4.6 MAIN STEAM ISOLATION VALVES

4.6.1 Safety Objectives

Two main steam isolation valves (MSIVs), one on each side of the primary containment barrier, in each of the main steam lines close automatically to:

a. Prevent damage to the fuel barrier by limiting the loss of reactor coolant water in case of a major leak from the steam piping outside the primary containment, and

b. Limit release of radioactive materials by closing the primary containment barrier in case of a major leak from the nuclear system inside the primary containment.

4.6.2 Safety Design Basis

The main steam isolation valves, individually or collectively, shall:

a. Close the steam lines within the time established by design basis accidents to limit the release of reactor coolant or radioactive materials,

b. Close the steam lines at a speed slow enough so that simultaneous (inadvertent) closure of all steam lines will not induce a more severe transient on the nuclear system than closure of the turbine stop valves while the bypass valves remain closed,

c. Close the steam lines when required despite single failure in either valve or the attached controls, to provide a high level of reliability for the safety function,

d. Use separate energy sources, as the motive force, to independently close the redundant main steam isolation valves in an individual steam line,

e. Use local stored energy (compressed air and springs) to close at least one main steam isolation valve in each steam line without relying on continuity of any variety of electrical power for the motive force to achieve closure,

f. Be able to close the steam lines during or after seismic loadings to ensure isolation if the nuclear system is breached by an earthquake, and

g. Be testable during normal operating conditions, to demonstrate that the valves will function.

4.6.3 Description

Two main steam isolation valves (MSIVs) are welded in a horizontal run of each of the four main steam lines, with one valve inside the primary containment barrier and the other as close as practical to the outside of the primary containment barrier (see Figures 4.5-1, 4.5-2, and 4.5-3 of Subsection 4.5). The valves, when closed, form part of the nuclear system process barrier for openings outside the primary containment, and part of the primary containment barrier for nuclear system breaks inside the containment.

The description and testing of the controls for the main steam isolation valves are included in Subsection 7.3, "Primary Containment and Reactor Vessel Isolation Control Systems."

A drawing of a main steam isolation valve is shown in Figure 4.6-1.

Each valve is a "Y"-pattern, 26-inch globe valve connected to matching 26-inch, schedule 80 (nominal I.D. 23.647 in.) pipe. A nominal rate of steam flow for Extended Power Uprate (3952 MWt) is 4.1 x 10^6 lb/hr at 1050 psia RPV dome pressure. The main disc or poppet is attached to the lower end of the stem and moves in guides at a 45-degree angle from the inlet pipe. Normal steam flow tends to close the valve and higher inlet pressure tends to hold the valve closed. The bottom end of the valve stem closes a small pressure-balancing hole in the poppet; when open, it acts as a pilot valve to relieve differential pressure forces on the poppet. The valve stroke for a 26-inch valve has approximately a 14-inch stem travel; the main poppet travels approximately 13 inches with approximately the last inch of valve travel closing the pilot hole. A helical spring between the stem and the poppet keeps the pilot hole open when the poppet is off its seat, but failure of the spring will not prevent closure of the valve. The air cylinder can open the poppet with a maximum of 200 psi differential pressure across the isolation valve in a direction tending to hold the valve closed.

The diameter of the poppet seat is approximately the same size as the inside diameter of the pipe, and the 45-degree angle permits stream lining of the inlet and outlet passage to minimize pressure drop during normal steam flow and to avoid blockage by debris. The valve stem penetrates the valve bonnet through a stuffing box having a set of replaceable packing. The poppet backseats on the bonnet cover in the fully open position, and leakage is prevented by the stem packing. The bonnet has provisions for seal welding in case leaks develop after the valve has extensive service.

The upper end of the stem is attached to a combination air cylinder and hydraulic dashpot that are used for opening and closing the valve and for speed control, respectively. Speed is adjusted by a valve in the hydraulic return line alongside the dashpot; the valve closing time is adjustable to meet the required Technical Specification limits (a minimum of three seconds and a maximum of five seconds).

The cylinder is supported on large shafts screwed and pinned into the valve bonnet. The shafts are also used as guides for the helical springs used to assist the valve to close. The springs exert downward force on the spring seat member which is attached to the stem. Spring guides prevent scoring in normal operation and prevent binding if a spring breaks. The spring seat member is also closely guided on the support shafts and rigidly attached to the stem to control any eccentric force in case of a broken spring.

On each MSIV, switches located at approximately 90 percent open, 85 percent open, and up to 7 percent open positions are actuated by the motion of the spring seat member. On each MSIV, the 90 percent open switches initiate reactor scram if several MSIVs close simultaneously (see Subsection 7.2, “Reactor Protection System”), the 85 percent open switch turns on the closed lights valve position, and the switch set at up to 7 percent open position indicates the valve is closed.

The MSIV is operated by pneumatic pressure and action of compressed springs. The control unit is attached to the air cylinder, and contains the pneumatic, AC and DC control valves for opening, closing, and slow-speed exercising of the main valve. The control power available is 120-V AC at 60 cycles and 250-V DC. Both the AC and DC control valve solenoids use approximately 0.5 amps of control power for each solenoid. Remote manual switches in the control room enable the operator to operate or close each valve either at fast speed for primary containment isolation or at the slow speed (approximately 45 to 60 seconds) for exercising or testing.

MSIV operating air is supplied at approximately 81 psig to 105 psig for the outboard valves and approximately 90 to 105 psig for the inboard valves from the various plant air systems through a check valve. An air accumulator between the control valve and the check valve provides a source of backup operating air.

This accumulator is designed to provide for one closing actuation following loss of air supply. Once closed, the valve is held closed by the springs.

The valve is designed for saturated steam flow at 1250 psig and 575°F, with a moisture content of approximately 0.23 percent.

In the event that the main steam line should rupture downstream from the valve, the steam flow quickly increases to no more than 200 percent of rated, flow being limited from further increase by the venturi flow restrictor upstream of the valves.

During valve closure, the MSIV initially has little effect in reducing flow because the flow is choked by the venturi restrictor upstream from the valves. After the main valve poppet enters the flow stream, flow is reduced as a function of the MSIV cross-sectional flow area versus travel characteristic.

The design objective for the valve is a minimum of 40 years of service at the specified operating conditions. The estimated operating cycles per year is 100 cycles during the first year and 50 cycles per year thereafter. In addition to minimum wall thickness required by applicable codes, a corrosion allowance of 0.120-inch minimum is added to provide for 40 years of service. For the 60 year operating life, the Technical Specification Surveillance Requirements will assure the MSIVs are capable of performing their design functions and the MSIV aging effects will be managed using the ASME Section XI Subsections IWB, IWC, and IWD Inservice Inspection Program, Chemistry Control Program, BWR Stress Corrosion Cracking Program and One-Time Inspection Program described in Appendix O, Sections O.1.4, O.1.5, O.1.10, and O.1.26.

Design specification normal and maximum ambient operating conditions for the MSIVs are tabulated in drawing 47E225-110 for each unit. See FSAR, Appendix M, Subsection M.8. However, the inside valves are not exposed to maximum conditions continuously, particularly during reactor shutdown, and the valves outside the primary containment and shielding are in much less severe ambient conditions.

The main steam isolation valve installations are designed as seismic Class I equipment to resist sufficiently the response motion at the installed location within the reactor building from the Design Basis Earthquake (see Appendix C). The valve assembly is manufactured to withstand the design basis seismic forces. The stresses caused by horizontal and vertical seismic forces are considered to act simultaneously and are added directly. The seismic coefficients are specified as 0.73g horizontal and 0.07g vertical. The stresses in the actuator supports caused by seismic loads are combined with the stresses caused by other live and dead loads including the operating loads. The allowable stress for this combination of loads is based on the ordinary allowable stress as set forth in the applicable codes. The parts of the main steam isolation valves which constitute a process fluid boundary are designed, fabricated, inspected, and tested as required by 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. The control valves and other equipment provided in the valve assembly were designed, manufactured, and shop-tested in accordance with the then-current revision of the following codes and standards, where applicable:

USA Standards Institute B31.1 and B16.5,
American Society for Testing and Materials (ASTM),
American Society of Mechanical Engineers (ASME),

ASME Boiler and Pressure Vessel Code, Sections I, III, and VIII,
American Institute of Electrical Engineers,
Pipe Fabrication Institute, and
National Electrical Manufacturers Association.

4.6.4 Safety Evaluation

In a direct cycle nuclear power plant, the reactor steam goes to the turbine and other equipment outside the reactor containments. The analysis of a complete sudden steam line break outside the primary containment is described in Section 14.0, "Plant Safety Analysis." It shows that the fuel barrier is protected against loss of cooling if main steam isolation valve closure takes as long as 5.5 seconds (includes up to 0.5 seconds for the instrumentation to initiate valve closure after the break and the maximum allowable valve stroke time). For the LOCA inside of containment, the inboard main steam isolation valve closure can take as long as 2 minutes, which is before any radiation releases occur as described in Section 14.6. The calculated radiological effects of the radioactive material assumed released with the steam are shown to be well within the guideline values for such an accident. Thus, safety design basis "a" is shown to be satisfied with considerable margin.

The shortest closing time (approximately 3 seconds) of the main steam isolation valves is also shown to be satisfactory by Chapter 14.0, "Plant Safety Analysis." The switches on the valves initiate reactor scram when several valves are ≤ 90 percent open. The pressure rise in the system, from stored and decay heat, may cause the nuclear system main steam relief valves to open briefly, but the rise in fuel cladding temperature will be insignificant. The transient is less than that from sudden closure of the turbine stop valves (in approximately 0.1 second), coincident with postulated failure of the turbine bypass valves to open. No fuel damage results. Thus, safety design basis "b" is shown to be satisfied with considerable margin.

The ability of this 45°, Y-design globe valve to close in a few seconds after a steam line break, under conditions of high pressure differentials and fluid flows, with fluid mixtures ranging from mostly steam to mostly water, has been demonstrated in a series of tests in dynamic test facilities. Dynamic tests with a 1-inch valve show that the analytical method is valid. A large size, 20-inch valve was tested in a range of steam/water blowdown conditions simulating postulated accident conditions.∗

The following specified hydrostatic, leakage, and stroking tests, as a minimum, were performed by the valve manufacturer in shop tests.

∗ E. Van Zylstra, W. Sutherland, and D. Rockwell, "Design and Performance of GE BWR Main Steam Isolation Valves," General Electric Co., Atomic Power Equipment Department, March 1969 (APED-5750).

a. Each valve was tested at rated pressure (1,000 psig) and no flow to verify capability to close between 3 and 10 seconds. The valve was stroked several times and the closing time recorded. The valve is closed by the air cylinder and springs, and may also be closed by the springs only. The closing time is usually slightly greater when closed by springs only.

b. At least the first valve of each size was tested to demonstrate that the valve will close at rated pressure and no flow in the specified time after the valve had been held open (energized) for 1 week.

c. Leakage with the valve seated and backseated was measured. Seat leakage was measured by pressurizing the upstream side of the valve to 1250 psig. The specified maximum seat leakage, using cold water at design pressure, was 2cc per hour per inch of seat diameter. In addition, an air seat leakage test was conducted using 50 psi pressure upstream. Maximum permissible leak was 1/10 SCFH per inch of seat diameter. No visible leakage from the stem packing at design pressure was allowed. The valve stem was operated a minimum of three times from the closed to open position, and the packing leakage was verified to still be zero by visual examination.

d. Each valve was hydrostatically tested at USAS B16.5-specified test pressure (2,380 psig) with cold water.

e. During valve fabrication, extensive nondestructive tests and examinations were made, including radiographic, liquid penetrant, or magnetic particle examinations of castings, forgings, welds, hardfacings, and bolts.

The spring guides, the guiding of the spring seat member on the support shafts, and rigid attachment of the seat member ensure proper alignment of actuating components. Binding of the valve poppet in the internal guides is prevented by making the poppet in the form of a cylinder longer than its diameter, and by applying the stem force near the bottom of the poppet. Clearance is provided between the poppet and its guides so that some cocking of the poppet or warpage of the seat can be tolerated and still achieve a seal.

After the MSIVs were installed in the nuclear system, each valve was tested several times in accordance with the extensive "Preoperational Test Procedures," and "Startup Test Procedures." The startup tests were performed at several reactor operating conditions.

During the initial plant startup tests, the MSIV leak tightness was determined. When nuclear system pressure had reached approximately 800 psig, the leak tightness was checked by closing the MSIVs, evacuating the steam lines downstream and the turbine steam chest to the condenser, closing the steam chest valves, and recording the steam chest pressure. No pressure rise meant the valves were tight. If leakage

is indicated, each valve may be checked individually by opening the other valve in the same steam line with all other MSIVs closed, evacuating and closing the steam chest, and checking for pressure rise.

Redundancy is provided by two MSIVs in each steam line so that either can perform the isolation function, and either can be tested for leakage after closing the other. The inside valve, the outside valve and their control systems are physically separated. Considering the redundancy, the mechanical strength, the closing forces, and the leakage tests discussed above, the main steam isolation valves satisfy safety design bases "c", "d", and "e" to limit the release of reactor coolant or radioactive materials, within the margins evaluated in Section 14.0, "Plant Safety Analysis."

The MSIVs and their installation are designed as seismic Class I equipment for inclusion of seismic loadings, as delineated in Appendix C.

The design of the MSIVs for seismic loadings is discussed in paragraph 4.6.3 above. These loads are small compared with the pressure and operating loads the valve components are designed to withstand. The cantilevered support of the air cylinder, hydraulic cylinder, springs, and controls is the key area. The increase in loading at the joints between the support shafts and the valve bonnet caused by the specified earthquake loading is negligible. Therefore, the seismic loading requirement of design basis "f" is met.

Electrical equipment, associated with the MSIVs, that operates in an accident environment is limited to the wiring, solenoid valves, and position switches on the MSIVs. The design and purchase specifications for the wiring, solenoid valves, and position switches for accident environmental conditions are contained in the BFN 10 CFR 50.49 program. Under the accident conditions, ambient pressure and temperature increase to approximately 50 psig and 337°F; each valve is required to close within a 2 minute exposure to these conditions. The valve closing is completed during this two minute time frame.

Operation of the valves in the normal operating conditions and postulated accident environments is ensured by the requirements of the purchase specifications, review and approval of equipment design and vendor drawings, extensive control of materials, fabrication procedures, fabrication tests, nondestructive examinations, shop tests, preoperational and startup tests of the installed valves, and prescribed periodic inspections and tests during the plant life.

Safety design basis "g" is met, as described in paragraph 4.6.5.

4.6.5 Inspection and Testing

The main steam isolation valves may be tested during plant operation, and tested and inspected during refueling outages. The test operations are listed below.

The main steam isolation valves may be tested and exercised individually to the 85-percent-open position in the following manner. A minimum amount of load reduction may be required during testing.

a. Press the test pushbutton until the closed light goes on (85-percent-open position). The valve moves at the slow speed.

b. Release the test pushbutton and the valve will automatically reopen, turning off the closed light.

c. Repeat the test on each MSIV.

The main steam isolation valves may be tested and exercised individually to the fully closed position in the following manner.

a. Reduce reactor power to approximately 75 percent of full power.

b. Turn the MSIV control switch to the closed position, observing the time interval between switch closure and the open light going off. The closing time should be within the established Technical Specification limits.

c. Return the MSIV control switch to the open position.

d. Repeat the test on each MSIV.

e. After all the MSIVs have been tested, reactor power may be returned to the normal level.

During reactor shutdowns for refueling, the main steam isolation valves are tested and visually inspected as necessary.

Leakage from the valve stem packing may become suspect, during reactor operation, from measurements of leakage into the primary containment or from observations or similar measurements in the secondary containment. During shutdown, while the nuclear system is pressurized, the leak rate through the packing can be observed by visual inspection.

The leak rate through the MSIV seats (pilot and poppet seats) can be measured accurately during shutdown by pressurizing between the closed valves with compressed gas.

During pre-startup tests following a refueling outage or MSIV disassembly, the valves will receive the same hydrostatic or inservice leakage tests which are imposed on the primary system.

This test and leakage measurement program will ensure that the valves are operating properly, and that a leakage trend is detected.