NEDO-24228
Class I
December 1979

DRESDEN-1 CORE SPRAY

PROGRAM UPDATE

1742 010

General Electric Company

November 1979

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

(Please read carefully)

The only undertakings of the General Electric Company respecting information in this document are contained in the contract between Commonwealth Edison Company and General Electric Company (CECO P.O. 804351) and nothing contained in this document shall be construed as changing said contract. The use of this information except as defined by said contract, or for any purpose other than that for which it is intended, is not authorized; and with respect to any such unauthorized use, neither General Electric Company nor any of the contributors to this document makes any representation or warranty (express or implied) as to the completeness, accuracy or usefulness of the information contained in this document or that such use of such information may not infringe privately owned rights; nor do they assume any responsibility for liability or damage of any kind which may result from such use of such information.

1742 011

TABLE OF CONTENTS

1742 012

I. INTRODUCTION

Over the past two years, extensive work has been done to evaluate the Dresden-1 core spray distribution. The results of the evaluation of the installed core spray sparger are contained in General Electric Report NEDO-24164,[1] which was presented to the NRC in December, 1978. As a result of this work and the NRC review, two major problem areas were identified. Namely, the effect of a high pressure (155 psia) environment on the spray distribution prediction and the pattern of the distribution during operation of the Post Incident system. As a result of the effort to resolve these concerns, a core spray grid concept was developed to provide better distribution of the core spray flow. The purpose of this report is to present the core spray grid concept in response to the outstanding NRC questions[2] relative to the present core spray sparger. This report does not address the outstanding questions specifically, since the grid concept and the proposed testing program effectively render them not applicable. This program update is being submitted to the NRC to permit early review of proposed safety system design changes and prompt feedback to Commonwealth Edison.

II. DESCRIPTION

The core spray grid design is uniquely suited for installation in the Dresden-1 reactor due to the removable turning vane which provides support and the existing core spray sparger slip joint which provides connection for water supply.

The grid concept core spray distribution system is a modification of the core spray sparger and turning vane system presently installed in the Dresden-1 pressure vessel. Figure 1 shows the existing assembly and Figure 2 shows the assembly in the pressure vessel. The existing assembly, as shown in Figure 1, consists of a funnel shaped turning vane which directs and turns the coolant flow from the core to the 12 exit nozzles. From the turning vane, a structural grid is supported by 10 posts just above the core top guide. This structural grid provides rigidity for the turning vane assembly and supports and locates 16 instrument guide tubes which match but do not connect to instrument guide tubes in the fuel assemblies. Above the turning vane is a pipe structure used for lifting the assembly which includes the continuation of the instrument guide tubes and the core spray piping up to the slip joint with the supply line.

The present core spray system consists of 60 spray nozzles on a 6-inch circular ring header supported in 6 places from the turning vane. Two pipes feed the circular header from a single pipe at the top center of the assembly. The single pipe in turn extends up through the turning vane assembly to a slip joint with the supply pipe coming through a penetration in the reactor vessel head.

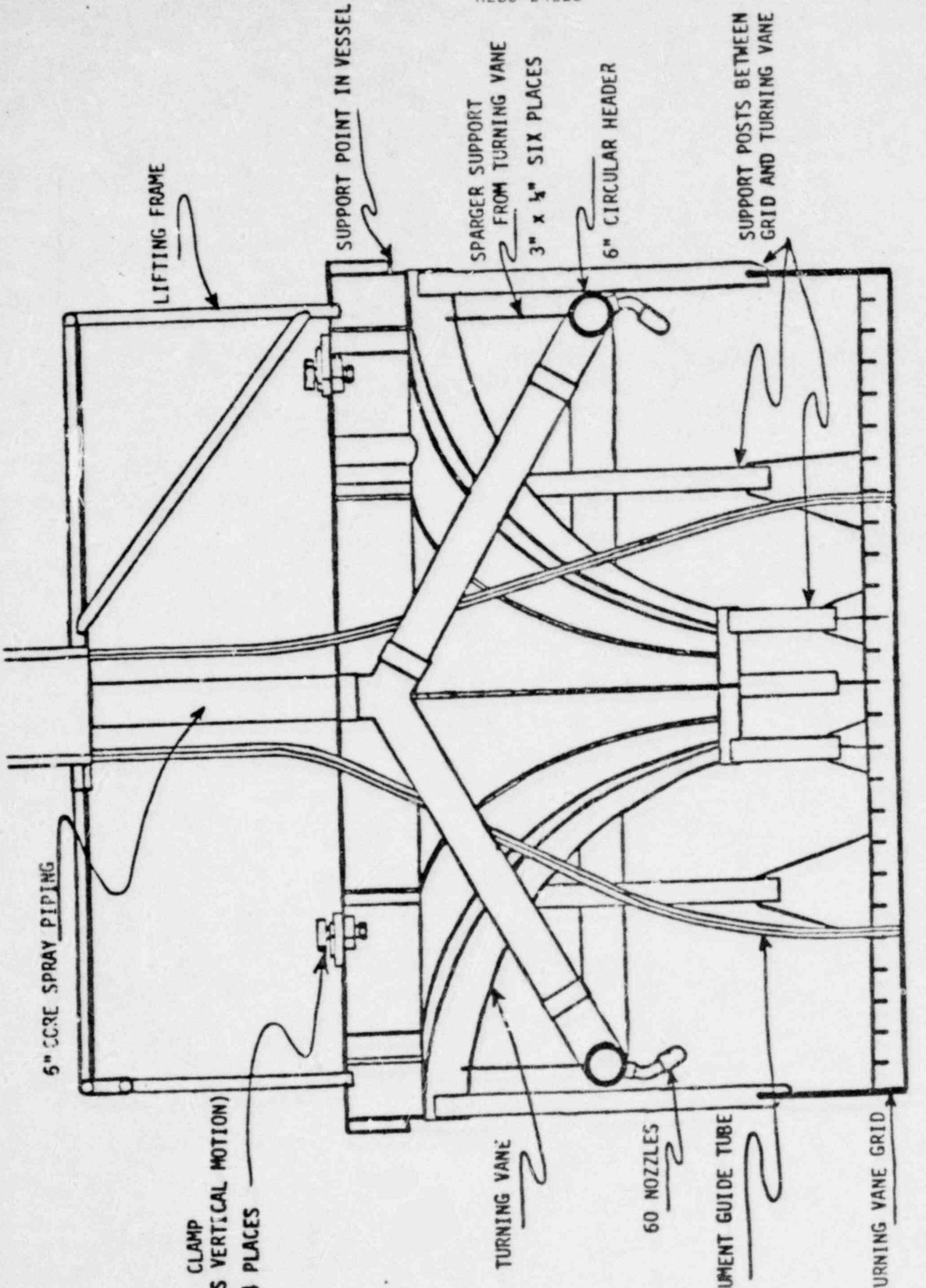

FIGURE 1 EXISTING DESIGN TURNING VANE ASSEMBLY

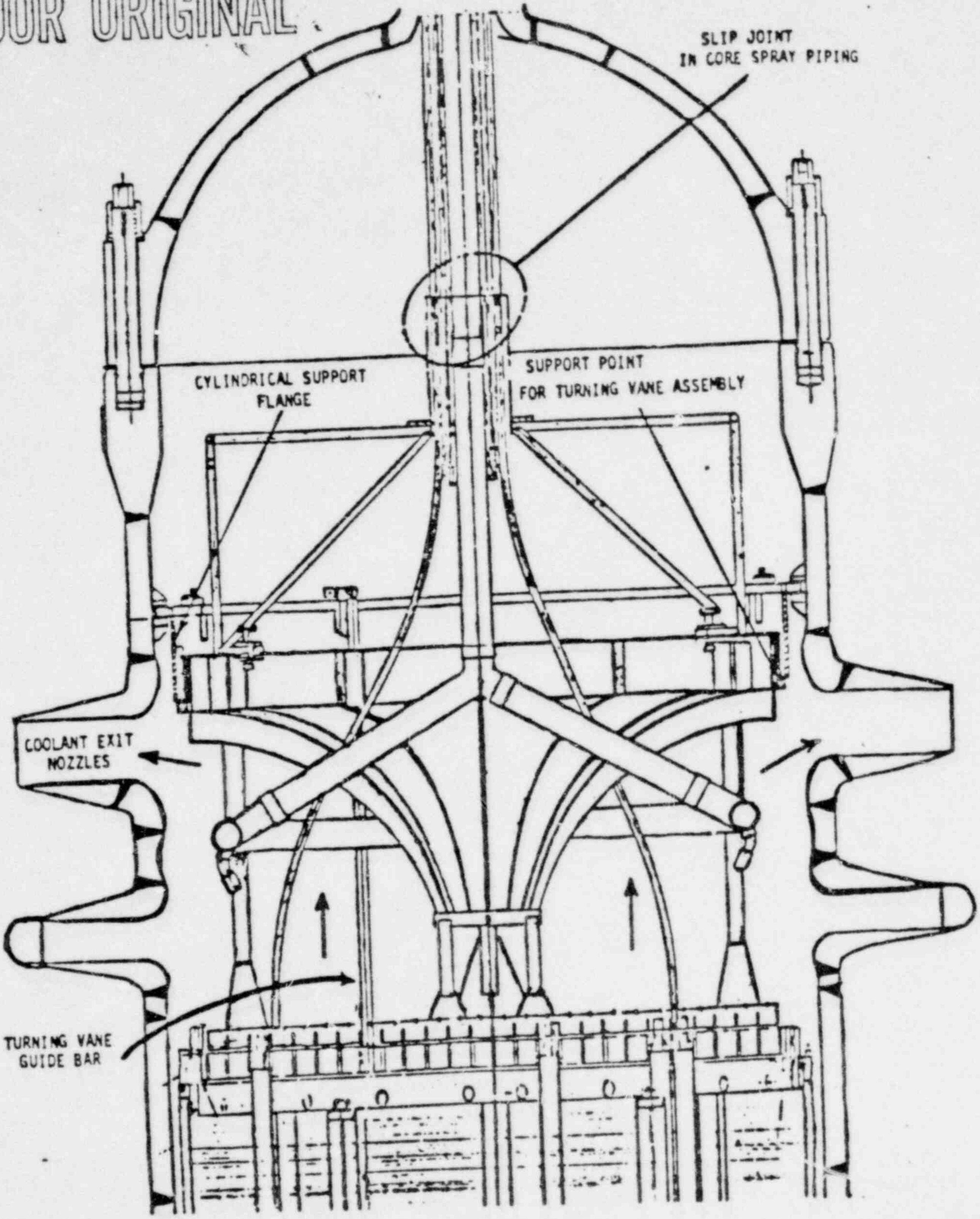

FIGURE 2 TURNING VANE ASSEMBLY INSTALLED IN THE PRESSURE VESSEL.

During refueling, the turning vane/co[illegible] system as shown in Figure 1 is removed from the pressure vessel as a complete assembly. A discontinuity in the instrument guide [illegible]s and a slip joint in the core spray piping allow a parting [illegible]e interface to the pressure vessel head. The turning vane assembly is supported in the pressure vessel (see Figure 2) on a cylindrical flange which is supported from lugs on the vessel wall [illegible] is not removed during refueling. Four clamps on the turning vane are engaged into slots on the cylindrical support to preclude vertical motion. During removal and replacement, guide bars between the vessel and top fuel guide provide positioning.

The modification to the present system design consists of the removal of the 60 nozzles from the 6-inch circular header and the addition of twenty-two 2-inch pipes which run down from the circular header to the structural grid, at the base of the turning vane, and horizontally across it. This modification can be seen by comparing Figure 1 and Figure 3.

Figure 4 shows a plan view of the distribution pipes including their supports from the turning vane grid and location of the instrument guide tubes. The distribution pipes run between every other row of fuel channels and each pipe delivers water to two rows of fuel channels. Except for two pipes at the edge of the core, the distribution pipes terminate and are capped at the center of the core. The longest run across the core is approximately 60 inches. At the capped end of the distribution pipe, the pipe is welded to a support which is welded to the turning vane grid. The outer support on each pipe is not welded to the pipe and is open on the upper side to allow for thermal contraction during operation. Figure 5 shows a typical outer support and is Section K-K taken from Figure 4.

Figures 6 and 7 give section views taken from Figure 4 and show the typical horizontal and vertical runs of the distribution piping and their support from the turning vane assembly.

Figure 8 shows an enlargement of a portion of the section shown in Figure 6 and depicts the distribution pipe relative to the turning vane grid, top fuel guide, and top of the fuel channel. This figure also shows the 3-inch long nipples which direct the water flow to each channel. These nipples are welded to the 2-inch distribution pipe and have a nominal 5/16-inch inside diameter. There is one nipple for each fuel bundle.

1742 016

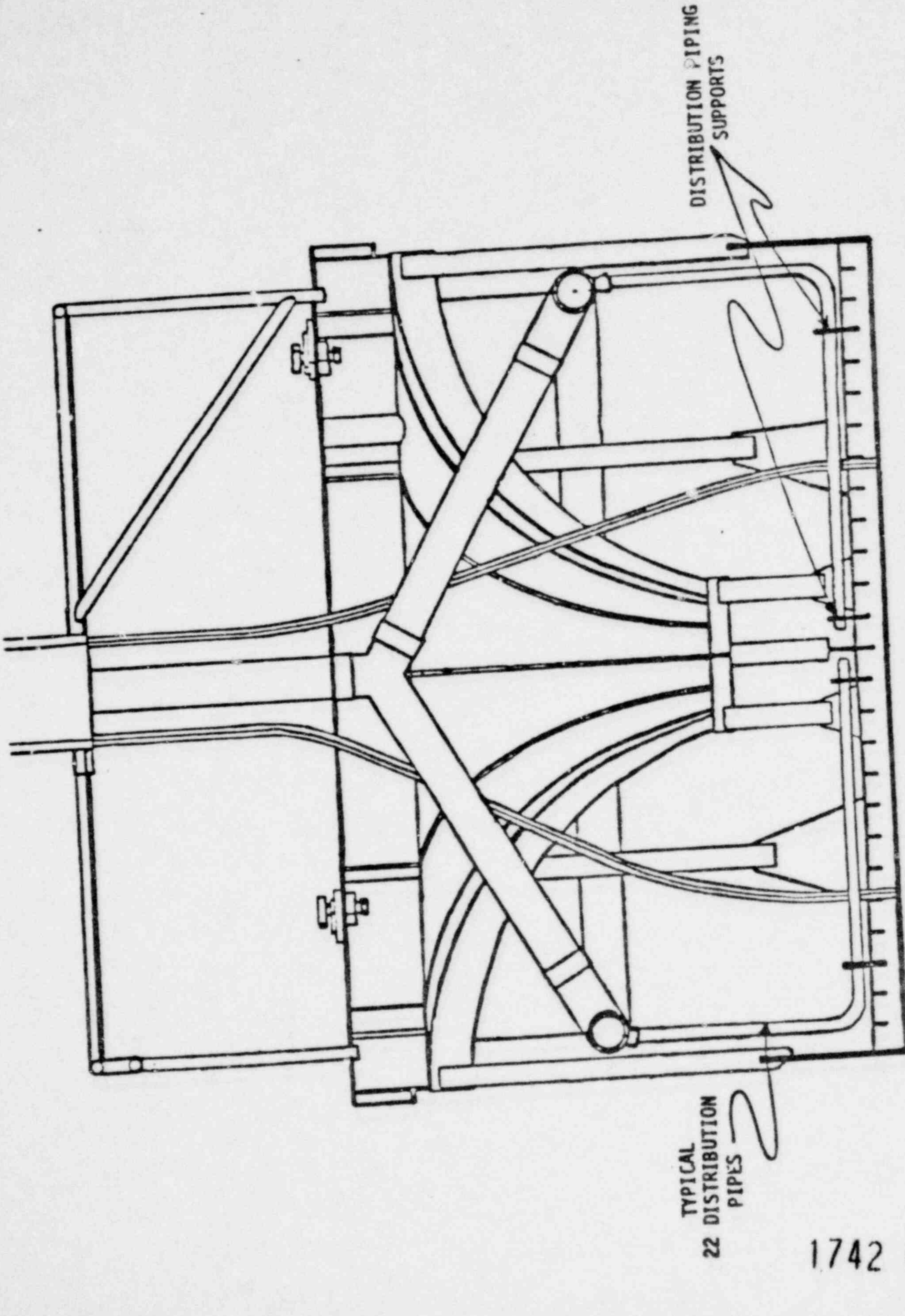

FIGURE 3 GRID CONCEPT TURNING VANE ASSEMBLY

POOR ORIGINAL

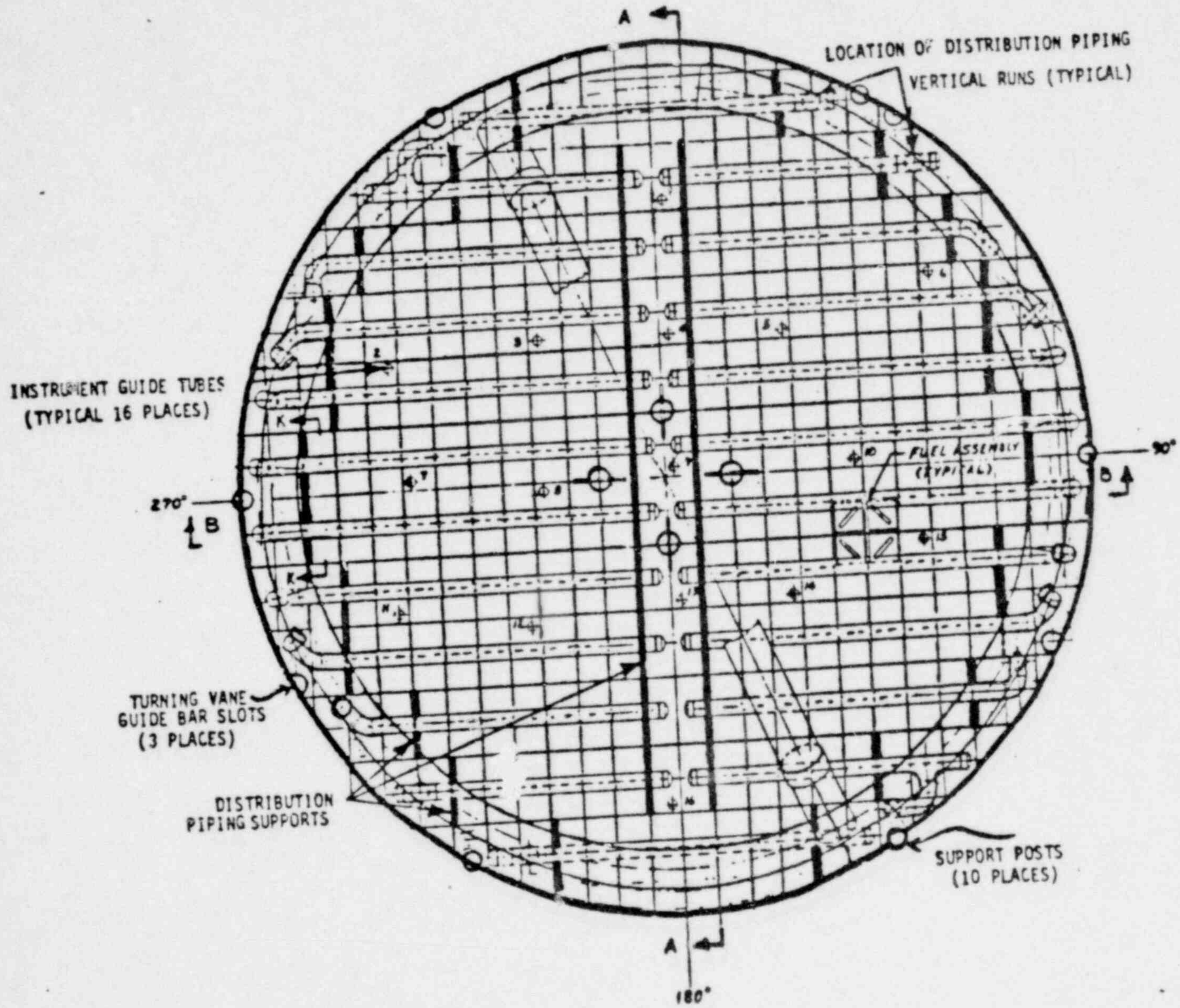

FIGURE 4 PLAN VIEW OF THE DISTRIBUTION PIPES RELATIVE TO THE TURNING VANE GRID.

1742 018

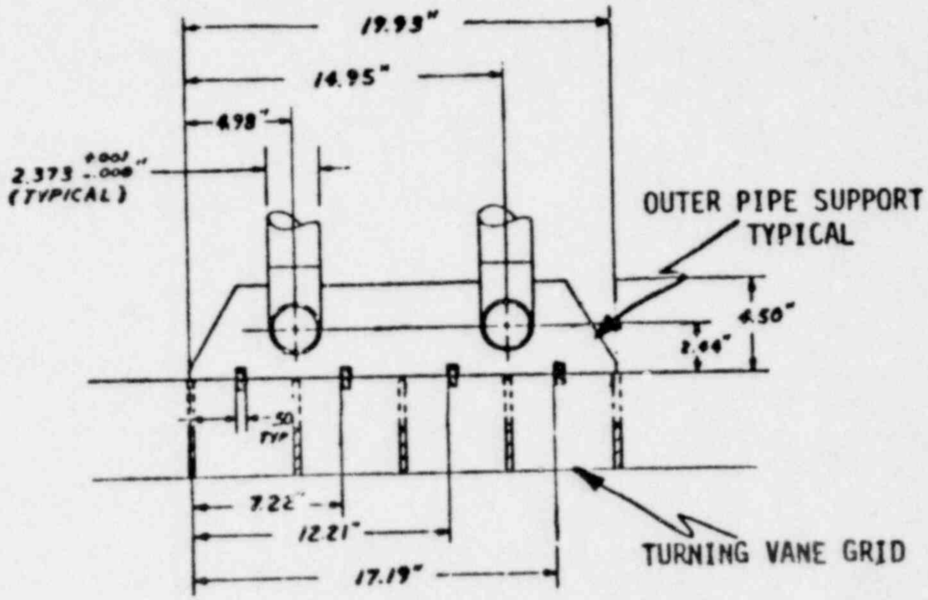

FIGURE 5 TYPICAL PERIPHERAL SUPPORT FOR GRID HEADER PIPE.

(SECTION K-K OF FIGURE 4)

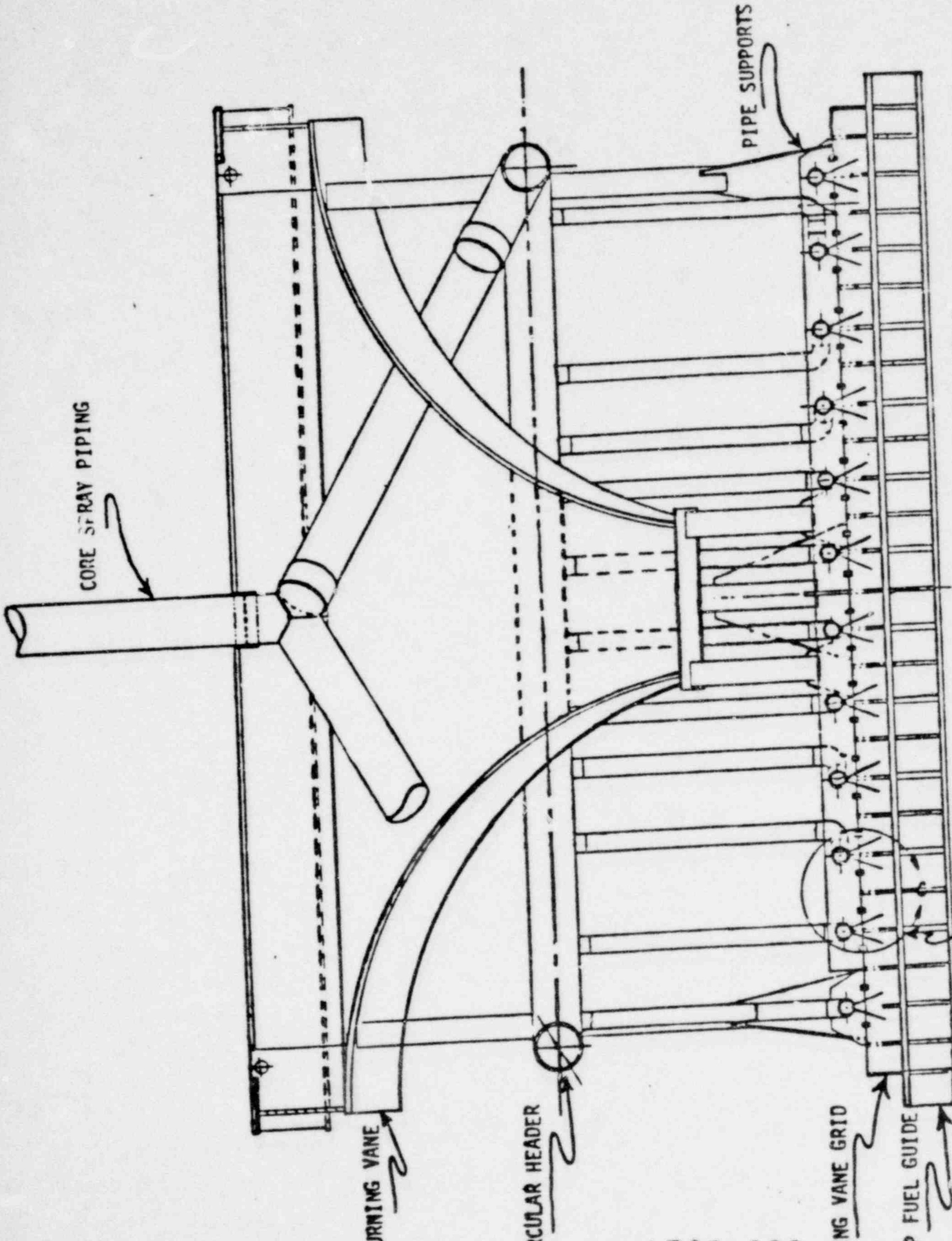

FIGURE 6 SECTION VIEW OF TURNING VANE ASSEMBLY SHOWING VERTICAL RUNS OF DISTRIBUTION PIPING

(SECTION A-A OF FIGURE 4)

1742 020

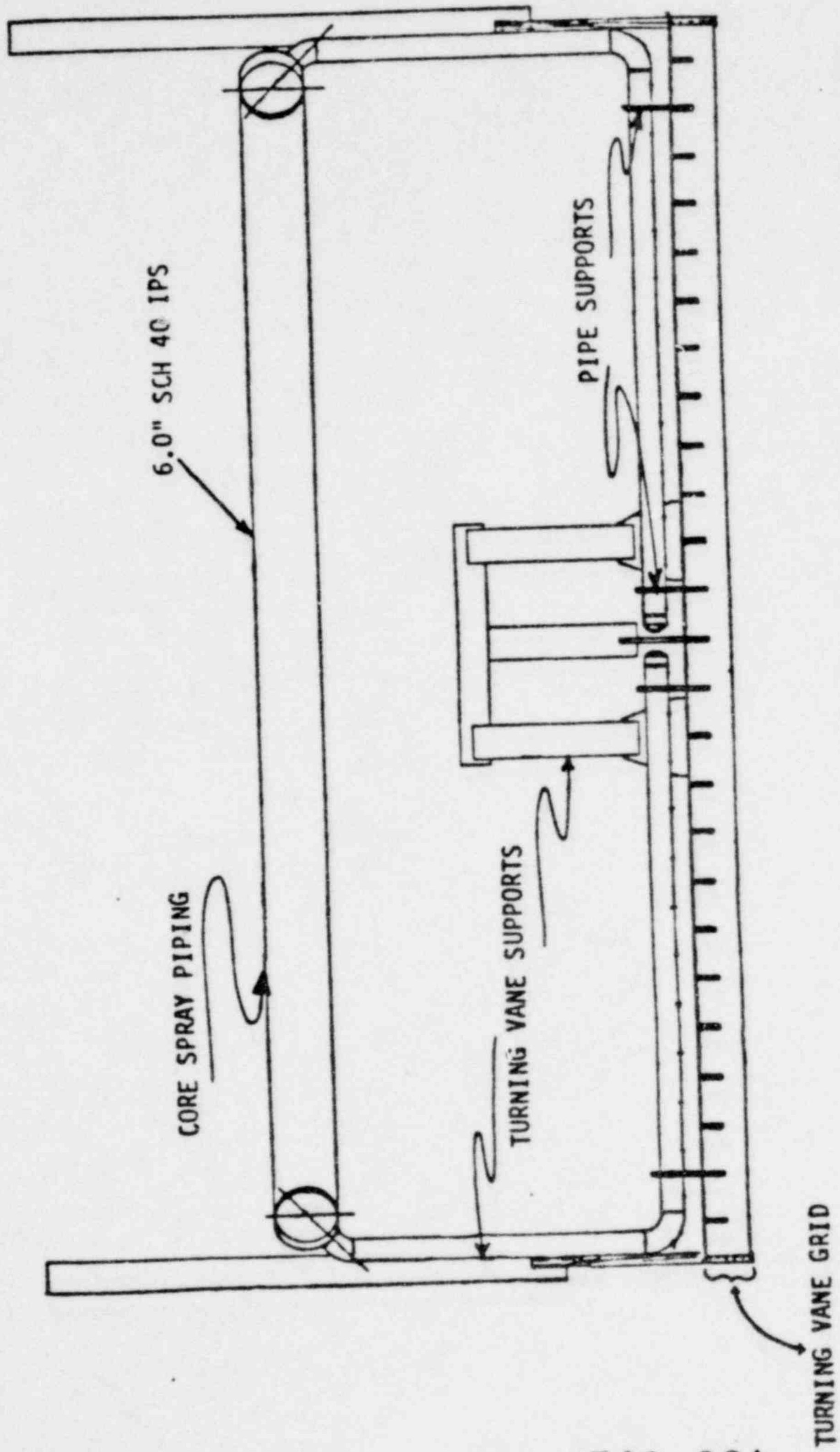

FIGURE 7 TYPICAL RUN OF DISTRIBUTION PIPING SHOWING SUPPORTS FROM THE TURNING VANE GRID.

(SECTION B-B OF FIGURE 4)

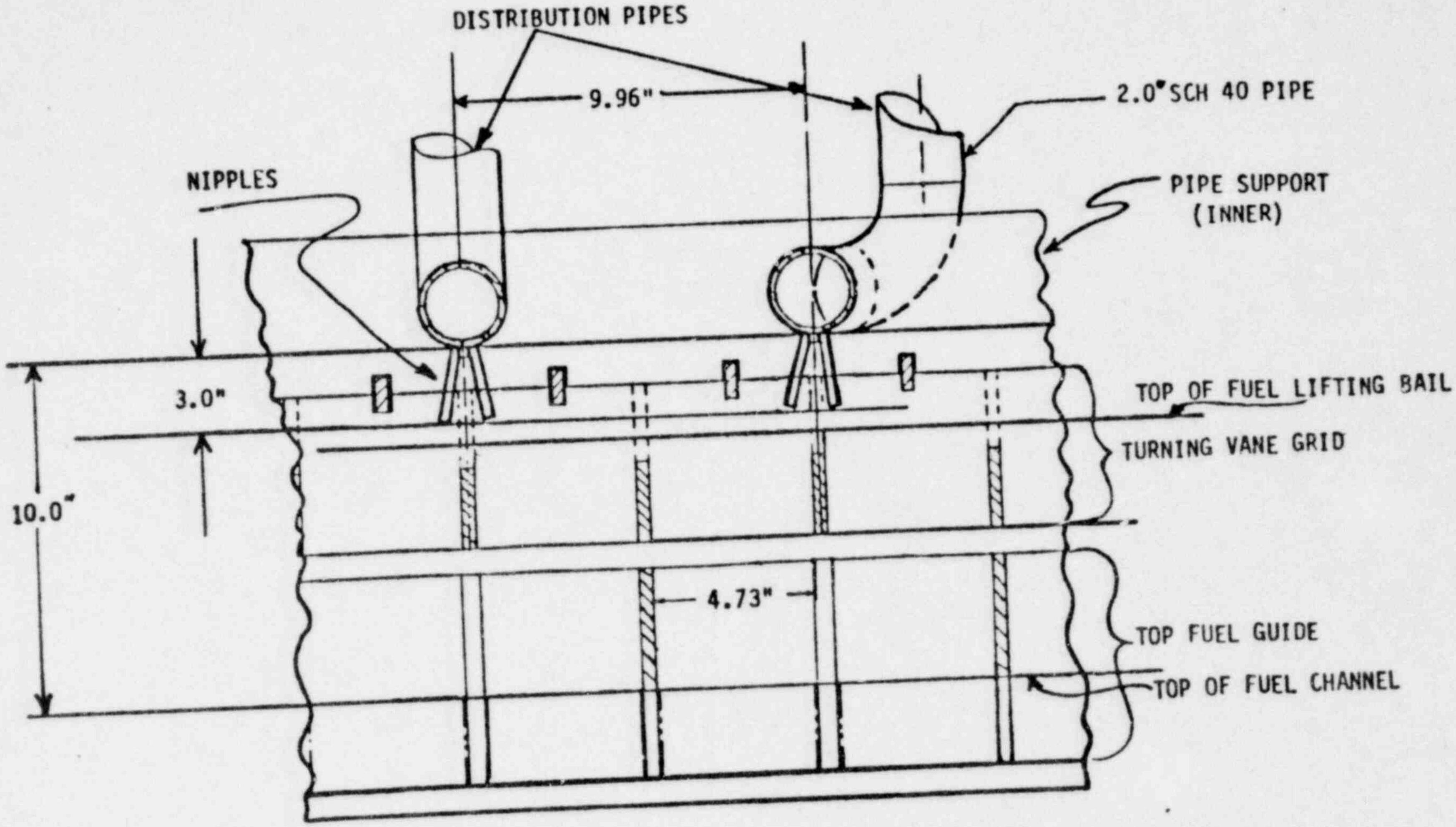

FIGURE 8 DETAIL SHOWING RELATIONSHIP OF HEADER PIPES AND NIPPLES TO THE TURNING VANE GRID, TOP FUEL GUIDE AND THE TOP OF THE FUEL CHANNELS.

(VIEW C OF FIGURE 6)

1742 022

III. SYSTEM CONSIDERATIONS

The core spray grid modifies only the existing core spray sparger. The existing core spray pumps, piping and system characteristics remain unchanged. The core spray grid is being developed because the coolant distribution can be well controlled and readily analyzed using classical hydraulic network methods. This control over the distribution makes a very uniform core spray distribution possible. The ratio of the average channel flow to the minimum flow received by a channel for a nozzle generated spray distribution is on order of 2.5; for the grid distribution a value close to 1.0 is expected. The grid system makes more efficient use of the available core spray flow.

The existing Post Incident system consists of two pumps which draw suction from the bottom of the containment sphere and discharge through heat exchangers into the core spray sparger. The capacity is 800 gpm per pump when the reactor and containment pressures are equal. With the control over the distribution provided by the grid, the minimum flow per channel is expected to be greater than the design flow of 1.8 gpm per channel when both pumps are operating (i.e. 1600 gpm). When only one pump is operating the distribution is still expected to be very uniform, with flow provided to all channels. However, even with a perfect distribution it is not possible for 800 gpm to provide 1.8 gpm to 484 channels. While the actual flow will be less than the design value of 1.8 gpm per channel for one pump operation, the Post Incident system is designed to begin operation approximately one hour after a scram, by which time the Post Incident system one pump flow rate will be sufficient to provide adequate core cooling.

It is apparent from a consideration of the core spray system flow path that if foreign material could get into the grid system, the location where the flow would most likely be obstructed would be at the entrance to the 5/16-inch nipples. Several steps will be taken to preclude flow obstructions in the grid system. After fabrication, the grid will be inspected and then the entire grid assembly will be flow tested. The flow from each nozzle will be measured to verify that there is unobstructed flow from each nozzle. After installation of the grid system into the reactor, the only source of water is through the core spray piping which has a 100% flow strainer downstream from the pumps. This strainer effectively precludes any possibility of plugging the 5/16-inch nipples. The strainer has horizontal radially positioned cylindrical straining elements mounted in a vertical drum. The flow of water is into the interior of the drum and radially outward through the straining elements, into an outer chamber and then exits through the outlet nozzle. The straining elements are constructed of stainless steel sheet perforated with 3/16-inch diameter holes, which are smaller than the 5/16-inch nipples. The strainer also has an automatic backwash system which maintains the performance of the strainer and purges any debris out of the core spray system.

IV. HYDRAULIC DESIGN CONSIDERATIONS

The core spray grid has a network of 2-inch schedule 40 header pipes traversing the core which are mounted to the turning vane grid. The headers are mounted above and between rows of fuel bundles. A short (approximately 3-inch long) nipple is located on the header at each fuel bundle location to direct a jet of water into the bundle. A nipple was selected for several reasons. It straightens the flow which exits the header pipe at 90° from the pipe axis and aims the flow directly into the fuel bundle upper tie plate. The nipple has sufficient length (8 to 10 pipe diameters) such that a uniform steady jet is established.

It has been recognized for a number of years that a steam environment can effect the performance of spray nozzles. The nipple/jet configuration was designed and selected for the core spray grid system to avoid adverse effects due to the steam environment. The exit surface of the nipple is perpendicular to the injected flow such that pressure forces cannot be generated at the exit which might deflect the jet.

The core spray grid is being designed to operate over the reactor pressure range from 0 to 140 psig. The jet itself is unaffected by the environmental pressure. The only effect of environmental pressure on the core spray system is to increase the back pressure on the pumps. The grid system is intended to operate with a differential pressure equal to or less than the core spray nozzle system that it replaces. Therefore, system flow performance will not be adversely affected. The system flow rate ranges from about 800 gpm (one Post Incident pump) to approximately 2700 gpm (run-out condition for two core spray pumps). The core spray grid is being designed to operate and will be tested over this flow range to verify the flow received by each fuel assembly.

The effect of steam drafts on the performance of the grid spray jets has been considered. Because the jet is aimed downward approximately 8° from the vertical, it presents a very low profile for the vertical steam flows. A comparison of the momentum of the water jet with the momentum of the steam which could impact the cross-section area of the jet shows the jet to have 100 - 300 times greater momentum. Therefore, steam updrafts are not expected to deflect the jet.

The core spray grid distribution differs from other General Electric BWR core spray systems in that the coolant is directed to each fuel bundle as a jet of water rather than as spray coverage of the entire core. However, jet impact on the upper tie plate will scatter the water across and through the tie plate.

Based on a review of the General Electric core spray heat transfer tests, it has been concluded that changing the distribution of the coolant to the fuel bundle from a spray to a stream is not expected to effect the maximum bundle temperature.

V. MECHANICAL DESIGN CONSIDERATIONS

The grid concept core spray distribution system is a modification to an existing design and evaluation of that existing design is not necessary. However, all changes to the existing design will be evaluated in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB 1974 edition with addenda to Summer 1976. As described earlier, this is a modification to the existing design which adds 22 distribution pipes in place of 60 spray nozzles. As no mechanical problems exist with the present core spray piping and turning vane hardware, as demonstrated by seven years of reactor service, this modification could be made to the existing hardware, but would result in potentially high radiation exposure to maintenance personnel during the modification. To preclude this radiation exposure, a new turning vane and core spray distribution system will be built paralleling the existing design and modified as described. Materials and processes used will be updated to the present technology. The material used for the turning vane will be Type 405 stainless steel as was used for the original design, as its thermal expansion characteristics are similar to that of the pressure vessel. Material used for the core spray piping will be changed from Type 304 stainless steel used in the present design to Type 316 stainless steel with low carbon content, because of its better resistance to stress corrosion.

Loadings to be considered shall include but are not limited to: 1) Flow induced vibration; 2) seismic loading; 3) water hammer potential when the system is initiated; 4) loadings due to differential thermal expansion; 5) fatigue due to system and reactor operational cycles; 6) loadings as a result of the high pressure coolant injection system also to be installed at this time; and 7) pressure and momentum forces due to operation of the system.

The horizontal runs of the distribution pipes will be welded to the supports at the capped ends to preclude deleterious flow induced vibrations and assure alignment of each nipple with each fuel bundle.

Flow induced vibration is not a major concern for the turning vane as most components of the replacement turning vane are identical with the existing turning vane which has operated successfully. The newly designed 2-inch distribution pipes and nipples will be designed to all have natural frequencies at least three times the vortex shedding frequency.

The replacement turning vane will be almost identical, from a seismic point of view, to the existing turning vane. The only difference is an increase in mass of approximately 5% due to the 2-inch distribution pipes. Thus the seismic response of the replacement turning vane will be essentially identical to that of the existing turning vane. Since there is no existing structural dynamic model of the Dresden-1 reactor pressure vessel (RPV) and internals, the following procedure will be used to demonstrate the seismic adequacy of the replacement turning vane.

The Dresden-1 and 2 reactors are at the same site. The Dresden-2 reactor was designed to a peak horizontal ground acceleration of 0.1 g for the design basis earthquake and 0.2 g for the maximum credible earthquake. The seismic analysis contained in the Dresden-2 FSAR contains a plot of the peak acceleration of the RPV and pedestal as a function of elevation. Thus, an amplification factor can be determined between any two elevations.

The Dresden-1 reactor was designed to significantly lower seismic criteria than Dresden-2. The Dresden-2 ground design response spectra has conservatively been used in the Dresden-1 HPCI design. Thus, it is reasonable and conservative to use the Dresden-2 ground spectra to estimate the Dresden-1 turning vane seismic loads.

Dresden-1 and 2 RPVs are similar structures. Thus an amplification factor between elevations from Dresden-2 can reasonably be used for Dresden-1. The amplification factor between elevations that correspond to the base of the Dresden-1 pedestal and the attachment point of the turning vane is 2.21.

Reference 3 gives the ground design response spectra for Dresden-2. Since the Dresden-1 reactor building base mat is assumed rigid, the same spectra can be applied at the base of the Dresden 1 pedestal. The peak acceleration for the design basis earthquake (2% dampling) is 0.42 g which applies for natural frequencies between 2.5 HZ to 4.0 HZ. The peak acceleration, when multiplied by the RPV amplification factor, yields a conservative peak acceleration of 0.93 g for the turning vane.

It should be noted that recent work has shown that the Dresden 2 ground spectra may be conservative, which would increase the magnitude of conservatism in the above procedure.

Stresses in the turning vane will be calculated assuming a statically applied load of 0.93 g. The calculated stresses will be compared to the allowable stresses of ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, for an upset condition.

The turning vane assembly is being designed to accommodate the effects of thermal expansion and contractions. The ring header will be attached to the turning vane such that thermally induced deflections can be tolerated without the development of large stresses. Similarly, the 2-inch distribution pipes will be attached to the turning vane and the grid in a manner that will permit thermal motion without inducing large stresses. The turning vane assembly will be designed for the following number of core spray cycles:

(1) Normal Plant Operation. Isothermal at 70°F to isothermal at 550°F and return to isothermal at 70°F. Maximum heatup and cooldown rate shall be 120°F/hour. The frequency shall be 10 cycles/year.

(2) Core Spray System Operation. A step change in water temperature inside the core spray distribution system occurs with the following cycles:

Initial Temperature (°F)	Final Temperature (°F)	Cycles/Design Life
550	35	1
350	35	10
100	35	50

The flow from the newly designed high pressure coolant injection system will impinge on parts of the turning vane assembly. The components of most concern in this regard are the in-core instrument guide tubes. The worst case impingement forces will induce stresses in the instrument guide tubes that are within allowable values.

The worst case alignment of the nipple on the distribution pipe relative to the fuel channel will be determined to confirm that maximum turning vane misalignment will not cause a loss of cooling water to any bundle. The maximum tolerance will be determined by considering the following parameters.

a. Nipple location on the horizontal distribution pipe.

b. Differential expansion of the distribution pipe relative to the turning vane support grid.

c. Misalignment of the turning vane relative to the top fuel guide.

d. Fuel bundle location within the top fuel guide.

VI. TEST PROGRAM

Testing of the core spray grid will be conducted in two parts; 1) developmental tests will be conducted early in the program to confirm the hydraulic design and 2) the reactor hardware will be flow tested prior to installation to verify the flow distribution.

The new core spray grid system will be tested prior to fabrication of the reactor hardware. A hydraulic duplicate of the grid system hardware will be built for distribution testing at General Electric's Vallecitos Core Spray Test Facility. This facility will be modified to accept new flow measuring channels, fabricated to the Dresden 1 fuel bundle dimensions especially for this test, and installed to duplicate the Dresden 1 core configuration. The hydraulic mockup of the grid will be mounted above the measurement channels in the same configuration as they would be installed in the reactor. The grid piping will then be connected to the facility pumping system and the instrumentation installed and calibrated. The channel flow data for the full core will be obtained by computer and printed out at the conclusion of each test run.

These development tests will confirm the hydraulic design of the grid distribution system. Testing will be performed to confirm the core spray flow rate to each fuel assembly for the core spray system flow range of 2100 to 2700 gpm and the post incident flow rates of 800 and 1600 gpm. Component tests will also be performed with a mockup of one fuel bundle upper tie plate and all attaching hardware, including incore instrumentation funnel, to determine jet/bundle interaction. These tests will determine the jet breakup as it impinges on the upper tie plate. It will also demonstrate that the jet does not impact the fuel bail cross member, the instrument funnel, or tie nuts prior to striking the upper tie plate. A test of a rotated bundle will be conducted to show that cooling flow will not be impeded for an improperly loaded fuel element. The result of the component tests will be directly applied to the full scale mockup test to confirm the validity of those tests.

Following fabrication of the reactor hardware, the relacement turning vane (with the new grid device installed) will be sent to Vallecitos for verification testing. The turning vane will be mounted on a special frame to correctly position the core spray grid relative to the core. Flow distribution testing over the flow range of 800 to 2700 gpm will again be performed to verify the cooling flow rate to each fuel bundle location.

VII. CONCLUSIONS

The new design core spray grid distribution system provides a high confidence solution to the Dresden-1 core spray distribution concerns. The grid design is uniquely suited to the Dresden-1 reactor because of the removable turning vane and existing core spray slip joint, both of which allow the core spray grid system to be removed for refueling. The design of the grid system allows the use of classical hydraulic network methods for calculation of the flow distribution, which will be demonstrated by actual test of the replacement hardware.

By achieving a more uniform distribution of the cooling flow, adequate core cooling will be achieved with the existing core spray and post incident pumping systems.

The cooling jet is unaffected by the steam atmosphere or the steam pressure within the reactor and therefore there is a direct correlation between atmospheric air tests and in-plant performance.

And finally, the new hardware can be added to the existing reactor hardware design with a minimum of modifications.

REFERENCES

1) Evaluation of the Dresden 1 Core Spray Sparger Performance in a Steam Environment; General Electric Company, NEDO-24164, December 1978.

2) NRC Request for Additional Information on Core Spray (D. L. Ziemann letter to C. Reed dated February 1, 1979) Docket No. 50-10.

3) Sargent & Lundy Engineers; SAD-261, Rev. 0; January 18, 1977.

1742 029