4.4 NUCLEAR SYSTEM PRESSURE RELIEF SYSTEM

4.4.1 Safety Objective

The safety objective of the Nuclear System Pressure Relief System is to prevent overpressurization of the nuclear system; this protects the nuclear system process barrier from failure which could result in the uncontrolled release of fission products. In addition, the automatic depressurization feature of the Nuclear System Pressure Relief System acts in conjunction with the Emergency Core Cooling Systems for reflooding the core following breaks in the nuclear system process barrier; this protects the reactor fuel barrier (UO_2 sealed in cladding) from failure due to overheating, which would result in the uncontrolled release of fission products from the reactor fuel barrier.

4.4.2 Power Generation Objective

The power generation objective of the Nuclear System Pressure Relief System is to relieve normal overpressure transients occurring during normal plant isolations and load rejections.

4.4.3 Safety Design Basis

1. The Nuclear System Pressure Relief System shall prevent overpressurization of the nuclear system in order to prevent failure of the nuclear system process barrier.

2. The Nuclear System Pressure Relief System shall provide automatic nuclear system depressurization, if needed, for breaks in the nuclear system so that the Low Pressure Coolant Injection (LPCI) and the Core Spray Systems can operate to protect the fuel barrier. This depressurization is permissive on: (1) concurrent high drywell pressure and low reactor water level, or (2) sustained reactor low water level, and (3) availability of one of the RHR pumps in the LPCI mode or two of the appropriate core spray pumps.

3. The main steam relief valve (MSRV) discharge piping shall be designed to accommodate forces resulting from relief action and shall be supported for reactions due to flow at maximum MSRV discharge capacity so that system integrity is maintained. The MSRV discharge piping shall be routed to the pressure suppression pool.

4. The Nuclear System Pressure Relief System shall be designed for testing prior to nuclear system operation and for periodic verification of the operability of the Nuclear System Pressure Relief System.

4.4.4 Power Generation Design Basis

1. The nuclear system main steam relief valves shall not discharge to the primary containment drywell.

2. The main steam relief valves shall properly reclose following a plant isolation or load rejection, so that normal operation can be resumed as soon as possible.

3. The capacity of the main steam relief valves shall be sufficient to prevent reactor pressure from exceeding the allowable overpressure of ASME Boiler and Pressure Vessel Code, Section III, during an isolation transient with indirect scram.

4.4.5 Description

The Nuclear System Pressure Relief System includes 13 main steam relief valves, all of which are located on the main steam lines within the drywell between the reactor vessel and the flow restrictors.

The main steam relief valves provide three main protection functions:

1. Overpressure relief operation. All 13 main steam relief valves can be opened manually from the main control room or are self-actuated to limit the pressure rise.

2. Overpressure safety operation. The valves are opened (self-actuated) to prevent exceeding the design allowable stress limits on the reactor vessel and associated piping.

3. Depressurization operation. Six of the 13 valves are available to be opened automatically as part of the Emergency Core Cooling System (ECCS).

The main steam lines, in which the main steam relief valves are installed, are designed, installed, and tested 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. The main steam relief valves are distributed among the four main steam lines so that an accident cannot completely disable a safety, relief, or automatic depressurization function. (See Figure 4.3-2a sheet 1 of Subsection 4.3 and Figures 11.1-1a, 11.1-1c, and 11.1-1e of Subsection 11.1 for schematic location, and Figures 4.5-1, 4.5-2, and 4.5-3 of Subsection 4.5 for layout details of the valves and piping.)

The design and installation of the main steam relief valves include the following:

a. Clearance of at least 6 in. is provided between valves and other equipment (excluding MSRV pilot solenoid valves),

b. Space is provided between all welds on the header for inspection greater than 2t + 2" (where t is minimum wall thickness),

c. Clearance is provided between header and bottom of flange for bolt removal when valve is installed,

d. A flange rating of 1500 lb. was provided for structural stability instead of a 900 lb.-rated flange required for pressure-temperature rating,

e. An inlet pipe Schedule 160 was used for structural stability instead of Schedule 80 required for pressure-temperature rating, and

f. The discharge piping provides for equalization of discharge thrust forces.

For analysis, the special loadings listed below are considered in addition to the usual design loads such as weight, pressure, temperature, and earthquake:

1. The jet force exerted on the main steam relief valves during the first millisecond when the valve is open and steady-state flow has not yet been established. (With steady-state flow, the dynamic flow reaction forces will be self-equilibrated by the discharge piping.)

2. The dynamic effects of the kinetic energy of the piston disc assembly when it impacts on the internals of the valve.

All code-allowable stresses are met with these special loads acting concurrently with other design loads. The highest stress is at the branch connection to the header. The results of this analysis are contained in Appendix C, Table C.4-2.

The main steam relief valves are designed, constructed, and marked with data in accordance with the ASME Boiler and Pressure Vessel Code, Section III, 1968 edition and addenda through summer 1970 for the two-stage valves. Setpoint tolerance (pressure at which valve "pops" wide open) is in accordance with ASME Boiler and Pressure Vessel Code, Section I, paragraph PG-72(c). Pressure-containing parts of the valve body are fabricated of ASTM A216, Grade WCB. The main steam relief valve is designed for operation with saturated steam containing less than 1 percent moisture. The relieving pressures for overpressure relief and safety operating modes are adjustable between 1025 and 1190 psig, with a maximum backpressure of 40 percent of the set pressure. The lowest MSRV setpoint has been raised to 1135 psig. This serves to alleviate the "simmering" problems that contribute to valve failures. Also, the bore size of the valves has been increased slightly (from 4.94 or 5.03 inches to 5.125 inches) to accommodate more relief capacity. The delay time (maximum elapsed time between overpressure signal and actual valve motion) and the response time (maximum valve stroke time) are less than 0.5 second total.

Each valve is self-actuating at the set relieving pressure, but may also be actuated by remotely-operated devices to permit remote-manual or automatic opening at lower pressures. The remote air actuators are controlled by DC powered solenoid valves. The power actuated device is capable of opening the valve at any steam pressure above 50 psig and is capable of holding the valve open until the steam pressure decreased to about 20 psig. The solenoid valves are normally closed, fail-closed valves, and a power or valve malfunction will prevent the main steam relief valve from operating for Automatic Depressurization System (ADS). Abnormal solenoid-valve operation would be detected during the operational tests of the main steam relief valve. A complete rupture of the solenoid valve would result in a low air pressure/accumulator alarm.

Each of the six main steam relief valves provided for automatic depressurization is equipped with an air accumulator and check valve arrangement. These accumulators are provided to assure that the valves can be held open following failure of the air supply to the accumulators, and they are sized to contain sufficient air for a minimum of five valve operations. To ensure an emergency supply of air is available to provide for the five valve operations under accident conditions, an accumulator leak test is performed once per operating cycle. The first and second actuations are assumed to occur with drywell pressure at 35 psig and subsequent actuations with the drywell at 0 psig. Redundant sources of pneumatic pressure are provided by the Drywell Control Air (DCA) and Containment Atmospheric Dilution (CAD) systems. Accumulators are not required for the main steam relief valves not used for automatic depressurization. The main steam relief valves which are a part of the ADS normally receive their motive air from the drywell control air system. The air pressure in each accumulator is continuously monitored by a pressure switch which annunciates in the control room on low air pressure. The pressure switch, in order to ensure operability, is calibrated and functionally tested once per operating cycle. The drywell control air system is also continuously monitored for low air pressure by means of a pressure switch located in the system downstream of the receivers and which annunciates in the control room. A manual transfer can also be made to the plant control air system as another backup for control air. The main steam relief valves are designed to operate under maximum prevailing operating conditions and postulated accident conditions in the drywell. In addition, the ADS accumulators and piping up to and including the isolation check valves are seismically qualified and capable of performing their functions during and following an accident.

The automatic depressurization feature of the Nuclear System Pressure Relief System serves as a backup to the High Pressure Coolant Injection (HPCI) System under loss-of-coolant accident conditions. If high drywell pressure and low water level persist and one of the low pressure coolant injection (LPCI) pumps or two of the appropriate core spray pumps are available, the nuclear system is depressurized sufficiently to permit the LPCI and Core Spray Systems to operate to protect the fuel barrier. Depressurization is accomplished through automatic opening of some of the main steam relief valves to vent steam to the pressure suppression pool. For small line breaks, if the HPCI system fails, the nuclear system is depressurized in sufficient time to allow the Core Spray or LPCI Systems to provide core cooling to prevent excessive fuel clad temperatures. When HPCI is considered to be the single failure, six ADS valves are required to meet the requirements for ADS. As shown in Table 6.5-3, dependent upon the recognized single failure, between four and six valves remain available and the results of LOCA analyses confirm that the requirements for ADS continue to be met. For large breaks, the vessel depressurizes rapidly through the break without assistance from ADS. Discharge pressure indication of one LPCI pump or two core spray pumps combined with one of the following initiation paths will cause the main steam relief valves to open: (l) reactor vessel low water level and primary containment (drywell) high pressure in conjunction with a 120 seconds timer timed out; or (2) sustained reactor low water level for 360 seconds. Further descriptions of the operation of the automatic depressurization feature are found in Section 6.0, "Emergency Core Cooling Systems," and Subsection 7.4, "Emergency Core Cooling System Control and Instrumentation." The Automatic Depressurization System is designed as seismic Class I equipment in accordance with Appendix C.

A manual depressurization of the nuclear system can be effected in the event the main condenser is not available as a heat sink after reactor shutdown. The steam generated by core decay heat is discharged to the pressure suppression pool. The main steam relief valves are operated by remote manual controls from the Main Control Room to control nuclear system pressure.

The number, set pressures, and capacities of the main steam relief valves are shown in Table 4.4-1a (it should be noted that the ± three percent tolerance is for analytical purposes only). Actual MSRV opening setpoints following testing must still be set at nominal values ± one percent.

The original three-stage Target Rock valves (Model 67F) have been changed to two-stage valves (Target Rock MSRV model No. 7567F) to minimize spurious openings and to respond to NUREG 0737, Item II.K.3.16.

Two-Stage Valve Operation

The Target Rock pilot-operated main steam relief valve (Model 7567F) consists of two principal assemblies: a pilot stage assembly and the main stage assembly (refer to Figure 4.4-1). These two assemblies are directly coupled to provide a unitized, self-actuated safety/relief valve. The pilot stage assembly is the pressure sensing and control element and the main stage assembly is a hydraulically (system fluid) actuated follower valve which provides the pressure relief function. Self-actuation of the pilot assembly at set pressure vents the main piston chamber, permitting the system pressure to fully open the main assembly. The pilot assembly consists of two relatively small, low-flow, pressure-sensing elements. The spring loaded pilot disc senses the set pressure, and the pressure-loaded stabilizer disc senses the reseat pressure. Spring force (preload force) is applied to the pilot disc by means of the pilot rod. Thus, the adjustment of the spring preload force will determine the set pressure of the valve.

The main assembly of the Target Rock main steam relief valve is a reverse-seated, hydraulically-actuated angle globe valve. Actuation of the main assembly permits discharge of fluid from the protected system at the valve's rated flow capacity and provides the system pressure-relief function of the valve. The major components of the main stage are the valve body, disc/piston assembly, and preload spring.

A typical sequence of operation for overpressure relief self-actuation can be described as follows (refer to Figures 4.4-1 and 4.4-2).

1. In its normally closed position, the main stage disc is tightly seated by the combined forces exerted by the system internal pressure acting on the area of the disc and the preload spring. Note that in the closed, no-flow position, the static pressures will be equal in the valve inlet nozzle and in the chamber over the main stage piston. This pressure equalization is made possible by leakage past the piston, via the ring gap and drain and vent grooves.

2. When system pressure increases to the valve set pressure, pilot stage operation will vent the chamber over the main stage piston to downstream of the valve via internal porting. This venting action creates a differential pressure across the main stage piston in a direction tending to open the valve. The main stage piston is sized such that the resultant opening force is greater than the combined spring preload and hydraulic seating force.

3. Once the main stage disc starts to open, the hydraulic seating force is reduced, causing a significant increase in opening force and the characteristic full opening or "popping" action.

4. When system pressure has been reduced sufficiently, the pilot disc reseats and precludes depressurization of the main piston chamber. Leakage of

system fluid, past the main stage piston and stabilizer seat, repressurizes the chamber over the piston, canceling the hydraulic opening force and permitting the preload spring and flow forces to close the main stage. Once closed, the additional hydraulic seating force, due to system pressure acting on the main stage disc, seats the main stage tightly and prevents leakage.

A remotely-controlled air operator is fitted to the pilot stage assembly to provide selective operation of the valve at system pressure other than set pressure. This is a diaphragm-type, pneumatic actuator which must be actuated to open the valve. It is actuated by means of a solenoid control valve which admits drywell control air to the air-operator piston chamber and strokes the air operator stem, in turn stroking the pilot disc via the pilot rod. The main stage then opens as described in previous paragraphs. Deenergizing the solenoid vents the air operator and permits the pilot disc to reseat. The main stage then reseats as previously described.

Main Steam Relief Valve Position Indication

The main steam relief valve position is monitored by two systems. A single-train acoustic monitoring system has been installed on all the main steam relief valves to provide unambiguous Main Control Room indication (and alarm) of valve position. The system responds to NRC requirements of NUREG 0578, item 2.1.3.a. The system is qualified as seismic Class I and is powered by a Class 1E power supply. There also exists a temperature sensor in the discharge piping of each valve which can be used to determine individual valve positions. Temperature indications are also provided in the control room. The acoustic monitor satisfies the valve position alarm and annunciation requirements. Refer to Paragraph 7.4.3.3.4 for additional details. (High-temperature alarm and annunciation is removed for Units 1, 2, and 3)

Non Safety Related Alternate Automatic Means of Opening the MSRVs Upon Overpressurization:

During inservice pressure transient events in the relief mode, safety grade pressure sensors (found in Section 7.4.3, "Automatic Depressurization System") actuate the MSRVs. This method of automatically opening the MSRV permits application of the full main steam line pressure to break the corrosion bonds that may have developed between the pilot/disc interface. When the relief mode is actuated, the setpoint spring preload is removed from the pilot disc, and a rapidly applied full differential pressure is seen across the pilot disc. This alternate means of actuation is capable of opening the MSRVs. This non-safety related automatic means of opening the MSRV is applicable for Units 1, 2, and 3.

Main Steam Relief Valve (MSRV) Discharge

The main steam relief valves are installed so that each valve discharge is piped through its own uniform-diameter discharge line to a point below the minimum water level in the primary containment pressure suppression pool to permit the steam to condense in the pool. Thermal mixing in the pool during main steam relief valve blowdown is enhanced by T-quencher discharge devices at the pressure suppression pool end of the main steam relief valve discharge lines. Water in the line above pressure suppression pool water level would cause excessive pressure at the valve discharge when it is again opened. For this reason, one small check valve and one large check valve venting to the drywell are provided on each main steam relief valve discharge line to prevent drawing water up into the line, due to steam condensation, following termination of main steam relief valve operation. The main steam relief valves are located on the main steamline piping, rather than on the reactor vessel top head, primarily to simplify the discharge piping to the pool and to avoid the necessity for removing sections of this piping when the reactor head is removed for refueling. In addition, the main steam relief valves are more accessible during a quick shutdown to correct possible valve malfunctions when located on the steam lines.

The discharge piping has been modified as part of the torus integrity program. This modification has been described in a letter from L. M. Mills to Harold R. Denton dated May 22, 1981. A submittal by GE (NEDO-21888, "Mark I Containment Program Load Definition Report," December, 1980), on behalf of TVA, describes the reassessment of the torus design to include pressure suppression pool hydrodynamic loads due to MSRV discharge and pressure suppression pool response.

The reassessment of Mark I containments was precipitated from the large-scale testing of the Mark III containment system. Pressure suppression pool hydrodynamic loads resulting from the effect of drywell air and steam being rapidly forced into the pressure suppression pool during a postulated LOCA and/or MSRV discharge were identified, which had not been considered in the original design. The Mark I Owners Group, of which TVA is a member, and GE responded by submitting the Mark I Containment Program Load Definition Report (described above) and the Mark I Containment Program Structural Acceptance Criteria Plant Unique Analysis Application Guide (NEDO-24538-1). These reports describe the generic pressure suppression-pool hydrodynamic-load definition and assessment procedures for use in plant-unique pressure suppression-chamber design analyses. TVA has applied the load definitions and approved structural acceptance criteria to the entire torus, torus internals, MSRV piping, and attached piping of Browns Ferry Nuclear Plant.

A plant-unique main steam relief valve discharge test was performed as part of the Browns Ferry Nuclear Plant Unit 2 unique analysis, as requested by the NRC in NUREG-0661. This test did confirm the methods used to calculate containment loads from the various MSRV discharge cases. For the results of this test to be completely acceptable, all modifications which significantly influence torus motion had to be in their final configuration.

The magnitude of the MSRV discharge related loads is a function of the type of discharge device used. The device found to substantially reduce the hydrodynamic discharge loads, compared to other devices, is the T-quencher developed specifically for the Mark I torus (see Figures 4.4-6, 4.4-7, and 4.4-8). The devices have been added to the MSRV discharge lines at Browns Ferry Nuclear Plant. Discharge piping and relief valves were analyzed for deadweight, thermal, seismic and relief valve blowdown loads. The support locations, orientation, and design loads satisfy ASME Boiler and Pressure Vessel Code, Section III, Class 2, equations and stress allowables. One main steam safety valve (1-501 from line B) and one safety valve (1-537 from line C) were removed and the connections blanked off with blind flanges and a relief valve was added to Main Steam Line A and Main Steam Line D. Additionally, the valve throat diameters were increased from 5" nominal size to 5.125" nominal size. These modifications increased the installed relief from 61 percent of rated steam flow to 84.1 percent (pre-uprate) or 79.5 percent (uprate) (based on 870,000 lbm/hr at 1090 psig). The addition of these MSRVs do not adversely affect the stresses imposed on the headers to which the valves are attached. The torus shell is also adequate for the larger discharge loads.

4.4.6 Safety Evaluation

The ASME Boiler and Pressure Vessel Code requires that each vessel designed to meet Section III be protected from pressure in excess of the vessel design pressure. A peak-allowable pressure of 110 percent of the vessel design pressure is allowed by the code.

The main steam relief valves are set to open by self-actuation (overpressure safety mode) in the range from 1135 to 1155 psig. This satisfies the ASME code specifications for safety valves, since the lowest-set valve opens below the 1250 psig nuclear system design pressure, and the highest-set valve opens below 1313 psig (105 percent of nuclear system design pressure). The setpoints are also set high enough to avoid MSRV simmering problems.

The required pre-uprate main steam relief valve capacity was determined by analyzing the pressure rise accompanying the main steam flow stoppage resulting from a 3-second main steam isolation valve closure initiated from turbine-generator design operating conditions with a turbine admission pressure of 1020 psig. The analysis hypothetically assumed the reactor is shut down by an indirect scram. For the analysis, the self-actuated setpoints of the 13 main steam relief valves were assumed to be as shown in Table 4.4-1. The analysis indicated that the main steam relief valve capacities shown in Table 4.4-1 provide sufficient flow to maintain an adequate margin below the peak ASME code-allowable pressure in the nuclear system (1375 psig). Figure 4.4-3 is representative of the nuclear system response which might be expected during such a transient. For power uprate, the required main steam relief valve capacity was determined by analyzing the pressure rise accompanying the main steam flow stoppage resulting from a three second main steam isolation valve closure initiated at an initial dome pressure of 1055 psig (corresponding to the Improved Technical Specifications LCO value of 1050 psig plus 5 psi margin). The analysis hypothetically assumed the reactor is shutdown by a high neutron flux scram signal (i.e., failure of the MSIV position direct scram signal). For the analysis, the self-actuated setpoints of the 12 main steam relief valves were assumed to be as shown in Table 4.4-1a (one MSRV with the lowest opening setpoint is assumed inoperable). The analysis indicated that the main steam relief valve capacities shown in Table 4.4-1a provide sufficient flow to maintain an adequate margin below the peak ASME code-allowable pressure in the nuclear system (1375 psig). Additional discussion and results of this overpressurization analysis are documented in Chapter 14.

The results of the specific analysis for each unit can be found in the current reload licensing analysis for that unit (Appendix N). The sequence of events assumed in this analysis was investigated only to meet code requirements for pressure-relief-system evaluation

Evaluations of the automatic depressurization capability of the Nuclear System Pressure Relief System are presented in Section 6.0, "Emergency Core Cooling Systems" and Subsection 7.4, "Emergency Core Cooling System Controls and Instrumentation."

The piping attached to the main steam relief valve discharges was initially designed, installed, and tested 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. New analyses of the main steam system and MSRV discharge piping have been performed in accordance with ANSI B31.1, 1973 edition, with Addenda up to Summer 1975. This analysis included deadweight, thermal, seismic, and main steam relief valve blowdown loadings. Snubbers have been added to reduce stresses in the main steam and main steam relief valve piping.

4.4.7 Inspection and Testing

The main steam relief valves were tested in accordance with the manufacturer's quality control procedures to detect defects and prove operability prior to installation. The following final tests were witnessed by a representative of the purchaser:

a. Test at USAS-specified hydrotest pressure using nitrogen, and

b. Nitrogen leakage test at design pressure with a maximum permitted leakage of 2cc per inch of seat diameter per hour.

The main steam relief valves were installed as received from the factory. The setpoints were adjusted, verified, and indicated on the valves by the vendor prior to shipment. Proper manual and automatic actuation of the main steam relief valves was verified during the preoperational test program.

It is recognized that it is not feasible to test the main steam relief valve setpoints while the valves are in place or during normal plant operation. The valves are mounted on 6-inch-diameter, 1500-pound, primary service rating flanges so that they may be removed for maintenance or bench checks and reinstalled during normal plant shutdowns. The external surface and seating surface of all main steam relief valves are 100 percent visually inspected when the valves are removed for maintenance or bench checks.

Operational tests of the main steam relief valves are performed once per operating cycle by means of an automatic actuation of the ADS valve logic circuitry from a simulated or actual initiation signal and by means of a manual actuation of all the main steam relief valves until thermocouples or acoustic monitors downstream of the valves indicate steam is flowing from the valve. This can also be demonstrated by the response of the turbine control valves or bypass valves, by a change in measured steam flow, or by any other method suitable to verify steam flow.

Main steam relief valves are removed and bench-tested following each operating cycle. The testing procedures include criteria for set pressure and seat leakage to determine valve acceptability. Monitoring and recording of valve stroke time, disc lift, and blowdown reseat pressure are included in the test to determine proper valve operation. Bench-testing is also required following any activity that will affect valve operability or set pressure prior to installing the valve.

During unit operation, discharge tailpipe temperatures and acoustic monitors are monitored and evaluated to determine if the valves are leaking excessively.

In response to NUREG-0578, Item 2.1.2, "Performance Testing for Relief and Safety Valves," TVA elected to participate in the BWR Owners Group Test Program of the safety/relief valves. The test program addressed those conditions that could result in single-phase liquid or two-phase flow through the safety/relief valves at low-pressure conditions.

The results of the tests are summarized in the BWR Owners Group S/RV Test Program Final Report, entitled "Analysis of Generic BWR Safety/Relief Valve Operability Test Results," NEDO-24988, submitted to D. G. Eisenhut by T. J. Dente, September 25, 1981.

The tested valves satisfy the acceptance criteria for operability; and therefore, the operational adequacy of the Browns Ferry MSRVs has been demonstrated.