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NORTHEAST UTILITIES SERVICES COMPANY

HADDAM NECK PLANT

CORE BYPASS FLOW SUMMARY REPORT

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Reactor Pressure Vessel System Analysis
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ABSTRACT

This report summarizies the work performed to calculate the core bypass flow for the Northeast Utilities Services Company Haddam Neck Plant during Normal Reactor Operation. It includes the actual core bypass flow values and provides the recommended design core bypass flow value to be used in Fluid System and Nuclear Safety analyses.

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1.0 INTRODUCTION

A schematic view of the reactor pressure vessel system at the Haddam Neck plant (CYW) is presented in Figure 1. The primary coolant enters the pressure vessel through the four inlet nozzles. A majority of the flow impinges on the side of the core barrel and is directed downward through the annulus formed by the gap between the outside diameter of the core barrel and the inside diameter of the reactor vessel. The flow then enters the plenum area between the bottom of the lower core barrel assembly and the vessel and is redirected upward through the core. After passing through the core, the coolant enters the upper core support region and then turns radially out through the outlet nozzles.

Core bypass flow is defined as the total amount of reactor coolant flow which bypasses the core region. The following flow paths have been identified as bypass:

1) Baffle-Barrel Region

   In CYW the nuclear fuel assemblies are contained within a lower internals structure consisting of the core barrel, former plates, baffle plates and the upper and lower core plates. In this design a small fraction of the inlet flow enters the baffle/former/barrel region through the gap between the bottom of the baffle plate and the upper surface of the lower core plate. This flow then turns upward and flows parallel to the core flow and rejoins the main flow by exiting through the gap between the top of the baffle plate and the lower surface of the upper core plate.

2) Head Cooling Spray Nozzles

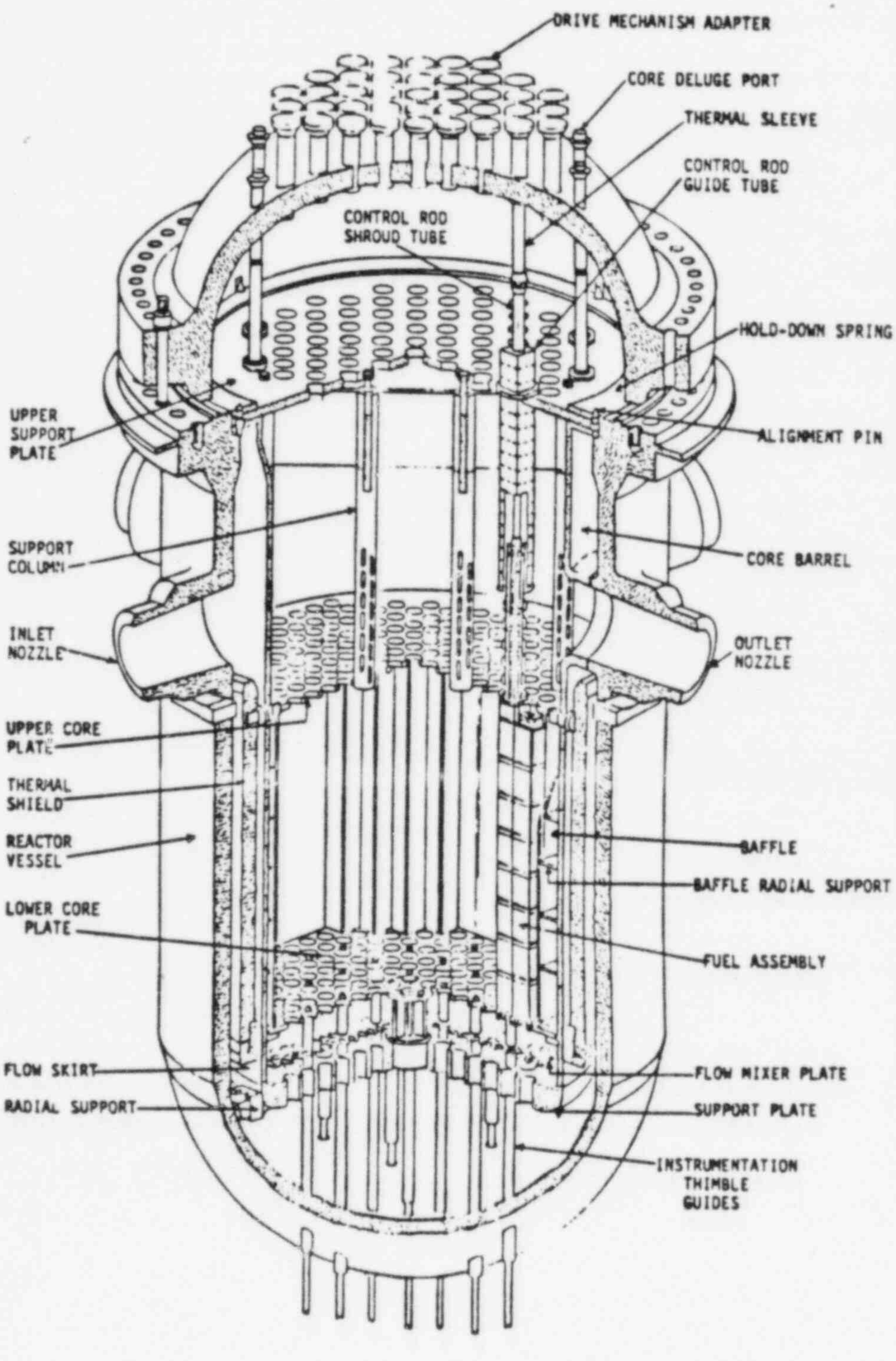
   The head cooling spray nozzles allow a small fraction of the flow entering the downcomer region to go into the upper head region.

3) Fuel Assembly/Baffle Plate Cavity

   The fuel assembly/baffle plate cavity bypass flow path (also known as the core cavity bypass), is the flow which bypasses the core by flowing through the annulus formed by the baffle plates and the peripheral fuel assemblies.

FIGURE 1

HADDAM NECK REACTOR PRESSURE VESSEL SYSTEM



4) Outlet Nozzle

The outlet nozzle bypass flow is the flow which goes from the downcomer directly to the outlet nozzle. This flow occurs because of the small gap which exists at each outlet nozzle penetration in the core barrel and the pressure differential between the downcomer region and the outlet nozzle.

5) Thimble Tubes

Thimble tube bypass flow is the flow which cools core component rods. Although this flow is partially effective in cooling the core, it is not considered as such and is treated as a bypass flow. The total thimble tube bypass flow is the sum of the individual component bypass flows weighted appropriately to reflect the total number of each component in the core.

Tables 4.3-1 and Section 6.1 in References 1 and 2 respectively indicated that during the mid 1960's the design core bypass flow for CYW was set at 9.0% of the total vessel flow. A portion of this large bypass flow value was apparently due to the cruciform control rod design. However, with the advent of the rod cluster control assembly design, the actual core bypass flow value decreased. In order to minimize the impact on core accident analysis to primary coolant flow reduction which could be incurred by performing extensive steam generator tube plugging, an analysis to determine the actual core bypass flow for CYW, at the present plant conditions, was performed.

2.0 METHOD OF ANALYSIS

Two computer models of the reactor pressure vessel system were generated to calculate the core bypass flows at CYW. The first model solves the following continuity and momentum equations for a flow system which represents the entire reactor vessel and internals system.

$$W = \rho VA = \text{constant}$$

$$P_j = P_i + \sum_i^j (K + fL/D) \frac{\rho V^2}{2g_c}$$

This first model provided velocities, pressure drops, bypass flows and forces in the reactor vessel and internals system given the coolant inlet conditions, the total coolant flow rate, the total core power, the loss coefficients of various components and the pertinent dimensions for the vessel and core internals. This input was obtained from Westinghouse documents and from the information provided to Westinghouse by NUSCO (Reference 3). The bypass flows for the baffle/barrel region, head cooling spray nozzles, fuel assembly/baffle plate cavity and outlet nozzle were obtained from this first model.

The second model provided the thimble tube bypass flow by solving the continuity, momentum and energy equations for a flow system consisting of two parallel flow paths. One was the flow inside the thimble or instrumentation tube. The other one was the flow outside the thimble or instrumentation tube i.e. the core side flow. The code iterated on the thimble tube bypass flow until the pressure drop inside the thimble tube equaled the fuel assembly pressure drop. The thimble tube bypass flow was calculated by determining the flow rate through a thimble tube assuming each type of core component (e.g. sources, control rods, thimble plugs) was inserted into the tube.

The thimble tube was divided into a number of axial increments (length steps) and the pressure drop inside the thimble tube was calculated by the following equation:

$$\Delta P = \sum_{i=1}^{N} \left[\left(K + \frac{fL}{D_e}\right)_i \frac{\rho_i V_i^2}{2g_c} + (\rho L)_i \right]$$

where "k" is the form loss coefficient for rod nose, abrupt expansion or contraction or the form loss coefficient for the thimble dashpot lower end plug in length step i and "f" is the friction factor for length step i.

The overall fuel assembly pressure drop can be inputted directly into the code or calculated based on appropriate loss coefficient information. For this CYW evaluation, the overall fuel assembly drop, supplied in Reference 3, was used. In addition, the following assumptions were used:

1) Isothermal flow

2) The control rods were fully withdrawn and the remaining core components were fully inserted.

3) The instrumentation flux detector was fully withdrawn.

In the vessel/internals hydraulic model, uncertainity factors were applied to account for the effects of geometric tolerances and the uncertainity of the hydraulic loss coefficients of some of the major internal components (i.e. fuel assemblies). For example, in order to maximimize the baffle/barrel bypass flow, the hydraulic resistance in the core was increased and the resistance in the former plates was decreased. For the thimble tube bypass flow calculation, a [ ]^{a,c} uncertainity was used to maximize that bypass flow.

3.0 RESULTS

The results of this core bypass flow study for CYW at normal reactor operation is presented in Table 1. Please note that these actual core bypass flow percentages include the effect of uncertainities which were applied to maximize the core bypass flow.

TABLE 1

CYW CORE BYPASS FLOW

NORMAL REACTOR OPERATION

BYPASS FLOW PATH	PERCENTAGE OF TOTAL VESSEL FLOW[(1)]
Baffle/Barrel Region	[ ]a,c
Head Cooling Spray Nozzles	
Fuel Assembly/Baffle Plate Cavity	
Outlet Nozzle	
Thimble Tube	
a) with thimble plug	
b) with control rod	
c) with source rod	
d) with source assy. plug	
Instrument tube without flux detector	
TOTAL	[ ]a,c

NOTES: 1) All bypass flow values include uncertainities. Thimble tube and Instrumentation tube bypass values include a [ ]a,c uncertainty.

4.0 CONCLUSIONS

The objective of this study was to calculate the core bypass flow for CYW at the present plant conditions. Table 1 provides the breakdown of the bypass flow percentages at normal reactor operation. Based on these results, it is concluded that the design bypass flow for CYW should be set at 4.5% of the total vessel flow.

5.0 REFERENCES

[ ]a,c