attaching the nozzle thermal sleeve to the nozzle safe end or a support attachment to the RPV is involved in the replacement, ASME Class 1 requirements shall be invoked for the replacement design within the ASME Section III and vessel jurisdiction.

5. Design Objectives

5.1 Design Life

Content Deleted -
EPRI Proprietary Information

5.2 Safety Design Bases

Content Deleted -
EPRI Proprietary Information

5.3 Safety Analysis Events

Content Deleted -
EPRI Proprietary Information

5.4 Structural Integrity

Content Deleted -
EPRI Proprietary Information

5.5 Retained Flaw(s)

Content Deleted -
EPRI Proprietary Information

5.6 Loose Parts Considerations

Content Deleted -
EPRI Proprietary Information

Content Deleted -
EPRI Proprietary Information

5.7 Physical Interfaces with Other Reactor Internals

Content Deleted -
EPRI Proprietary Information

5.8 Installation

Content Deleted -
EPRI Proprietary Information

6. General Design Criteria

Content Deleted -
EPRI Proprietary Information

Table 6-1 Summary of Recommended ASME Design Guidance

Content Deleted -
EPRI Proprietary Information

7. Structural and Design Evaluation

7.1 Significant Loads

Content Deleted -
EPRI Proprietary Information

Dead Weight (DW)

Seismic Inertia

Content Deleted -
EPRI Proprietary Information

Seismic Anchor Displacement

Content Deleted -
EPRI Proprietary Information

Fluid Drag

Content Deleted -
EPRI Proprietary Information

Core Spray Injection Loading (CSIN):

Content Deleted -
EPRI Proprietary Information

Pressure/Thermal Loads and Anchor Displacements:

Content Deleted -
EPRI Proprietary Information

Content Deleted -
EPRI Proprietary Information

7.1.2 Loads - Core Spray Spargers and Supports

Content Deleted -
EPRI Proprietary Information

7.2 Service Level Conditions

Content Deleted -
EPRI Proprietary Information

Service Level A (Normal Plant/System Operation):

Content Deleted -
EPRI Proprietary Information

Service Level B (Upset Conditions):

Content Deleted -
EPRI Proprietary Information

Service Level C (Emergency Conditions):

Content Deleted -
EPRI Proprietary Information

Service Level D (Faulted Conditions):

7.3 Load Combinations

Content Deleted -
EPRI Proprietary Information

7.3.1 Load Combinations - Internal Core Spray Piping and Supports

Content Deleted -
EPRI Proprietary Information

7.3.2 Load Combinations - Core Spray Spargers and Supports

Content Deleted -
EPRI Proprietary Information

7.4 Allowable Stresses

Content Deleted -
EPRI Proprietary Information

7.5 Consideration of Shroud Repair or Cracking

Content Deleted -
EPRI Proprietary Information

7.6 Flow Induced Vibration

Content Deleted -
EPRI Proprietary Information

7.7 Impact on Existing Internal Components

Content Deleted -
EPRI Proprietary Information

7.8 Radiation Effects on Replacement Design

7.9 Analysis Codes

Content Deleted -
EPRI Proprietary Information

7.10 Thermal Cycles

Content Deleted -
EPRI Proprietary Information

7.11 Corrosion Allowance

Content Deleted -
EPRI Proprietary Information

8. System Evaluation

8.1 Leakage

Content Deleted -
EPRI Proprietary Information

8.1.1 Leakage Impact - Normal Operation

Content Deleted -
EPRI Proprietary Information

8.1.2 Leakage Impact - Accident Conditions

Content Deleted -
EPRI Proprietary Information

8.1.3 Leakage Acceptance Criteria - Internal Core Spray Piping

Content Deleted -
EPRI Proprietary Information

8.1.4 Leakage Acceptance Criteria - Core Spray Spargers

Content Deleted -
EPRI Proprietary Information

8.2 Internal Core Spray Piping Pressure Drop

Content Deleted -
EPRI Proprietary Information

8.3 Impact to Flow Distribution

8.4 Emergency Operating Procedure (EOP) Calculations

Content Deleted -
EPRI Proprietary Information

8.5 Power Uprate

Content Deleted -
EPRI Proprietary Information

8.6 Internal Core Spray Piping High Point Vent

Content Deleted -
EPRI Proprietary Information

8.7 Sparger Spray Distribution

Content Deleted -
EPRI Proprietary Information

9. Materials, Fabrication and Installation

9.1 Materials

Content Deleted -
EPRI Proprietary Information

Content Deleted -
EPRI Proprietary Information

9.2 Crevices

9.3 Welding and Fabrication

Content Deleted -
EPRI Proprietary Information

Content Deleted -
EPRI Proprietary Information

9.4 Pre-Installation As-Built Inspection

Content Deleted -
EPRI Proprietary Information

9.5 Installation Cleanliness

Content Deleted -
EPRI Proprietary Information

Content Deleted -
EPRI Proprietary Information

9.6 ALARA

Content Deleted -
EPRI Proprietary Information

9.7 Qualification of Critical Design Parameters and Process

Content Deleted -
EPRI Proprietary Information

10. Inspection and testing

10.1 Inspection Access

Content Deleted -
EPRI Proprietary Information

10.2 Pre and Post Installation Inspection

Content Deleted -
EPRI Proprietary Information

11. Quality Assurance Program

Content Deleted -
EPRI Proprietary Information

12. DESIGN BASIS Documentation

Content Deleted -
EPRI Proprietary Information

13. REFERENCES

1. NRC I&E Bulletin 80-13
2. ASME Boiler and Pressure Vessel Code Section III, 1989 Edition
3. ASME Boiler and Pressure Vessel Code Section V, 1989 Edition
4. ASME Boiler and Pressure Vessel Code Section XI, 1989 Edition
5. USAS B31.1.0, Power Piping
6. Regulatory Guide 1.85, Materials Code Case Acceptability - ASME Section III, Division I
7. 10 CFR 50.55a, Codes and Standards
8. Regulatory Guide 1.44, Control of the Use of Sensitized Stainless Steel
9. EPRI Document NP-7032, Material Specification for Alloy X-750 for Use in LWR Internal Components, Revision 1
10. ASTM A-262, Detecting Susceptibility to Intergranular Attack in Stainless Steel
11. Regulatory Guide 1.31, Control of Ferrite Content in Stainless Steel Weld Metal
12. EPRI Document 84-MG-18, Nuclear Grade Stainless Steel Procurement, Manufacturing and Fabrication Guidelines
13. Code Case N-516, Underwater Welding Section XI, Division, Approved August 9, 1993
14. AWS Standard D3.6-89, Specification for Underwater Welding
15. 10 CFR 50.59
16. EPRI Document TR-106983, "Internal Core Spray Piping and Sparger Repair Design Criteria", BWRVIP-19, August 1996
17. EPRI Document TR-106740, "BWR Core Spray Internals Inspection and Flaw Evaluation Guidelines", BWRVIP-18, July 1996

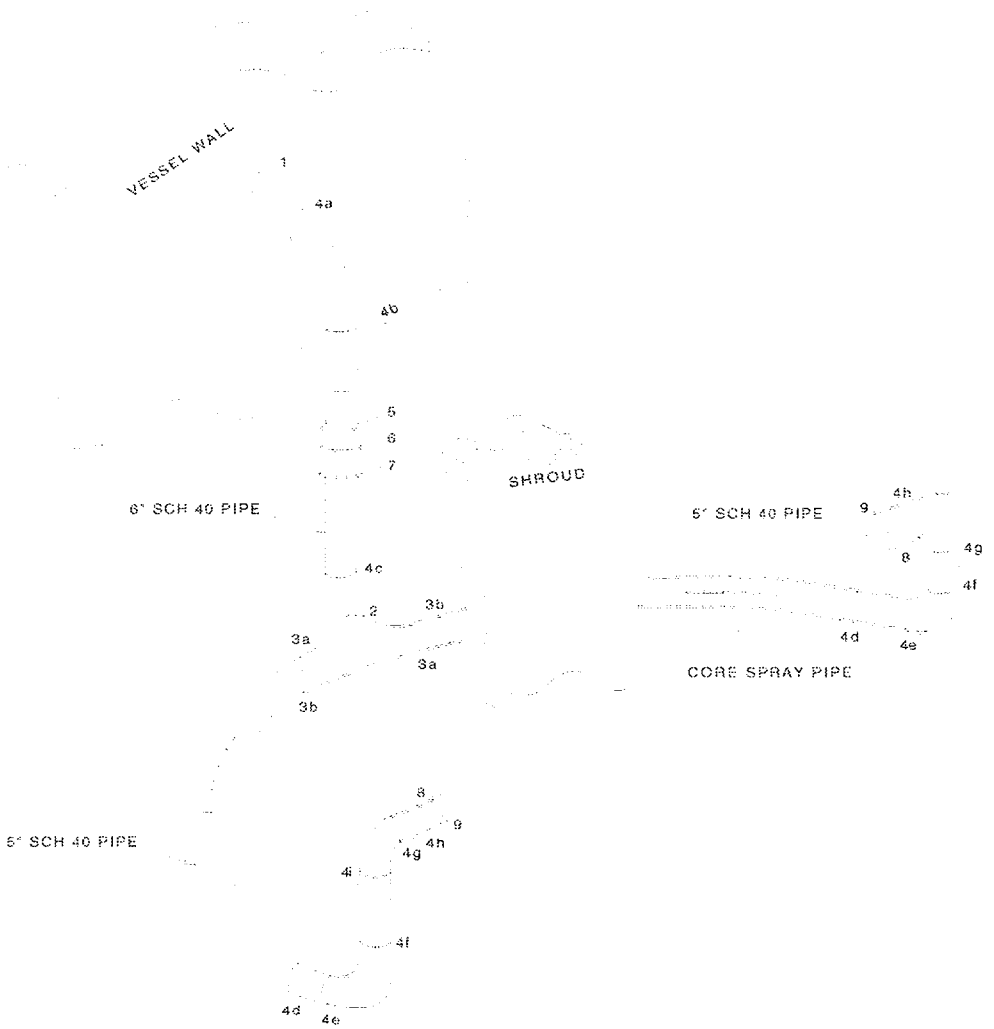

Figure 1 BWR 2 Typical Core Spray Piping Configuration

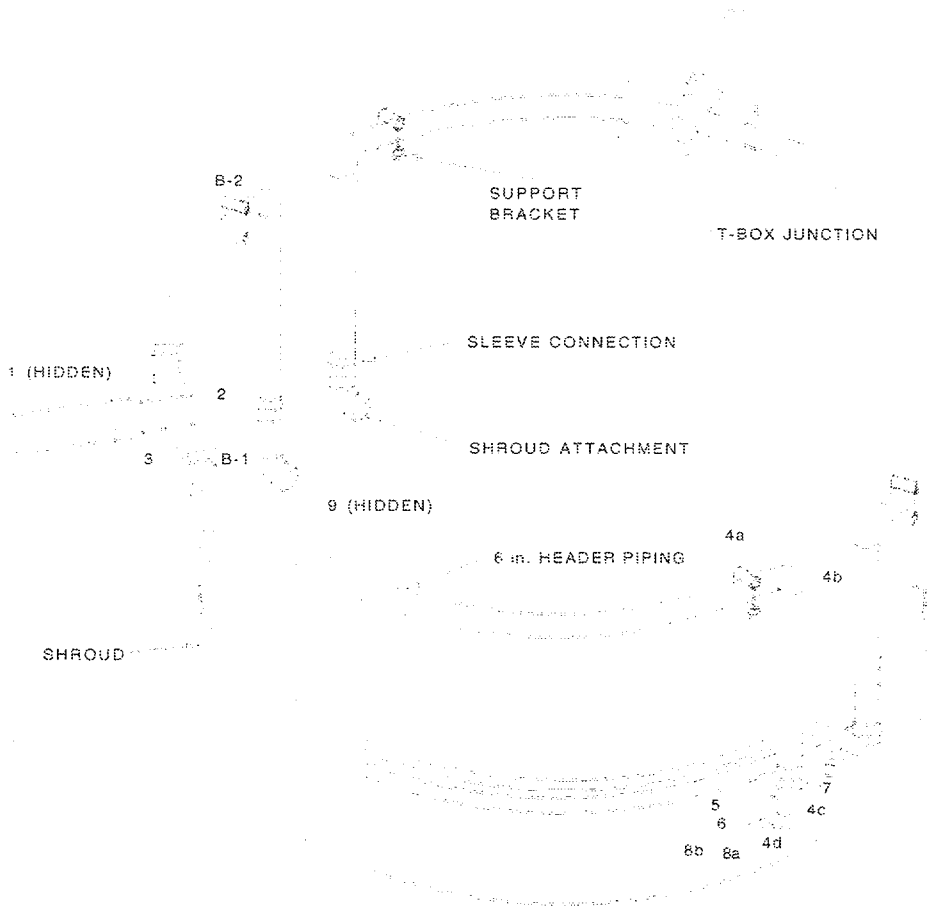

Figure 2 BWR 3-5 Typical Core Spray Piping Configuration

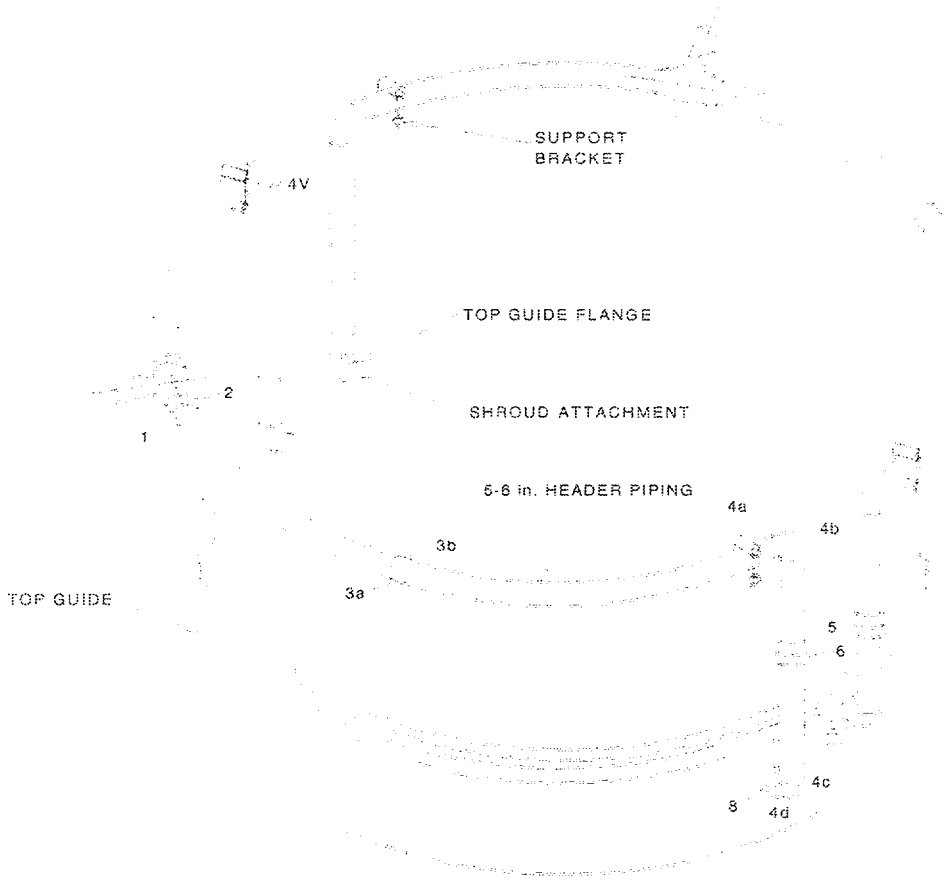

Figure 3 BWR 6 Typical Core Spray Piping Configuration

Content Deleted -
EPRI Proprietary Information

Figure 4 Elevation View of Typical BWR Showing Core Spray Spargers and BWR3/4/5 Coupling

Content Deleted -
EPRI Proprietary Information

Figure 5 Plan View of Typical Core Spray Spargers

Targets:
Nuclear Power

About EPRI

EPRI creates science and technology solutions for the global energy and energy services industry. U.S. electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 1000 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engieers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems.

EPRI. Powering Progress

Printed on recycled paper in the United States of America

TR-106708NP

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.1212 • askepri@epri.com • www.epri.com