# Design and Analysis of Flow Diverters for Reactor Safety System

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Abstract

The design and analysis of a flow diverter for a nuclear power plant is presented. Such a device can divert the steam directly into the containment volume preventing high pressures from forming inside the sacrificial shield wall. The analysis of the flow diverter was performed by the use of a finite element program.

## 1. Introduction

The flow diverter is a device which, during reactor operation, is capable of diverting steam directly into the containment volume in the event of a LOCA resulting from a pipe break at the reactor nozzle. This reduces the amount of steam which can flow into the annulus between the reactor vessel and the concrete shield wall.

During the operation of the reactor, the flow diverter is in the closed position, i.e., the moveable guard pipe is 1"+3/32" clear of the reactor vessel. In the closed position, the flow diverter is subject to the specified seismic and LOCA loadings, during which it must maintain its function of diverting steam directly into the containment. During reactor shut-down, the flow diverter does not perform a nuclear safety function, but must be capable of being moved in order to accommodate weld inspection.

Under normal conditions, the flow diverter guard pipe is supported by guide bars which can slide in Lubrite bronze guide shoes which are connected to the fixed sleeve. The arrangements of guide bars and shoes limit vertical motion, rotation, and horizontal motion normal to the axis of the sleeve. In the closed position, horizontal motion parallel to the sleeve is limited by clamps which secure the moveable guard pipe to the fixed sleeve.

The flow diverter moveable guard pipe is designed to slide 30¼", axially, powered by a rotary air actuator. Positive stops are set to automatically control the positioning in the open and closed positions. The motor is operated from a remote control station.

2. Description

The moveable guard pipe has an inside diameter of 3' 6", a thickness of 1 1/8" and an overall length of 5'-6". The material used is ASME SA-516 GR 70. The moveable guard pipe has a cut-out in the lower part of the outside end in order to clear the coolant pipe when the flow diverter is in the open position. A 2 1/8 inch annulus is provided between the guard pipe and the fixed sleeve. Within the annulus there are two guard bar and shoe supports on each side of the moveable guard pipe. The guide shoes which consist of Lubrite bronze are attached to the fixed sleeve at each side at the horizontal axis. It is assumed that the installation will be made during a temperature condition of approximately 70° F. A gap of 1/32 inch is provided between the guide shoe and the guide rail. Due to the arrangements of the guide shoe and guide bar, rotation as well as transverse horizontal and vertical movement is limited.

Longitudinal horizontal movement parallel to the axis of the sleeve in the closed position is restrained by the four restraining clamps. Each clamp consists of 1½ inch diameter A307 bolt which is welded to the fixed sleeve. Inadvertent operation of the rotary air actuator when the flow diverter is in the closed position would result in either a failure in the adjustable link or stalling of the air motor. When the clamps are unlocked, no nuclear safety requirement exists; however, horizontal movement is restrained by the actuator. Tension in these bolts is caused by the longitudinal horizontal forces. Tangential and radial forces are transmitted from the moveable guard pipe to the fixed sleeve by means of restraint blocks. Redundant vertical restraints are also provided. These are provided because large unbalanced pressure forces result from the cut out in the moveable guard pipe.

The rotary air actuator has a rated torque of 9000 in. lb. at 90 psi which at mid-stroke can provide a linear horizontal force of about 554 lb. As the flow diverter sleeve approaches the fully opened or closed position, the linear horizontal force which can be provided by a torque of 9000 in. lb. is increased by a factor equal to the cotangent of one half the angle made between the adjustable link and the crank. However, the maximum horizontal thrust required is well under 554 lbs. The system of crank and linkage and limit stops has been designed so that the open and closed position can be very accurately set in the field by means of the adjustable link. After this initial adjustment, the positioning will automatically repeat. The rotary air actuator is supported by a structural framework welded to the shield wall.

3. Analysis

The ANSYS computer program was used to perform structural analysis for the following loading conditions: Dead load, seismic loading (frequency analysis), jet impingement and internal pressure. There are also loads caused by earthquake, safety relief valve blowdown and loss of coolant accident. These loads which cause vibrations around the flow diverter are defined by different acceleration response spectra. A frequency analysis as obtained from the ANSYS computer program showed that frequencies of the flow diverter were 89.6 cps and higher. Therefore, the effects of the dynamic loads are obtained by using constant accelerations as shown in the corresponding response spectra.

The pressure during emergency condition is represented by a static pressure of 811 psia. The pressure is applied normal to the inside surface of the moveable guard pipe. The inside temperature is 550° F during the emergency condition.

The finite element model developed for the analysis is shown in Figures 1 and 2. The element selected was STIF63, a quadrilateral shell element. Beam elements, STIF4, were used for the edge stiffener around the cutout. A total of 332 elements and 330 nodes were used. The boundary conditions established simulated the support conditions.

4. Conclusion

The results of the analysis were reviewed and compared to allowables established by ASME Boiler and Pressure Vessel Code 1974 including Winter addendum, Article NC-3650.

The only loading which results in significant stresses is the pressure loading. While the pressure loading causes significant hoop membrane stresses, the longitudinal membrane stresses are insignificant due to the fact that the moveable guard pipe is open at both ends. The maximum hoop membrane stresses compared to allowables are shown in Table I.

Table I. Maximum and Allowable Stresses

| Loading Condition | Maximum Stress (ksi) | Allowable Stress (ksi) |
|---|---|---|
| Normal | 0.044 | 17.5 |
| Upset | 0.115 | 21.0 |
| Emergency | 26.82 | 31.5 |

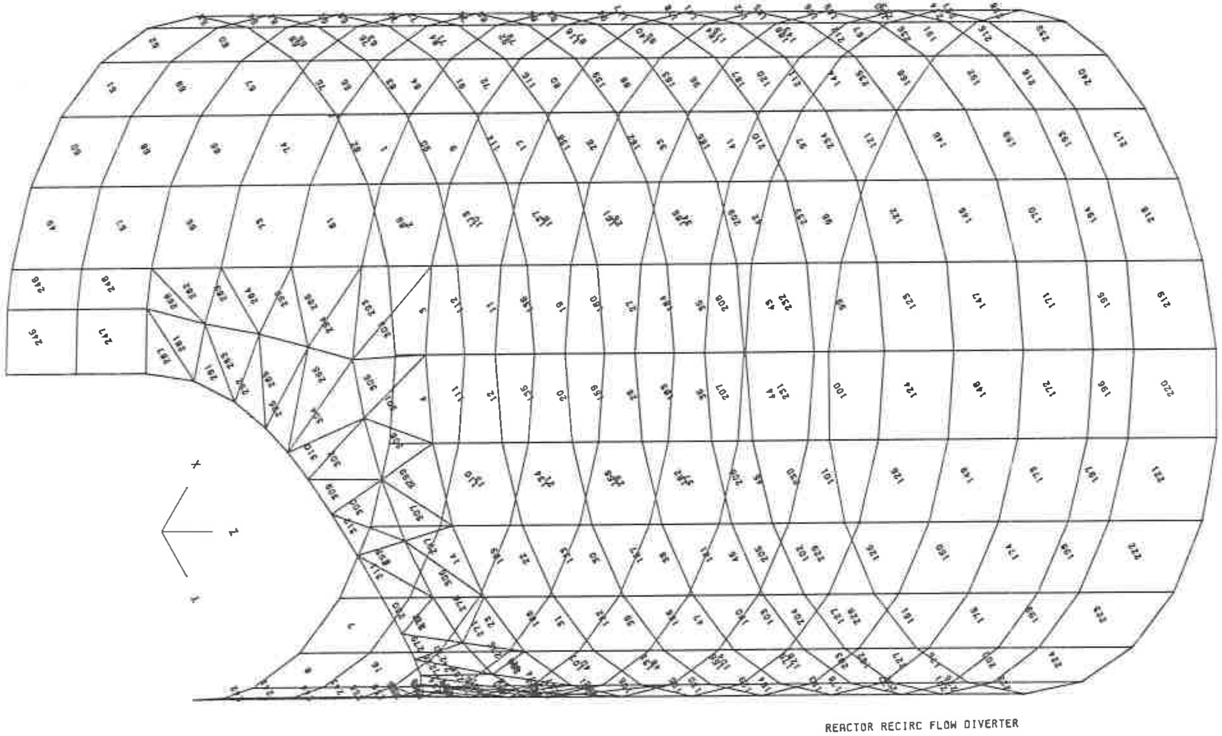


Figure 1. Finite Element Model

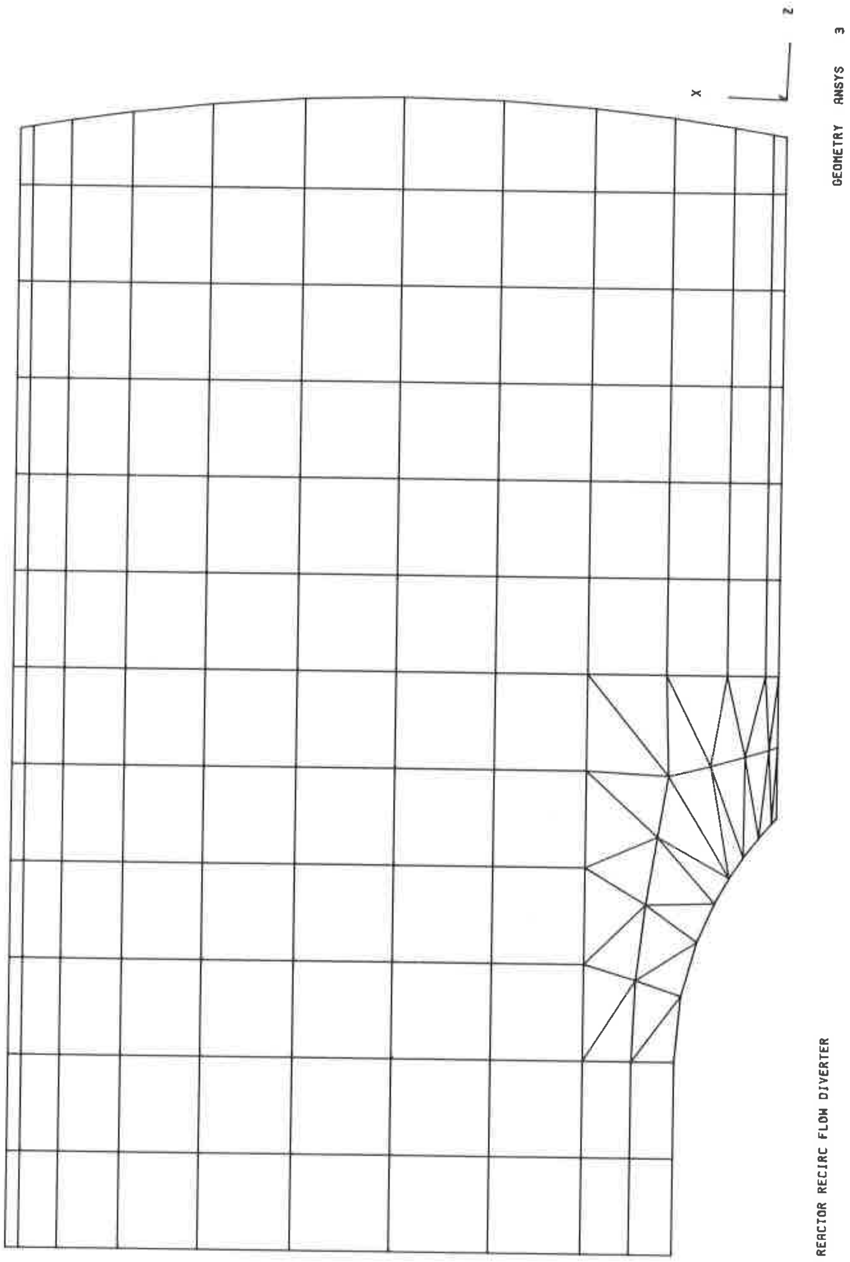


Figure 2. Side View of Flow Diverter