Jersey Central Power & Light Company

Oyster Creek Nuclear Generating Station

Core Spray Sparger

Preliminary Modification Report

1. INTRODUCTION

1. Introduct'on

During refueling outages in 1978 and 1980, several cracks and crack-like indications were found in the core spray system spargers installed within the core shroud in the Oyster Creek reactor vessel. A possible crack was also detected in a portion of the core spray inlet piping inside the reactor vessel between a core spray nozzle and the core shroud. Corrective actions taken in 1978 and 1980 include installation of supplemental mechanical supports to assure the structural integrity and full operational capability of the core spray systems. In addition, in spring, 1980, Jersey Central Power & Light Company (JCP&L), through contractor, the General Electric Company (GE), initiated work on the design of a replacement core spray sparger system for installation during a future refueling outage. The purpose of this report is to present the results of design work.

The sections of this report which follow include a discussion of plans for removing the presently installed core spray spargers, a description of the conceptual design of the replacement spargers and internal piping, a summary of pertinent design and performance criteria established, the replacement hardware, and an outline of planned analysis and tests which will be performed in support of the design. Design details and detail dimensions provided sketches accompanying the descriptions provided in this report are preliminary and subject to change as the detailed sparger design is developed.

The information presented herein summarizes and confirms information presented to the NRC staff by JCP&L during a meeting at the NRC on October 21, 19[illegible].

2. SUMMARY

2.0 Summary

The replacement core spray sparger design for Oyster Creek consists of an array of spray distribution pipes and nozzles mounted directly over the reactor core between the shroud and the shroud head. This overhead grid sparger system is described in detail in Section 4 of this report and has the following main features:

Two independent and redundant core spray delivery systems, including internal piping, are provided.

Each system includes a 5" header pipe and seven 3 1/2" distribution pipes which span across the plenum over the reactor core and under the shroud head.

The cross pipes feed individual nozzles located in cruciform assemblies, one nozzle over each group of four fuel bundles (with the exception of some peripheral bundles which will have individual spray nozzles). The spray nozzles are directed essentially verticially into the fuel bundles approximately 11" directly below each nozzle.

A spray flow in excess of 2.45 gpm per bundle (the original core spray flow requirement for Oyster Creek) will be provided by each of the redundant systems.

Inlet flow to each sparger assembly is directed through an existing reactor vessel nozzle, through new internal piping which penetrates the core shroud below the shroud flange and enters the spray distribution header through a mechanical disconnnect joint inside the shroud.

The spray delivery piping, headers and nozzles are supported by a rugged, deep-beam structural grid assembly. This structural support grid is attached at its periphery to a ring which is supported by, and sandwiched between, the shroud flange and the shroud head. The addition of this support ring will raise the existing shroud head and moisture separators by about 1 to 2" and will necessitate the use of new, longer shroud head bolts.

The sparger assembly will be designed and fabricated using ASME Code, Section III, Subsection NG as a guide. Materials and processes selected will be those which have been demonstrated to be resistant to intergranular stress corrosion cracking in the BWR environment.

Evaluations performed by General Electric have shown that the addition of the overhead grid core spray sparger will have no significant effects on reactor core stability and performance, separator and dryer performance, recirculation system performance or structural adequacy of the reactor internals.

The overhead grid replacement sparger is similar in design to the core spray sparger system installed in BWRs designed by ASEA-ATOM and was selected for installation in Oyster Creek because of the following main advantages:

The location of the spray nozzles directly over and above the fuel bundles results in a straightforward and predictable spray distribution with substantial margin in flow per bundle over a wide range of air and steam conditions. Further, the modual design facilitates and simplifies interpretation of spray tests in steam and air environments.

The sparger is removable for periodic inspection and, if necessary, replacement.

Removal of the existing spargers and internal piping will be accomplished with the reactor vessel flooded using special remote cutting and machining tools. Removal of the installed sparger rings with nozzles, all internal piping and nozzle safe ends is planned. The special remote tooling and support equipment is presently being designed and developed and will be qualified prior to use in the reactor using full scale mockups. Verification of the hydraulic performance capability and structural adequacy of the replacement sparger design will be accomplished by comprehensive analyses and tests. Tests now planned include:

Spray tests of each nozzle configuration in air and in steam at pressures from 15 psia to 125 psia. Multiple nozzle spray interaction tests will also be included.

Hydraulic testing of a full-scale sparger mock-up with replaceable orifices to verify the flow, pressure drop and flow distribution for the final sparger design.

Hydraulic flow and leakage tests of the internal piping disconnects and mechanical joints.

Low-impedance vibration testing to determine the dynamic characteristics of the sparger and support system and to confirm results of vibration analysis.

Results of these analyes and tests together with the details of the final spray nozzle configuration selected, will be provided in the final design report.

3. REMOVAL DESCRIPTION

3.1 General

The existing core spray sparger, internal piping, and safe end will be removed to allow access for installation of the replacement core spray system components (described in Section 4) and to eliminate possible concerns in regard to long term component integrity. The need for removal of the respective components and the methods to be used are described below.

The majority of the removal and installation work will be performed remotely with the fuel removed, working with the vessel flooded, from a platform located at the vessel closure flange elevation. Special tooling will be furnished for this work. The toolig will be designed for simplicity of operation, reliability, minimum radiation exposure to personnel, and minimum outage time. Tooling will be qualified for field use by mockup testing. The training of key operators will be accomplished using the tool qualification mockups. However, it is not necessary that all operators be trained on the mockups.

3.2 Sparger Removal

The existing core spray sparger is constructed of 3 1/2 inch Schedule 40 stainless steel pipe, formed in four semicircular ring sections. The spray nozzles are spaced around the circumference of these sections, mounted to stainless steel piping elbows. Core spray flow is routed from the internal piping through the shroud wall, into 5 inch Schedule 40 pipe tee-boxes located at the center of each sparger ring section. The tee-boxes are attached to the shroud by circumferential welds, and by gusset-type brackets welded to the shroud wall. The ring sparger arm sections are also retained in the shroud by a sliding fit with each of twelve vertical brackets which are welded to the shroud.

The existing sparger arms will be removed by cutting off the portions of the vertical brackets which retain the pipe. Removal of the sparger arms will allow adequate space where the ends are presently located to permit installation of the new sparger disconnect joint. The attachments to the shroud at the tee-boxes will be cut either by removal of the tee box itself, or by cutting off the arms adjacent to the tee box. To allow access for sparger removal, it may also be necessary to cut off portions of top guide attachments which project above the top guide at its periphery. These include four lifting eyebolts, four alignment pins, and four hold down clamps. The portion of the eyebolts and alignment pins which may be removed are not required for future use. Some or all of the hold down clamps will be replaced with a remotely installable design if it is found that the hold down feature is required.

3.3 Internal Piping Removal

The internal piping connects each tee-box to one of the two vessel nozzles, and is constructed of 5 inch and 6 inch Schedule 40 stainless steel pipe. The piping is routed downward from each nozzle to a tee from where it branches 90 degress horizontally in each direction, around the outside of the shroud to its welded attachments at the sparger tee-boxes. It is supported at intermediate locations from the shroud by a clearance fit with brackets attached to the shroud.

The piping will be removed by cutting it free at the ends where it attaches to the shroud and vessel nozzle, and by further cutting it into sections which can be withdrawn from the shroud annulus. Removal of at least the vertical sections extending downward from the vessel nozzles is required to allow access for the new coupling which will connect the thermal sleeve directly to the shroud penetrations. Removal of the remainder of the piping eliminates the need to provide support for the end of the piping.

3.4 Safe End Removal

The existing core spray nozzle safe ends and thermal sleeves will be replaced to allow installation of the required connecting pipe to the new sparger. Both the safe end and thermal sleeve will be cut near the Ni-Cr-Fe weld to the vessel nozzle, leaving a portion of the weld metal for welding to the new safe end. A short section of the external piping attached to the safe end will also be removed, as required, to gain access to perform this removal work and subsequent installation of the new components.

3.5 Steam Skirt Removal

The existing steam seal skirt consists of a 1/4 inch thick plate rim, projecting above the top of the shroud flange. The new sparger support flange must seat on the top of the shroud. Since the steam skirt would interfere with the seating, the steam skirt will be removed from the shroud flange.

4. REPLACEMENT OF SPARGERS

4.1 Extent of Replacement

Replacement of the core spray spargers will be accomplished by permanent installation of two new safe ends and thermal sleeves, each with a pipe coupling connecting to a new penetration through the wall of the shroud. The stationary portion of the sparger piping disconnect joint is attached at each of the shroud penetrations, inside the shroud. A new removable overhead grid sparger will be furnished, which will be removed and then reinstalled between the shroud and the shroud head at each refueling. A new set of shroud head bolts, having increased length to accommodate the added height of the sparger support flange in the shroud head joint, will also be provided.

4.2 Applicable Codes

The replacement of the core spray sparger and the associated parts which are included in this program will be performed in accordance with the ASME Boiler and Pressure Vessel Code, 1977 Edition with Addenda to and including Summer 1978, Section XI, Article IWA-7000 requirements. All hardware being replaced is "important to safety" and the provisions of 10CFR21 apply.

The sparger, internal pipe coupling, nozzle thermal sleeve, shroud head bolts, shroud penetration plugs, disconnect joint, and disconnect cover are non-code parts, but will be designed using ASME Subsection NG as a guide.

The vessel safe ends were originally furnished in accordance with the ASME Code, 1959 Edition with Addenda to and including Winter 1963, Section I. Replacement safe end material and fabrication will be performed in accordance with ASME Code, 1977 Edition with Addenda to and including Summer 1978, Sections II and III.

Class I requirements apply, except that N-stamping is not required and shop hydrostatic pressure testing wil not be performed. Hydrostatic pressure testing of the safe ends will be performed in the field in accordance with ASME Section XI, Article IWB-5000 requirements.

The piping connnecting to the safe ends was originally furnished in accordance with the American Standard Code for Pressure Piping, ASA B31.1, 1955 Edition. The portion of this piping which is replaced will also conform to this original Code, or a later Edition, consistent with material availability.

4.3 Design Description

4.3.1 General

The overhead grid core spray system replaces the function of the existing ring sparger core spray system. The overhead grid sparger assembly consists of two separate and independent water distribution piping systems located in the plenum over the reactor core and under the shroud head. Spray distribution is achieved by a series of spray nozzles oriented near vertically and aimed at the center of each four-bundle fuel cell, with additional nozzles aimed at some peripheral fuel bundles (Figure 4.3.1). The components of the overhead grid core spray system are described below.

4.3.2 Disconnect joint

The piping connection between the shroud and overhead grid sparger consists of a compliant joint called the disconnect joint (Figure 4.3.2) which accommodates horizontal, vertical, and rotational motion of the sparger relative to the shroud. The joint also permits removal of the overhead sparger from the vessel, allowing access to the core.

4.3.3 Support Structure

The overhead grid core spray system is supported from a "bridge" or "truss" type structure, which in turn, is supported from a ring that has a flange extending between the shroud and shroud head (see Figure 4.3.3). The support ring flange is secured between the shroud head and shroud by means of the preload exerted by the shroud head bolts between the shroud head and the shroud.

The overhead core spray system support is designed to allow for the motion of the core spray distribution piping due to contraction during core spray system operation. This is achieved by the flexure-type attachment between the distribution pipes and the "bridge" or "truss" support, which is stiff in the vertical and lateral directions, but allows axial motion for contraction of the sparger pipe. Resistance to flow induced vibration is provided by lateral supports between distribution pipes, of the same system, attached at the same locations as the flexure-type attachments.

Alignment of the core spray system relative to the reactor core is achieved by lugs on the sparger support flange which extend beyond the outside diameter of the shroud and interface with the alignment pin between the shroud head and shroud. Location of the alignment hole in the sparger support is established at initial assembly and the positioning of the core spray system is achieved thereafter by the sparger head alignment pin extending through the sparger support alignment hole and indexing in the corresponding alignment hole in the shroud.

Seismic restraints are provided on the core spray sparger support ring which will contact the upper flange of the shroud to limit motion during a seismic event. This will assure proper position of the core spray sparger and maintain operability after earthquake conditions.

4.3.4 Internal Piping

The core spray piping internal to the reactor pressure vessel is designed to connect the core spray grid sparger system to its water supply nozzle and to accommodate any misalignments which may exist between the shroud penetration and the vessel nozzle. Differential expansion between vessel and shroud penetration is also accommodated by this piping. This is done by a dual ball-joint type coupling patterned after the Low Pressure Coolant Injection (LPCI) system coupling used in later BWR designs.

4.3.5 Safe End and Thermal Sleeve

The design of the in-vessel core spray piping requires positive anchor points at the safe end and at the shroud. The existing safe end to thermal sleeve connection does not provide sufficient support to serve as an anchor. A new safe end and thermal sleeve will be provided and will be designed to accommodate loads at the thermal sleeve to safe end junction and will be fabricated from materials that are less susceptible to Intergranular Stress Corrosion Cracking (IGSCC) than the original materials.

The new safe end is to be made from Type 316 Austenitic Stainless Steel and will be buttered with Ni-Cr-Fe at the end to be welded to the Ni-Cr-Fe vessel nozzle. The new safe end is configured as a tuning fork (Figure 4.3.5).

The new thermal sleeve, fabricated from Type 316 Austenitic Stainless Steel, will be welded to the safe end, in the field, using automatic welding equipment.

4.3.6 Spray Nozzles

The spray nozzles provide the spray distribution to the fuel bundles. The nozzles are located at the ends of the cruciform piping, as shown in Figure 4.3.3. Two types of nozzles will be used; one type for some peripheral bundles and the other type for all other bundles. Several candidate nozzles will be developed for both nozzle types, as described in Section 7.2. A description of the spray nozzles selected will be presented in the final report.

4.3.7 Shroud Head Bolts

The purpose of the shroud head bolt is to provide the clamping force by which the shroud head flange and the shroud flange are joined. When the overhead core spray system is installed, it is supported by a flange between the shroud head and the shroud. The existing shroud head bolts must therefore be replaced with bolts which are longer to accommodate the added support flange thickness. The replacement shroud head bolts are of the same design as the existing bolts except for the added length and updated material and process requirements.

4.3.8 Tee-Box Hole Plugs

Four tee-box hole plugs will be provided to plug and seal the holes through the shroud resulting from removal of the existing ring spargers and the core spray piping within the reactor vessel. Plug materials will be selected from the ASME Code, Section II.

The plugs are not ASME Code components, and are not "important to safety". However, design, analysis and fabrication will meet the intent of the ASME Code, Section III, Subsection NG.

The plugs are expected to have a minimal leakage; however, the design requirements will be that the maximum leakage, at end of life, does not exceed 35 gallons per minute assuming single-phase flow. The plug design will incorporate positive mechanical retention features to eliminate the possibility of loose pieces in the reactor.

4.3.9 Disconnect Joint Cover

During refueling operations the grid sparger will be removed to provide access to the fuel bundles. The water supply piping will be disconnected at the joints located inside the shroud. The joints will be capped during these periods with a flow diverter which will direct core spray water downward toward the core in the event that the system pumps are activated during this time. The flow diverted will also prevent foreign objects from entering the core spray piping.

4.4 Fabrication Requirements

Material procurement and hardware fabrication will be to the present General Electric requirements for equipment "important to safety". Both the overhead core spray system and the shroud head bolts will be fabricated by the General Electric Company Manufacturing Facility at Wilmington, NC.

Material used in manufacture of the core spray system will include stainless steel Alloy 316 or 316L with 0.02% maximum carbon, Alloy X-750, and Alloy XM-19 material. Material used in the manufacture of the shroud head bolts will include stainless steel Alloy 304 or 316 with 0.02% maximum carbon, Ni-Cr-Fe Alloy 600, and Alloy X-750.

4.4.1 Installation Methods

As previously described for the removal operations, the replacement sparger components will be designed to facilitate installation with remote tooling and to minimize in-vessel work. Where possible, required field attachments will be made using mechanically fastened joints. An exception to this is the safe end and thermal sleeve, which must be joined to the vessel and piping by welding. Rquired structural welds will be made with the water level lowered or by using seal plugs so structural welding does not have to be performed under water.

The two new pipe coupling penetrations through the 1 1/2 inch thick shroud wall will be machined remotely, using either electrical discharge machining (EDM), or conventional machining techniques. The internal pipe couplings and sparger disconnect will be joined to the new shroud penetrations by remote installation of bolted flange joints. No new permanent attachment is required for the sparger assembly itself, as it is retained during operation by its fit up within the existing bolted joint between the shroud and shroud head.

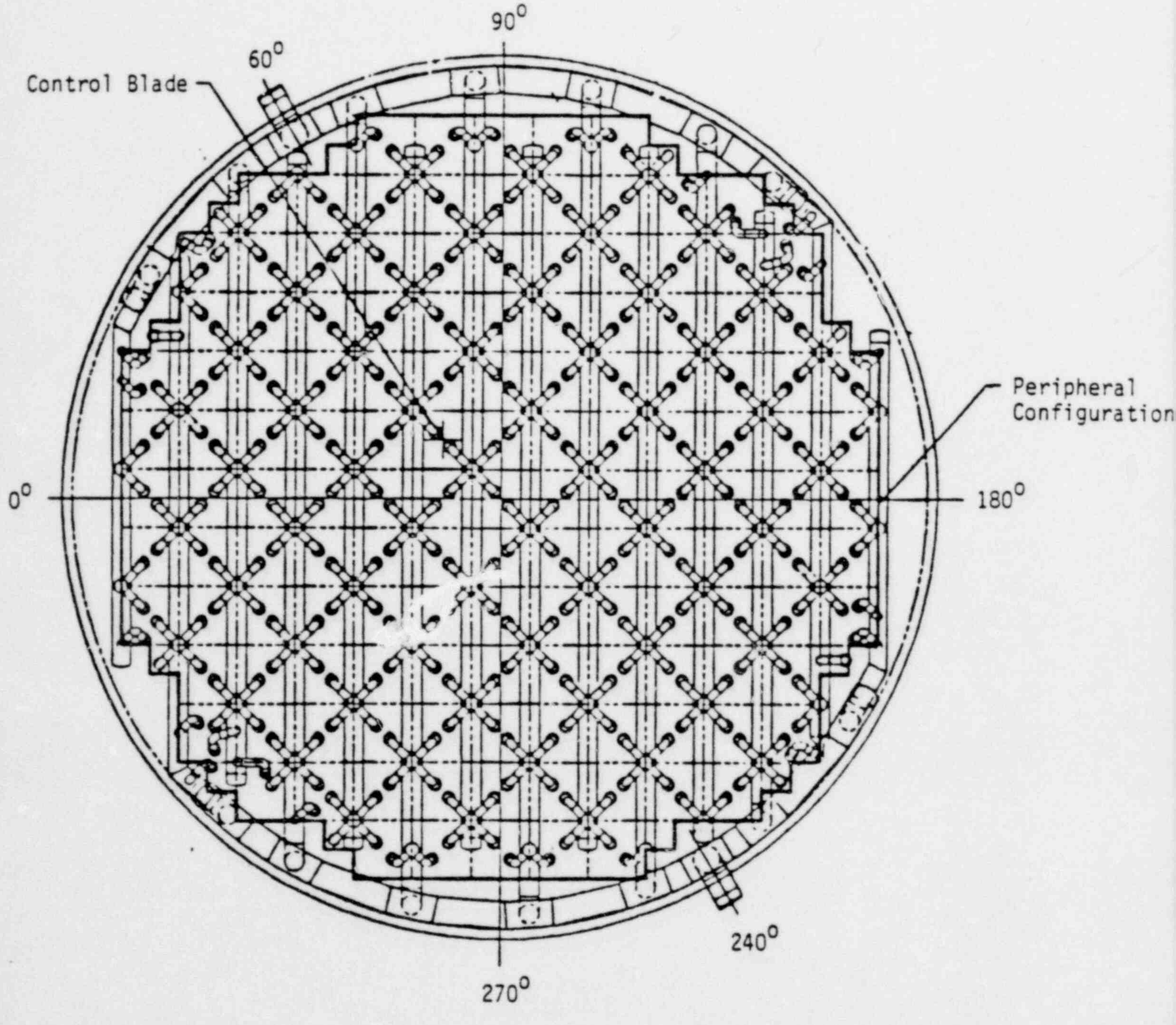

Figure 4.3.1 Overhead Grid Sparger

POOR ORIGINAL

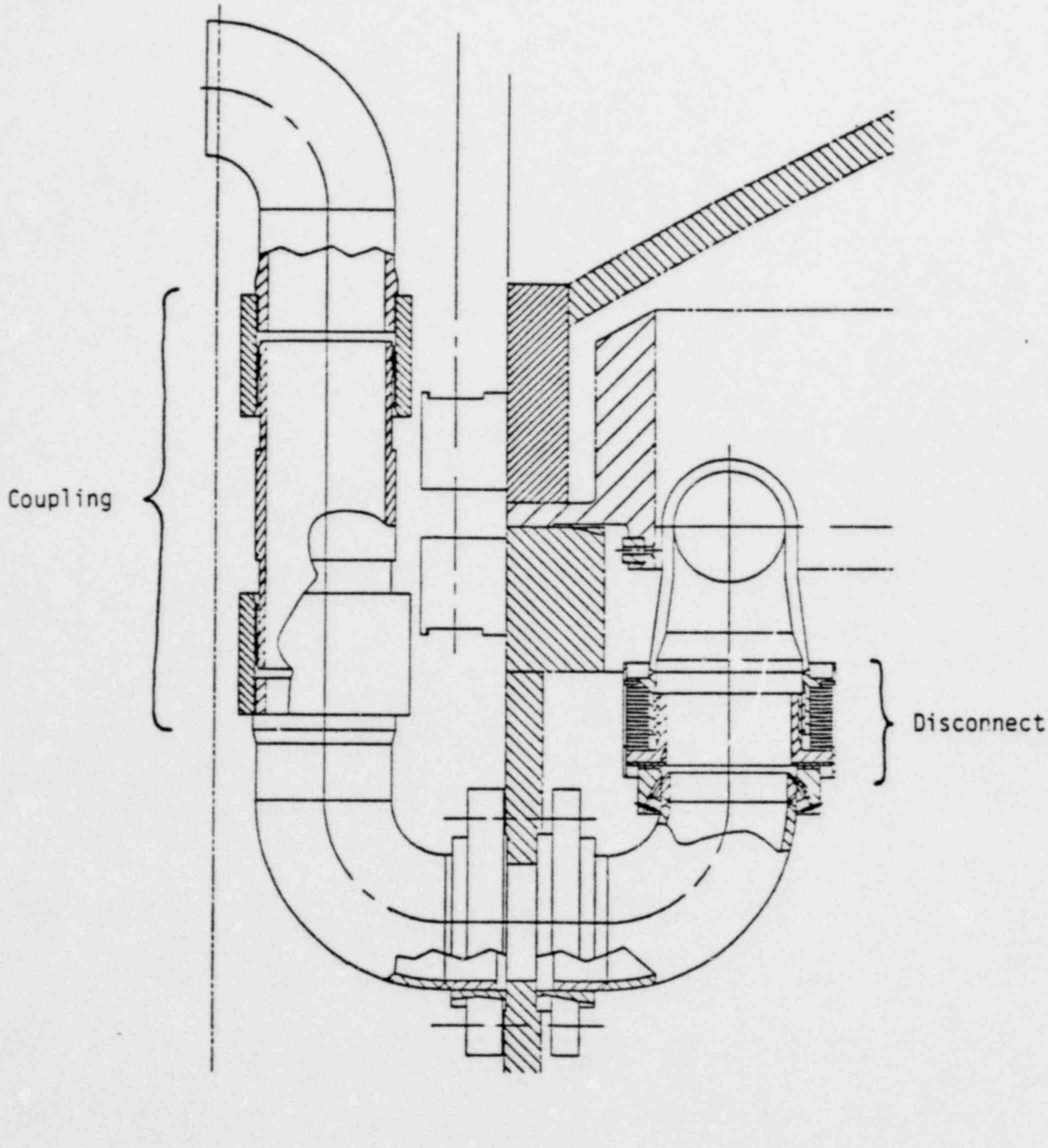

Figure 4.3.2 Overhead Grid Sparger Disconnect Joint and Coupling

POOR ORIGINAL

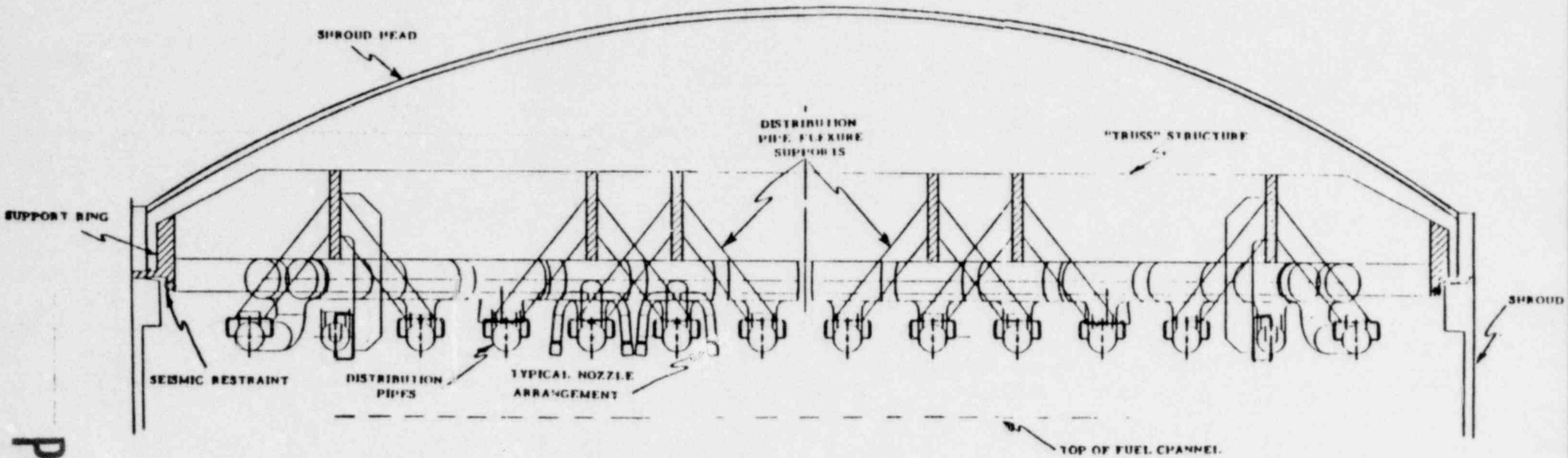

Figure 4.3.3 Overhead Grid Sparger and Support Structure

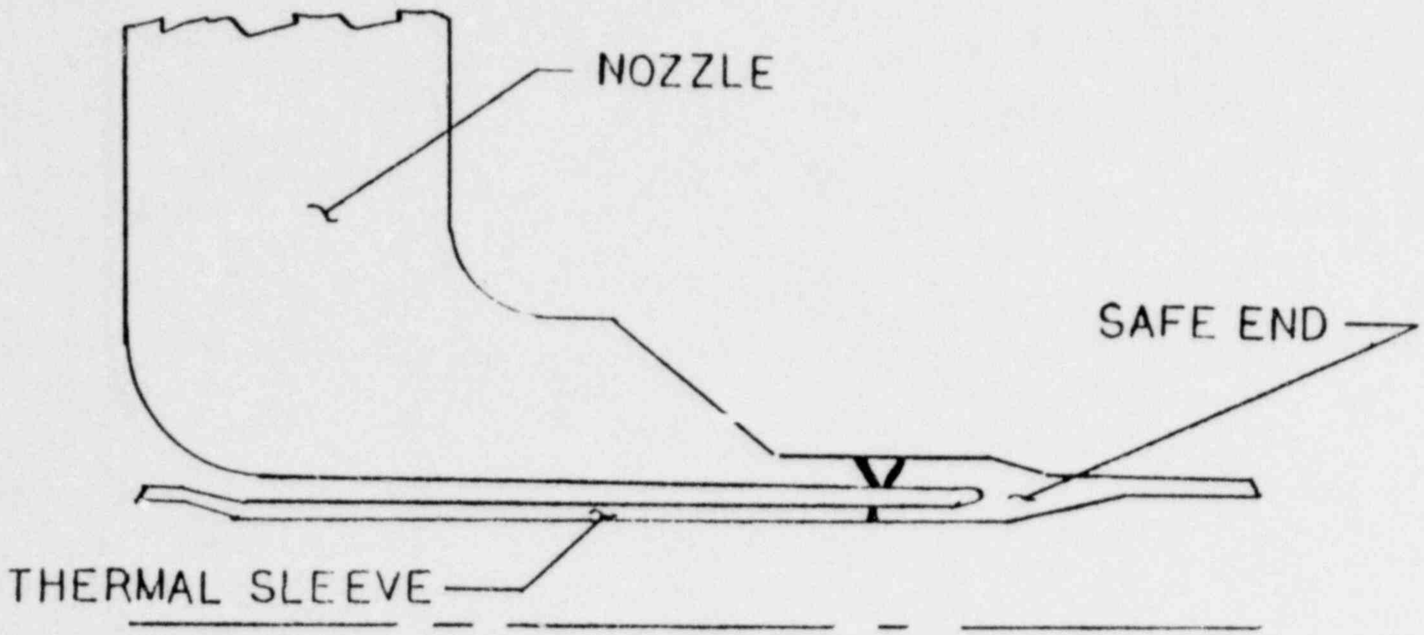

Figure 4.3.5 Core Spray Safe End and Thermal Sleeve

5. STRUCTURAL EVALUATION

The overhead grid core spray system and its supporting structure are classified as "important to safety". The system is not an ASME Code component; however, the design will be evaluated for structural adequacy using the requirements of Section III, Subsection NG of the ASME Code as a guide.

5.1 Load Combinations

5.1.1 Service Level "A" Loads

For structural analysis purposes, service level "A" conditions are defined to comprise all loads due to normal reactor operation combined with dead weight and design earthquake loading, or all loads due to core spray system operation combined with dead weight and the design earthquake loading: whichever case is more limiting.

5.1.2 Service Level "B" Loads

Service level "B" conditions include all laods due to normal reactor operation combined with dead weight and maximum earthquake loading, or all loads due to core spray operation combined with dead weight and maximum earthquake loading; whichever case is more limiting.

5.1.3 Service Level "C" and "D" Loads

No service level "C" or "D" conditions are specified for this structure.

5.2 STATIC LOADS

5.2.1 Deadweight Loads

Deadweight stresses are determined for the weight of the sparger and support structure. The total weight is reacted by the shroud.

5.2.2 Hydraulic Loads

Two types of hydraulic loads must be distinguished; namely, those which may be considered statically, and others which are dynamic in nature. The static hydraulic loading considered here is due to fluid flow momentum changes at branch locations in the core spray sparger during system injection. Other hydraulic loads of a dynamic nature are considered in Section 5.3.2.

5.2.3 Thermal Loads

In addition to thermal steady state reactor operation, four thermal transient conditions are identified along with their corresponding number of associated occurrences within a 40 year design life. These comprise 120 startup/shutdown cycles, 180 scram cycles, 10 cycles of inadvertent core spray injection, and one design basis accident LOCA cycle.

5.3 DYNAMIC LOADS

5.3.1 Seismic Loads

Conservatively specified Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE) horizontal seimic accelerations at the shroud head flange elevation are 1.0 g and 2.0 g's, respectively. The vertical acceleration is taken as two thirds of the horizontal acceleration. These loads may be considered statically when the system natural frequency exceeds 33 Hz (which corresponds to the frequency for zero period acceleration).

5.3.2 Flow Induced Vibration Loads

The sparger and its support structure will be designed for worst case vibration loads in order to provide a very conservative design. Specifically, the design criteria will conservatively assume the following:

The maximum flow velocity (9.8 ft/sec) can be applied simultaneously across any point in any direction.

Maximum possible lift and drag coefficients (1.0).

Fluctuating forces are equal to 100% of lift or drag forces.

Fluctuating forces are applied at the natural frequency of the part in question (i.e., in resonance)

Damping is 2% of critical.

Peak alternating stresses will be within the endurance limit for high cycle fatigue (10,000 psi) under the assumptions outlined above.

The natural frequency of any part will be at least a factor of 2 greater than any first order vortex shedding frequency.

The above criteria will result in a very rugged design with negligible vibration. In essence, peak will be within the endurance limit even with a dynamic amplification factor of 25 applied to the maximum possible hydraulic loads. Natural frequencies will be high so that actual amplification factors will be quite low. Even if some vibrations were assumed to occur, with the above assumption of all worst case parameters and with the requirement that stresses still be within the endurance limit, there would be no failure due to vibration. Finally, as discussed in Section 8.3, tests will be performed to confirm the vibration adequacy of the design.

5.4 ANALYSES COMPLETED TO DATE

In the case of mechanical loads, the conservative characterization of flow induced vibration is the highest single load contribution to the loading combination identified in Section 5.1. It has been demonstrated that calculated peak alternating stresses satisfy the 10 ksi limit for the loads defined in Section 5.3.2 . Furthermore, ASME Code Section III, Subsection NG primary code stress limits are also satisfied for the loading combination identified in Section 5.

5.5 FUTURE ANALYSES

To avoid jumping of the vortex shedding frequency to the structural natural frequency it will be demonstrated, by mode frequency analysis, that sufficient separation exists between vertex shedding and the lowest structural natural frequency in order to avoid lock-in.

Thermal stress analysis will be performed for the transients identified in Section 5.2.3 for the purpose of evaluating fatigue usage as well as primary plus secondary stress intensity ranges.

Structural adequacy of interface components affected by installations of the new overhead sparger system will also be evaluated. These components include the shroud and shroud head bolts.

6. REACTOR PERFORMANCE ANALYSIS

This section describes the effect of the overhead grid core spray sparger on reactor performance during normal operation at rated conditions.

6.1 SEPARATOR/DRYER PERFORMANCE

The effect of the overhead grid core spray sparger on steam separator and dryer performance would be degraded due to reduced spacing between the separators and dryer and the obstruction of the peripheral separators by the sparger.

The sparger support ring when installed between the shroud and shroud head will cause a one and one-half inch reduction in the separator/dryer spacing. The normal Oyster Creek separator/dryer spacing is 27 inches, the same as the standard BWR/5. On the standard BWR/6 plants, the spacing is reduced by 12 inches, i.e. from 27 inches to 15 inches. Studies performed in support of this change have demonstrated that the dryer performance will be unaffected. Therefore, it is concluded that a one and one-half inch reduction in the separator/dryer spacing at Oyster Creek will not result in a degradation of dryer performance.

Because of the relative small clearance (6 inches to 12 inches) between the sparger header pipe and the shroud head, the flow to peripheral steam separators could be partially obstructed on 18 of the 151 separators. The performance of the steam separators was evaluated by assuming that the 18 separators were totally blocked, requiring the remaining separators to handle the total core flow. The evaluation showed that the flow per separator increases by 13.5%, resulting in a 1.7 psi higher pressure drop. However, both the carryunder and carryover remain within design limits. Thus the performance of the separators will be unchanged. The effect of the higher drop is discussed in Section 6.3

6.2 SHROUD LEAKAGE

The installation of the overhead grid sparger ring between the shroud and shroud head creates a new flow path whereby steam could leak into the downcomer annulus. In the present plant configuration a steam skirt exists on the shroud flange, creating a column of water over the shroud/shroud head joint preventing steam from reaching the joint. The sparger ring creates two joints, and the existing skirt is to be removed. There is no concern of steam leakage through the upper joint as the ring design will create the equivalent of a steam skirt. However, the lower joint is susceptible to steam leakage.

An evaluation was performed to evaluate the steam leakage between the sparger ring and shroud. It was assumed that a 0.015 inch gap existed between the ring and shroud flange around the entire periphery and that the pressure differential across the shroud is 10 psi. Both of these assumptions are conservative.

The single phase (liquid) flow through the gap with or without the steam skirt was determined to be 0.27 Mlb/hr (0.44% of total core flow). Because of higher hydraulic losses for two-phase flow, the leakage would be reduced to 0.15 Mlb/hr, of which 0.018 Mlb/hr would be steam. The steam carryunder fraction for this leakage path would be 0.03%.

The design basis total carryunder fraction is 0.25%, and hence the 0.03% additional carryunder would have little, if any impact on recirculation system performance. However, this additional carryunder would increase the core inlet enthalpy by less than 0.04 BTU/lb, slightly increasing fuel cycle costs. Further, the inlet enthalphy increase (0.04 BTU/lb) would have an inconsequential effect on the plant safety analysis and normal plant operation. If the carryunder fraction increases by 0.03% the plant would lose about one-half full day power in each reload cycle.

6.3 RECIRCULATION SYSTEM PERFORMANCE

The overhead core spray sparger grid will introduce an additional hydraulic loss in the recirculation system. This loss was conservatively evaluated using the following assumptions:

1) The projected flow blockage area of the sparger system is used to determine the hydraulic loss. In conjunction with this, the hydraulic loss is conservatively modeled as the loss across a square-edged orifice.

2) The upward fluid flow velocity is constant over the projected flow area and is conservatively taken to be that of the maximum average central bundle type.

3) The hydraulic loss of the sparger piping support is neglected except for that part of the loss due to the support skirt.

4) The friction loss is negligible.

5) The fluid is homogeneous.

The evaluation yielded a sparger pressure loss of 0.8 psi . Combining this loss with the potential increased separator loss of 1.7 psi produces a net increase of less than 2.5 psi on the recirculation system. This will not pose a problem for the recirculation pumps, as BWR/2 plants have substantial excess flow capability, and are able to reach rated core flow with one pump out of service.

6.4 REACTOR INTERNAL PRESSURE DIFFERENCES

Reactor internal pressure differences for the steam line break accident were evaluated to consider the effects of raising the shroud head, water inventory changes, and volume of the sparger. The results showed inconsequential changes to the loads on components of interest, such as the shroud support, core plate, and shroud head. Existing margins for design limits are sufficient to account for these changes as well as the conservatively estimated 1.7 psi increase on the shroud head (Section 6.1) during normal operation.

7. CORE SPRAY SYSTEM PERFORMANCE

This section presents the design criteria and design objectives for the core spray distribution, the core spray nozzles, and the flow distribution in the sparger. The results of analyses completed to date, and a description of planned future analyses work, is also presented.

7.1 CORE SPRAY DISTRIBUTION

The design criterion for the spray distribution is that each fuel bundle in the core will receive a minimum flow of 2.45 gpm/bundle. This is the original core spray bundle flow design criterion, which is conservative. The spray distribution will be tested under the following environmental conditions: 15 psia air; and 15 psia steam to 125 psia steam. Spray distribution testing is described in Section 8.2.

The current design objectives for the spray distribution are as follows:

1. A uniform flow per bundle across the core.

2. The one inch pipe between the cruciform and the nozzles and/or the 3 1/2 inch sparger arms will be orificed as necessary to approach the design objective of a uniform flow distribution to each spray nozzle.

3. The design should minimize the sensitivity to physical location of the nozzles with respect to the core.

4. The design will be modular to facilitate design and testing.

7.2 CORE SPRAY NOZZLES

Two types of spray nozzles will be used:

1. One nozzle per four bundles with approximately 24 gpm rated flow.

2. One nozzle per peripheral corner bundle with approximately 6 gpm rated flow.

Several candidate nozzles will be developed for both of the above nozzle types. Nozzle selection will be made from testing conducted on the candidate nozzles in steam and air environments. The nozzles will be developed in accordance with the following objectives:

1. A maximum nozzle pressure drop of 15 psi at rated flow (to be compatible with the existing core spray system).

2. The minimum hole size in the nozzles will be determined based on the existing core spray system design criteria.

3. The nozzles will fit within a cylindrical envelope 2 inches in diameter and 3.5 inches long.

4. Large water droplet size.

5. The spray distribution in an air environment will be symmetrical about the nozzle vertical centerline, with a design objective of a uniform spray density (±10%) within the conical spray envelope of any

one nozzle.

7.2.1 Analyses Completed to Date

A study was performed on the desired nozzle spray pattern and on the expected behavior of spray nozzles over the above environmental range. The results are summarized below:

1. The nozzle spray cone in a steam environment is expected to be lower than in an air environment.

2. A narrow spray cone angle results in a higher sensitivity to fabrication tolerances and sparger misalignment.

3. A wide spray cone angle is expected to decouple the spray distribution from specific fabrication tolerances or sparger misalignment. This design is progressing on this basis.

The program for core spray nozzle testing is described in Section 8.2

7.3 SPARGER FLOW DISTRIBUTION

The flow distribution in the sparger should allow a minimum flow of 2.45 gpm/bundle at the system rated flow of 3400 gpm. The design maximum sparger pressure drop (ΔP) is 40 psi at rated flow.

7.3.1 Analyses Completed to Date

Sparger flow distribution analyses were performed to determine the orificing required, using classical hydraulic design methods. The results are summarized below:

1. Orifices are required in order to balance the flow to the seven arms (see Figure 7.3.1-1).

2. Within each arm the flow through the nozzles along the arm is essentially uniform, and therefore different orifices along the arm are not required. (see Figure 7.3.1-2).

3. An increase of the sparger pressure drop is expected for the new overhead sparger system compared to the existing system. However, it will be within the existing core spray system capacity.

7.3.2 Future Analyses

Further flow distribution analyses will be performed in order to specify hydraulic characteristics for flow distribution tests. These tests, described in Section 8.1, will be performed to confirm that design criteria and other objectives are achieved with ample margin to preclude the necessity of full scale flow and/or distribution tests with the actual reactor hardware.

POOR ORIGINAL

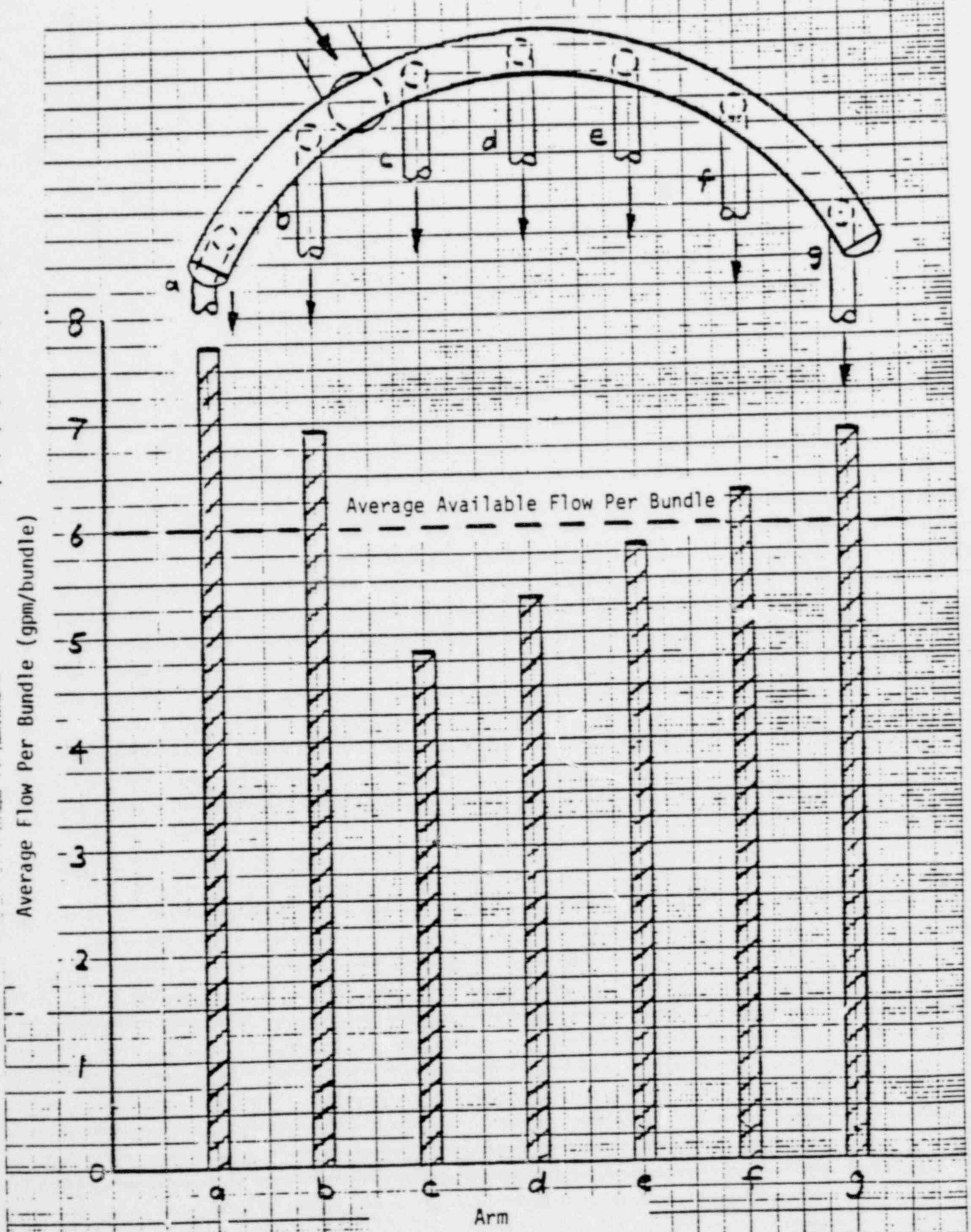

Figure 7.3.1-1 Predicted Arm Flow Distribution Without Orificies

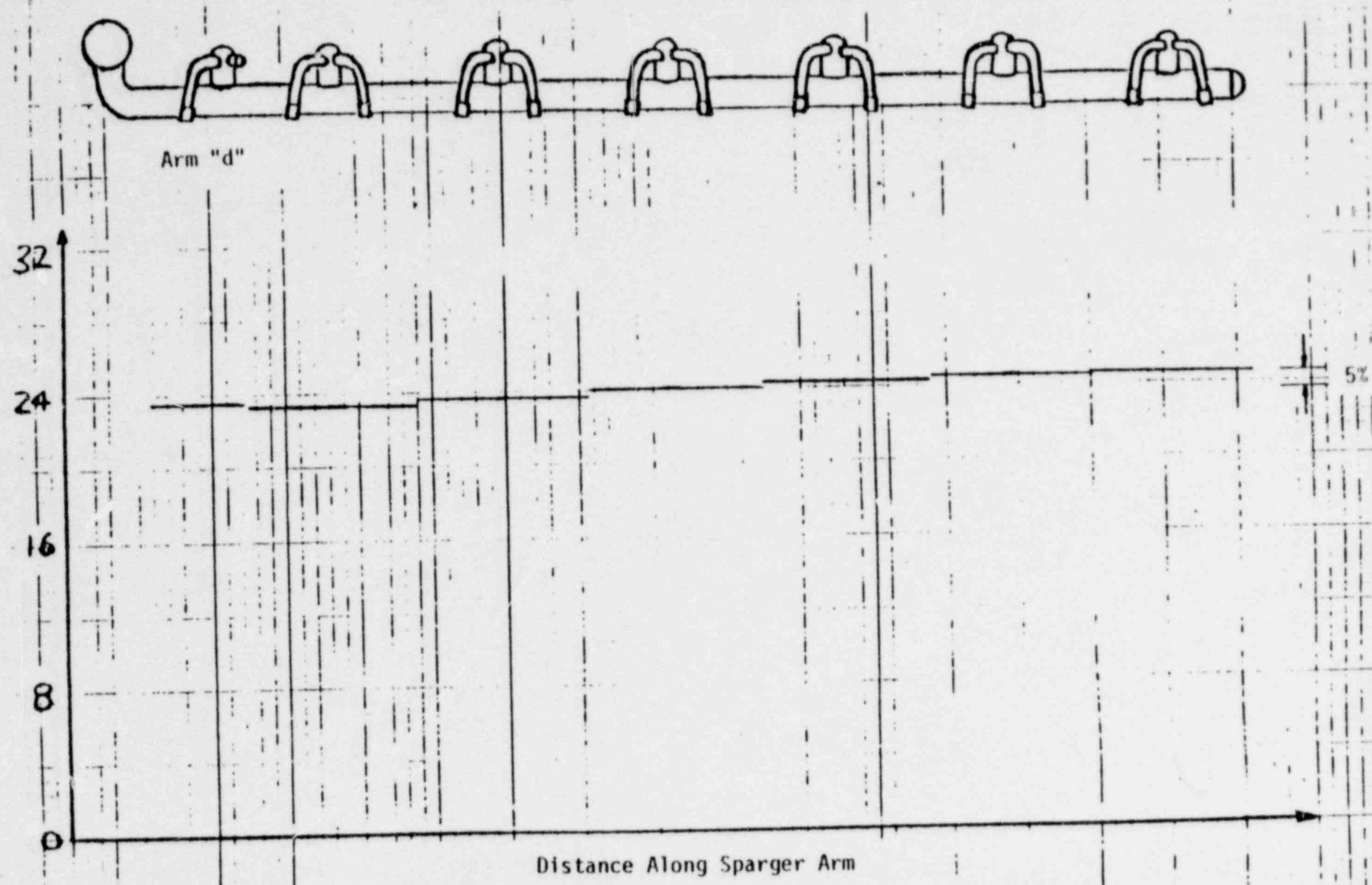

Figure 7.3.1-2 Predicted Nozzle Flow

8. QUALIFICATION TESTING

This section describes the qualification testing to be performed to support the overhead grid core spray sparger performance and structural integrity. The results of the qualification testing will be provided in a final report.

8.1 SPARGER FLOW TESTS

This program is expected to consist of a series of tests, changing the initial orifice sizes by experimentation, until acceptable flow distribution is obtained without exceeding the maximum allowable sparger pressure drop.

The tests will be conducted on a full-scale sparger mock up with replaceable orifices. The flow will be measured through all the nozzles. As a minimum, the orifices size, the sparger ΔP, and the flow through the nozzles will be recorded for verification of the design analyses. Additional information is presented in Section 7.3.

The primary objectives of the test are to demonstrate the sparger is correctly orificed in order to balance the flow to the arms and to the nozzles, and to measure the actual sparger ΔP.

8.2 SPRAY DISTRIBUTION TESTS

The purpose of this program is to design adequate core spray distribution (2.45 gpm/bundle minimum) throughout the performance range, and to establish allowable tolerances, or judge lesser deviations acceptable for the sparger fabrication and installation. The test program consists of three major parts:

> Part 1 - Single nozzle tests will be conducted in the GE Horizontal Spray Facility (HSF) with several candidate nozzles (see Section 7.2). Nozzle selection will be based on performance over the environmental range (15 psia air; and 15 psia steam to 125 psia steam) and on tolerance sensitivity tests.
>
> Part 2 - Modular multiple spary interaction effect tests will be conducted in the HSF as follows:
>
> a. Double nozzle interaction effect tests with the double sparger geometry, in steam and air environment, to confirm adequate spray distribution for both systems operating simultaneously.
>
> b. Spray interaction effect tests, in steam and air environment, for nozzles from the same system, testing 4 nozzles over 16 bundles.
>
> Part 3 - Full scale core spray distribution tests will be conducted in the Vallecitos Spray Facility, in an air environment, primarily to determine the sparger flow distribution. Air spray distribution tests will be performed, if necessary.

8.3 DYNAMIC TESTING

The structural integrity of the overhead grid sparger system will be qualified by combined test and analysis for all dynamic loads specified in Section 5.3.

The detailed method of dynamic analysis is described in Section 5. The dynamic testing will include the determination of the dynamic characteristic of the structure. Specifically, the measurement of natural frequencies and mode shapes of the overhead grid sparger will be made prior to installation of the sparger in the reactor. Low impedance excitation tests will be performed by using portable exciters attached at points on the structure which will best excite the various modes of vibration of the sparger structural system.

The data obtained from vibration sensors placed on the overhead grid sparger will be used to analyze the sparger dynamic performance. This test will provide a greater degree of certainty in the analysis since the analytical model can be confirmed or adjusted to reflect the measured natural frequencies.

9. SAFETY ANALYSIS

This section presents the results of evaluations of core hydraulic stability, anticipated operational transients, and loss-of-coolant accidents with the overhead grid core spray system. A safety evaluation of the overhead grid core spray system, as described in this report, will also be presented. It will be shown in the final report that plant operation with the overhead grid core spray system will not result in the reduction of safety margins, and will not result in an unreviewed safety question as defined in 10CFR50.59.

9.1 CORE HYDRAULIC STABILITY

An evaluation was performed to determine the effect of the overhead core spray sparger design on core hydraulic stability. This evaluation was performed by conservatively modeling the sparger hydraulic loss as an additional upper tie plate loss for all fuel assemblies. The results showed that the core stability decay ratio increased by about seven percent (7%). Since the Oyster Creek core stability decay ratio is significantly below the ultimate core decay ratio performance limit of 1.0, the overhead sparger design will not adversely affect core hydraulic stability.

9.2 ANTICIPATED OPERATIONAL TRANSIENTS

Selected anticipated operational transients were evaluated to consider the effect of raising the shroud head, water inventory changes, and volume of the sparger. The results of the evaluations show virtually no changes in peak vessel pressure ($\sim$1 psi) or peak heat flux ($<$1%). Therefore, it is concluded that anticipated operational transients are unaffected by the presence of the overhead grid core spray sparger in the reactor vessel.

9.3 LOSS OF COOLANT ACCIDENTS

The overhead grid sparger is being designed to assure minimum required core spray flow per bundle, and a total system flow to meet or exceed the original system criteria. Hence there will be no effect of the overhead grid core spray system on the current LOCA analyses or MAPLGHR limits.

Since the overhead grid core spray design requires removal of the sparger during refueling, emergency core cooling capability relies on makeup flow from the core spray system during this period. Considering the reduced risk of pipe rupture with the vessel totally depressurized, and the relatively small percentage of time the sparger is removed, it is concluded that adequate core cooling capability exists during this period.

9.4 SAFETY EVALUATION

A safety evaluation is required by the regulations of 10CFR50.59 whenever charges are made in a licensed facility as described in the Safety Analysis Report (SAR).

In the final report this section will present a safety evaluation to support operation of the plant with the overhead grid core spray system described in this report. The safety evaluation will address the requirements of 10CFR50.59 and will show that plant operation with the overhead core spray system will not result in the reduction of safety margins, and will not result in an unreviewed safety question as defined in 10CFR50.59.