4.5 MAIN STEAM LINE FLOW RESTRICTOR

4.5.1 Safety Objective

To protect the fuel barrier, the main steam line flow restrictors limit the loss of water from the reactor vessel before main steam isolation valve closure in case of a main steam line rupture outside the primary containment.

4.5.2 Safety Design Basis

1. The main steam line flow restrictor shall be designed to limit the loss of coolant from the reactor vessel following a steam line rupture outside the primary containment to the extent that the reactor vessel water level does not fall below the top of the core within the time required to close the main steam isolation valves.

2. The main steam line flow restrictor shall be designed to withstand the maximum pressure difference expected across the restrictor following complete severance of a main steam line.

4.5.3 Description

A main steam line flow restrictor is provided for each of the four main steam lines. The restrictor is a complete assembly welded into a vertical section of the main steam line between reactor vessel and the first main steam isolation valve, and downstream of the main steam relief valves. The restrictor limits the coolant flow rate from the reactor vessel in the event of a main steam line break outside the primary containment to the maximum (choke) flow. The restrictor assembly consists of a venturi-type nozzle insert welded into a carbon steel pipe. The venturi-type nozzle insert is constructed utilizing all austenitic stainless steel and is held in place with a full circumferential fillet weld. The restrictor assembly is self draining (low point pockets are internally drained to steam line).

The flow restrictor is designed and fabricated in accordance with USAS B31.1.0, 1967 edition and the applicable GE design and procurement specifications, which were implemented in lieu of the outdated B31 Nuclear Code Cases-N2, N7, N9, and N10. Preinstallation inspection and testing are in accordance with the ASME Boiler and Pressure Vessel Code, Sections I, III, and IX, 1965 edition. The container pipe is also designed and fabricated in accordance with USAS B31.1.0, 1967 edition, the applicable GE design and procurement specifications, and with the ASME Boiler and Pressure Vessel Code, Sections I, III, and IX, 1965 edition. The flow restrictor has no moving parts, and the mechanical structure of the restrictor is capable of withstanding the velocities and forces under main steam line break conditions where maximum differential pressure is approximately 1375 psi.

The ratio of the venturi throat diameter to a steam line diameter is approximately 0.6. This results in less than a 9 psi pressure difference at rated flow. This design limits the steam flow in a severed line to about 200 percent of its rated flow, yet it results in negligible increase in steam moisture content during normal operation. The restrictor is also used in the measurement of steam flow to provide indication in the control room, to provide input to the feedwater level control system, and to initiate closure of the main steam isolation valves when steam flow exceeds preselected operational limits.

4.5.4 Safety Evaluation

In the event of a main steam line break outside the primary containment, steam flow rate is restricted in the venturi throat by a two-phase mechanism similar to the critical flow phenomenon in gas dynamics. This limits the steam quantity flow rate, thereby reducing the reactor vessel coolant blowdown and the fuel clad temperature increase subsequent to the blowdown. The probability of fuel failure and its consequences are therefore decreased.

Analysis of the steam line rupture accident (see Section 14.0, "Plant Safety Analysis") shows that the core remains covered and that the amount of radioactive materials released to the environs through the main steam line break does not exceed the values of 10 CFR 50.67.

Pressure surges caused by a two-phase mixture impinging on the flow restrictor result in stresses which do not exceed code-allowable limits. There is adequate margin in the code for withstanding the pressure load due to impact pressure from the possible oncoming two-phase mixture predicted during main steam line break accident conditions.

Tests were conducted on a scale model to determine final design and performance characteristics of the flow restrictor, including maximum flow rate of the restrictor corresponding to the accident conditions, irreversible losses under normal plant operating conditions, and discharge moisture level. The tests showed that the flow restrictor operation at critical throat velocities is stable and predictable. Unrecovered differential pressure across scale model restrictor is consistently about 10 percent of the total nozzle pressure differentials, and the restrictor performance is in agreement with existing ASME correlation. Full size restrictors have slightly different hydraulic shape and a differential pressure loss of approximately 15 percent.

4.5.5 Inspection and Testing

Because the flow restrictor forms a permanent part of the main steam line piping and has no moving components, no testing program is planned. Only very slow erosion will occur with time, and such a slight enlargement will not have safety significance.