10.2 TURBINE GENERATOR

The main turbine receives steam from the two steam generators, and converts a portion of the available enthalpy to electrical energy by driving a generator. Figures 10.2-2 to 10.2-4 show the turbine generator design features and their related flow diagrams.

10.2.1 DESIGN BASES

The design bases of the turbine generator are:

a) The turbine generator is designed to operate from 0 to 100 percent load at varying steam pressures shown in Figure 10.2-1.

b) The turbine generator is designed to trip automatically under upset, emergency, or faulted conditions.

c) The turbine generator is designed to regulate steam flow to the turbine, depending on load requirements (load following).

d) The turbine generator is tripped when the reactor is tripped. This is the only restriction imposed by the Nuclear Steam Supply System (NSSS) on turbine operation.

→(DRN 04-719, R14)

e) The turbine generator is designed to the Westinghouse Process Specification and/or Design Specifications equal to or exceeding the original Process Specification.

←(DRN 04-719, R14)

Westinghouse, over the years, has developed its own specifications which are designed specifically for turbines and generators. Westinghouse, through its own research programs and by reviewing applicable changes to the Society Codes and Standards, continuously updates its own standards. Generally Westinghouse specifications are more restrictive than the closest similar Society Codes or Standards. The Process Specifications used on the subject unit are the same as those used on all of the Westinghouse nuclear units designed and built in the same period.

10.2.2 DESCRIPTION

10.2.2.1 General Description

The turbine generator is a Westinghouse unit and is provided with automatic devices, alarms, and trips that control and regulate its operation.

→(DRN 04-719, R14; 06-812, R15; EC-8465, R307)

The turbine generator has an 1239 MWe output at normal hydrogen pressure of 60 psi running at 1800 rpm, and typical conditions shown in Figure 10.2-2. The turbine is tandem-compound, reaction type with one stage reheat and consists of one double flow, high pressure cylinder and three double flow, low pressure cylinders driving in tandem. The generator is a hydrogen and water cooled, four pole unit. The rated steam conditions at the turbine inlet are 796.4 psia and 1198.2 Btu/lb.

←(DRN 04-719, R14; 06-812, R15; EC-8465, R307)

No safety related equipment is located in the vicinity of the turbine generator.

10.2.2.2 Component Description

10.2.2.2.1 High Pressure Turbine

→(DRN 04-719, R14)
The high pressure turbine is a double flow element employing full arc admission through blading in each end of the element. See Figure 10.2-7.

The steam enters the high pressure element through two throttle valve steam chest assemblies, one located on each side of the turbine. The steam chest outlets are connected to the high pressure casing through four inlet pipes, each of which connects to a inner cylinder enclosed within the high pressure casing. Two of these inlet connections are in the base and two are in the cover. The steam flows axially in both directions from the inlet flow guide to the reaction blading to the six exhaust openings (two in the cover and four in the casing base), then through the cross-under piping to the moisture separator-reheaters. Crossover pipes return the steam through the reheat stop and interceptor valves to the three low pressure turbines.
←(DRN 04-719, R14)

10.2.2.2.2 Low Pressure Turbine

The low pressure turbine is of a double flow design employing reaction blading. This element consists of a double flow rotor assembly, an outer cylinder, two inner cylinders, and blade rings.

The rotor assembly consists of a shaft with ten shrunk-on discs and two shrunk-on couplings. The low pressure turbine blading is carried on the rims of ten shrunk-on discs. Steam enters the top of the outer cylinder and is routed to the inlet chamber of the inner cylinders through internal channels.

In the inlet chamber, the steam splits into two portions and flows axially through the blading at each end of the LP rotor to the condenser. The shrunk-on discs are made of NiCrMoV alloy steel.

10.2.2.2.3 Turbine Steam Valves

The unit is provided with two throttle valve steam chest assemblies, one located on each side of the high pressure turbine casing. Each assembly consists of the two horizontally mounted throttle valves and two plug type governing valves. Each of these valves is controlled by the Electrohydraulic Governing System through individually operated valve actuators. The valves are closed by springs, providing them with a fail-safe feature.

A low pressure intercept valve and a low pressure stop valve are installed in each steam inlet pipe to each low pressure turbine element. Butterfly-type valves are used. Provisions are made on all valves for on-load testing over the full work stroke.

10.2.2.2.4 Moisture Separator-Reheater

→(DRN 00-786, R11-A; 02-90, R11-A)
Two horizontal axis, cylindrical shell combined moisture separator and reheater assemblies are installed in the steam lines connecting the high pressure and low pressure turbines. Steam from the high pressure turbine passes up through the moisture separator. The water separated from the steam is drained from
←(DRN 00-786, R11-A; 02-90, R11-A)

→(DRN 00-786; 02-90)
the moisture separator-reheater to the moisture separator reheater shell drain tank that drains into the shell side of the No. 2 intermediate pressure feedwater heater. The steam then flows through the reheater section of the moisture separator-reheater, where it is heated by a steam tube bundle. Main steam is supplied to this tube bundle from the main steam line. The condensate from this tube bundle is drained to the moisture separator reheater drain collector tank, which drains into the shell side of the high pressure feedwater heaters.
←(DRN 00-786; 02-90)

Safety valves are provided on the moisture separator-reheater for overpressure protection.

10.2.2.2.5 Generator

The 25 kV, 60 Hz, four-pole generator has a rating of 1,333,200 kVA at 60 psig hydrogen pressure when operating at 0.9 power factor. The generator employs hydrogen for cooling the rotor conductors. The hydrogen is circulated by fans mounted on the exciter end of the shaft. The normal operating hydrogen pressure is 60 psi. Water is used for cooling the hydrogen and stator.

The generator frame is a welded steel structure suitably bolted and seal-welded to form a gas-tight casing. The center section contains the core and windings.

10.2.2.2.6 Extraction Steam System

The Main and Extraction Steam Systems are shown in Figure 10.2-4.

→(DRN 00-786)
The heating steam for the feedwater heaters is extracted from the turbine as follows: extractions for the high pressure heaters (1A, 1B, and 1C) are from the high pressure turbine element; intermediate pressure heaters (2A, 2B, and 2C) are from high pressure turbine exhaust; the extractions for the remaining intermediate pressure heaters 3A, 3B and 3C; 4A, 4B and 4C; and low pressure heaters 5A, 5B and 5C; and 6A, 6B and 6C are from the low pressure turbine elements. Shell side condensate of high pressure heaters 1A, 1B and 1C is drained into intermediate heaters, 2A, 2B, and 2C. The condensate accumulated in internal heaters 2A, 2B, and 2C are then pumped by the three heater drain pumps to the steam generator feedwater pump suction common header. Alternate drains are provided to automatically drain all heaters directly to the condenser at high heater water level. In addition, heaters 2A, 2B, and 2C collect the drains from moisture separator reheater shell sides through moisture separator shell drain tanks as shown on Figure 10.4-4 (for Figure 10.4-4, Sheet 1, refer to Drawing G155, Sheet 1). Extraction steam valves and their closure times are described in Table 10.2-1.
←(DRN 00-786)

10.2.2.2.7 Digital Electrohydraulic Control System (DEH)

The turbine is equipped with a digital electrohydraulic (DEH) control system shown on Figure 10.2-6, to control turbine valve movement. The system is designed to provide automatic speed/load control and overspeed protection for the turbine.

The flow of the main inlet steam is controlled by the throttle and governing valves. Each valve is actuated by an actuator assembly mounted directly on the valve. The valves are spring loaded and close automatically whenever the unit is tripped manually or automatically by protective signals.

DEH control is a digital system with an analog subsystem. It positions the throttle and governing valves by electrohydraulic servo loops. DEH Control System receives three feedbacks from the turbine: speed, generator MW output, and first-stage pressure which is proportional to the turbine load. The feedback signals are used to develop control signals to turbine steam valves for speed/load control of the turbine and overspeed protection.

10.2.2.2.8 Overspeed Protection

The turbine generator is provided with two overspeed protection systems:

a) Electrical

b) Mechanical Overspeed Protection System

The electrical system and the mechanical system do not share any common sensing devices. Interfacing between the two systems are illustrated on Figure 10.2-6.

The Electrical Overspeed Protection System

The electrical overspeed protection is achieved through the Overspeed Protection Control (OPC) System. Figure 10.2-9 shows the logic.

The OPC system is an electrohydraulic control system that controls turbine overspeed in the event of a partial or complete loss of load, and if the turbine reaches or exceeds 103 percent of rated speed. It trips the turbine at 111.5 percent of rated speed.

The operator's panel, which is located on the Reactor Turbine Generator Board (RTGB), is the units control center. Operator settings made at that panel are used by the electronic controller to position the steam valves by comparing the turbine speed, low pressure turbine inlet pressure, and megawatt signals to the reference setting selected by the operator. These signals are produced through speed pulse reluctance pickup, LP turbine inlet pressure transducer and generator KW transducer, respectively. These quantities are compared and if they differ by a preset amount, protective logic is activated. The signals for the transducers are checked against high and low reference voltage to determine when a transducer fails high or low.

Overspeed information (in rpm) is supplied by reluctance pickup speed sensors coupled magnetically to a notched wheel on the turbine rotor. Four speed sensors are used to monitor turbine speed as shown on Figure 10.2.5. Three speed analogue signals from these speed sensors are brought to DEH control system selector for development of one output signal. This output signal is selected from two out of three inputs and is used for turbine speed control and overspeed protection. All speed sensors are Electro Products, EP Model 3040A, EP Part 721374.

The OPC monitor light in the main control room is lit to indicate failure of any of the following:

a) KW Transducer

b) OPC Pressure Transducer

c) Speed Channel Failure

→

The CIV function described below has been disabled. During partial loss of load, the LP turbine inlet pressure transducer (representing the mechanical power input for the turbine) and the generated power (as detected by the megawatt transducer) are compared. If they differ by an adjustable amount, and neither transducer has failed, the Close Interceptor Valve (CIV) Flip-Flop is set. This causes the interceptor valve to close. If the generator breaker does not open, this condition is detected as a partial load loss. The interceptor valves remain closed for a short period of time. After the time delay, the CIV Flip-Flop is reset and the interceptor valves reopen. Closing the interceptor valves provides a momentary reduction in generator input and aids in achieving power system stability.

←

If the load is greater than 30 percent, as determined by the LP turbine inlet pressure transducer, and the generator breaker opens, the Load Drop Anticipation (LDA) is set, initiating OPC action. All governor and interceptor valves are then rapidly closed. Load drop reset time is fixed at 10 seconds. After a 10 second reset time, the interceptor valves will reopen. Both CIV and LDA load loss circuits are inoperable below 22 percent rated load.

The turbine steam valves close rapidly when the hydraulic fluid drain valves are opened. Table 10.2-2 shows which drain valves are opened for overspeed protections. The hydraulic fluid solenoid drain valves 20-1/ OPC and 20-2/OPC open to close the governor and interceptor valves. To trip the turbine the hydraulic fluid solenoid drain valve 20/ET and auto stop oil header drain valve open to allow all turbine steam valves to close. Redundant features are described in Table 10.2-2 and shown on Figure 10.2-6.

Mechanical Overspeed Protection System

The mechanical overspeed device consists of an eccentric weight mounted at the end of the turbine shaft. The weight is balanced in position by a spring until the turbine speed reaches 111 percent of normal speed. The centrifugal force of the weight then overcomes the spring compression and the weight activates a trigger which opens the overspeed trip valve depressurizing the auto stop oil header. Loss of pressure in the auto stop oil header allows the diaphragm operated auto stop oil header drain valve to open and thus trips all turbine valves. An air operated pilot valve used to monitor all extraction non-return valves is also triggered from loss of auto stop oil header pressure.

The auto stop valve is also tripped when any one of the protective devices such as the low bearing oil, low-vacuum, solenoid or thrust bearing trip, are actuated.

Provisions are made for testing the overspeed trip mechanism without actually overspeeding the turbine. If the overspeed trip mechanism reset lever is held to prevent the trip valve from opening, it can be tested without taking the unit off line or removing load. This is accomplished by admitting oil under pressure to the chamber beneath the trip weight and noting the pressure required to move the weight outward.

10.2.2.2.9 Valve Closure Times

All turbine steam valves close in 0.25 seconds after overspeed condition is detected. This time includes 0.1 second signal delay time and 0.15 second valve closure time.

10.2.2.2.10 Overspeed Protection System Evaluation

The turbine is provided with two diverse and redundant overspeed protection systems; they are the electrical and mechanical overspeed protection systems.

The electrical overspeed protection system consist of two subsystems. They are the overspeed protection controllers (OPC) which controls turbine speed when the speed reaches 103 percent and the overspeed protection system which closes all turbine valves when turbine speed reaches 111.5 percent of rated speed.

At 103 percent speed, the redundant hydraulic fluid drain valves 20-1/OPC and 20-2/OPC are energized. Opening of these valves will drain the Control (Governor) Valve Emergency Trip Fluid which results in the closing of the control (governor) and interception valves. The momentary closing of these valves will reduce turbine speed but will not trip the unit.

At 111 percent speed, the mechanical overspeed trip system will open the Mechanical Overspeed and Manual Trip Device. This results in the draining of the Auto Stop Oil Header. The resultant low pressure in the header will open the Auto Stop Oil Header Drain Valve. In addition, the low pressure in this system as detected by 63-1/AST, 63-2/AST and 63-3/AST, will result in the opening of valve 20/ET. The opening of either the Auto Stop Oil Header Drain Valve or valve 20/ET will drain the Stop (TV) Emergency Trip Fluid Header and the Control (Governor) Valve Emergency Trip Fluid Header which results in the closing of all turbine steam valves.

At 111.5 percent speed, the electric overspeed trip system will energize redundant valves 20-1/AST and 20-2/AST. The opening of these valves will also drain the Auto Stop Oil Header. The resultant low pressure in this header will open the Auto Stop Oil Header Drain Valve. In addition, the low pressure in this system, as detected by 63-1/AST, 63-2/AST and 63-3/AST, will result in the opening of valve 20/ET. The opening of either the Auto Stop Oil Header Drain Valve or valve 20/ET will drain the Stop (TV) Emergency Trip Fluid Header and the Control (Governor) Valve Emergency Trip Fluid Header which results in the closing of all turbine steam valves.

Power for the redundant hydraulic fluid drain valves is independent and provided from 125V dc bus TGB-DC-A and TGB-DC-B,respectively. These buses are powered from bus TGB-DC which is normally energized from battery chargers TGB-A and TGB-B. Upon loss of offsite power (LOOP), battery TGB supplies power to the dc system for a minimum of 90 minutes following the event.

10.2.3 TURBINE DISK INTEGRITY

As a result of Westinghouse testing, new criteria have evolved for predicting the missile containing ability of the low pressure turbine structures. The previous calculations have been redone using these new criteria and the results show the original position on the containment of disk fragments within the turbine casing can no longer be maintained.

The Turbine Overspeed Protection System is completely independent of the normal turbine governing and mechanical overspeed protective devices. In the event of a turbine trip, this system ensures that the turbine-generator unit will not exceed the design overspeed which is 120 percent of rated speed.

Present manufacturing and inspection techniques for turbine rotor and disk forging makes the possibility of an undetected flaw extremely remote. Forgings are subject to inspection and testing both at the forging suppliers and at Westinghouse. Current design procedures are well established and conservative, and analytical tools such as finite element and fracture mechanics techniques allow in depth analysis of any potential trouble spots such as area of stress concentration or inclusions which could give rise to crack propagation.

10.2.3.1 Materials Selection

10.2.3.1.1 High Pressure Turbine

→(DRN 04-719, R14)

The high pressure turbine element, as shown on Figure 10.2-7 is of a double flow design. Flow design is thrust balanced. Steam from the four control valves enters the turbine element through four inlet pipes. These pipes feed into an inner cylinder and then to the inlet flow guide. Steam leaves the inlet flow guide and is directed by full arc admission through the reaction blading. The reaction blading is mounted in the blade rings which in turn are mounted in the turbine casing.

The high pressure rotor is made of NiCrMoV alloy steel. The specified minimum mechanical properties are as follows:

Tensile strength	$\geq$ 820 N/M^2
Yield strength (0.2 percent offset)	580 – 680 N/M^2
Elongation in 2 in. percent, min.	16
Reduction of Area, percent, min.	50

←(DRN 04-719, R14)

→(DRN 04-719, R14)

Impact Strength, Charpy V-Notch (min. at room temperature)	≥100J
50 percent fracture appearance transition °F, temperature, maximum	50

The main body of the rotor weighs approximately 125,000 pounds. The approximate values of the transverse centerline diameter, the maximum diameter, and the main body length are 36 in., 66 in., and 138 in., respectively.

The inner cylinder casing and the guide blade carrier rings (ASTM A217 Gr. CA5) are made from stainless steel castings. The outer casing cover and outer base (both ASTM A216-66) are made of carbon steel castings. The specified minimum mechanical properties are as follows:

	OUTER CYL. CASING	INNER CYL. CASING GUIDE BLADE CARRIER
Tensile Strength, psi, min.	70,000	540 – 690 N/M^2
Yield Strength, psi, min.	36,000	≥ 355 N/M^2
Elongation in 2 in. percent, min.	22	18
Reduction of Area, percent, min.	35	45

The bend test specimen is capable of being bent cold through an angle of 90 degrees and around a pin one inch in diameter without cracking on the outside of the bent portion.

The approximate weights of the two guide blade carriers, the outer casing cover, the outer casing base and inner cylinder casing are 63,500 lbm., 115,000 lbm., 115,000 lbm. and 37,000 lbm, respectively.

The casing cover and base are tied together by means of more than 100 studs. The stud material is hot rolled alloy steel (ASTM A193-66 Gr. B16) except in critical areas near the glands and #2 blade rings. The studs in critical areas of the horizontal joint are "high strength" studs of forged stainless steel (ASTM A565 Gr. 616 Cond. HT and UNS 542200). These studs have the following mechanical properties:

	ASTM A193		ASTM A565	UNS 542200
	2 1/2 In. and Less	Over 2 1/2 to 4 In.		
Tensile Strength, psi, min.	125,000	115,000	140,000	135,000
Yield Strength, psi, min. (0.2 percent offset)	105,000	95,000	110,000	110,000
Elongation in 2 in., percent, min.	16	16	13	14
Reduction of Area, percent min.	50	50	30	32

←(DRN 04-719, R14)

10.2.3.1.2 Low Pressure Turbines

The double flow low pressure turbines incorporate high efficiency blading and diffuser type exhaust design. The low pressure turbine cylinder is fabricated from carbon steel plate to provide uniform wall thickness, reducing thermal distortion to a minimum. The entire outer casing is subjected to low temperature exhaust steam.

The temperature drop of the steam from its inlet to the LP turbine to its exhaust from the last rotating blades is taken across three walls, an inner cylinder number 1, a thermal shield, and an inner cylinder number 2. This precludes a large temperature drop across any one wall, except the thermal shield which is not a structural element, thereby virtually eliminating thermal distortion. The fabricated inner cylinder number 2, is supported by the outer casing at the horizontal centerline and is fixed transversely at the top and bottom and axially at the centerline of the steam inlets, thus allowing freedom of expansion independent of the outer casing. Inner cylinder number I is, in turn, supported by inner cylinder number 2, at the horizontal centerline and fixed transversely at the top and bottom and axially at the centerline of the steam inlets, thus allowing freedom of expansion independent of inner cylinder number 2. Inner cylinder number 1 is surrounded by the thermal shield. The steam leaving the last row of blades flows into the diffuser where the velocity energy is converted to pressure energy.

The disks are made of NiCrMoV alloy steel. There are two identical sets of five shrunk-on disks, one set for each of the two flows. Each disk in a set is numbered; the disk closest to the transverse centerline is designated number 1. When the turbine is in operation each disk experiences a different stress and is, consequently, machined from a suitable grade of alloy steel. Disk number 2 experiences the highest stress, while disk number 5 experiences the lowest. The specified mechanical properties disk materials are shown in Table 10.2-3.

The outer cylinder and the two inner cylinders are fabricated mainly of ASTM A515-65 material. The specified minimum mechanical properties are shown in Table 10.2-3.

The rotors are made of NiCrMoV alloy steel. These specified minimum mechanical properties are described in Westinghouse's document IOPRO3 entitled "Calculation Method for Critical Crack Size" and its attachment "L. P. Turbine Disk Information."

10.2.3.2 <u>Fracture Toughness</u>

Fracture of the disks into 90, 120 and 180 degree segments was considered as criteria in selecting number of disk segments.

A 120 degree segment has an initial translational kinetic energy 12.5 percent greater than that of a 90 degree segment, however it also has a 33 percent greater rim periphery resulting in greater energy loss while penetrating the turbine casing. This results in nearly equal kinetic energy of the 90 and 120 degree segments leaving the turbine casing. However, since the 90 degree segments have the smaller impact areas they represent a more severe missile.

The initial translational kinetic energy of a half disk is equal to that of a quarter disk. Because of kinematic considerations, a half segment will always impact with the rotor after fracture. The 180 degree segment, due to its larger size, will subject the stationary parts to greater deformation. As a result the 180 degree segment will leave the turbine casing with lower energy than the 90 degree segment.

For the purpose of evaluating the missile containing ability of the turbine structure, the shrunk-on disks have been postulated to fail in four quarters.

To evaluate the missile containing ability of its steam turbines, Westinghouse conducted a test program at its research laboratories.

The tests involved spinning alloy steel disks to failure within various carbon steel containments. The disks were notched to ensure failure in. given number of segments at the desired speed. Test results were correlated with various parameters descriptive of the missile momentum and energy and the geometry of the missile and containment.

The containments were of varying geometry but all were axisymetric and concentric with the rotation axis of the disk. They ranged in complexity from a circular cylinder to containments which approximated actual turbine construction.

From these tests, logical criteria has evolved for predicting the missile containing ability of various turbine structures. In addition, the tests also served to determine the mode of failure which certain structural shapes common to turbine construction undergo when impacted by a missile. This is important since the mode of failure has a great influence on the account of energy absorbed by the containment.

→(DRN 00-786, R11-A)

Normal operating temperatures of each key point at high pressure and low pressure turbines are show in Figure 10.2-2. The minimum throttle steam temperature required for rolling the HP turbine from a cold start is 388°F with a corresponding pressure of 200 psig. The maximum LP turbine exhaust hood temperature is limited to 175°F.

←(DRN 00-786, R11-A)

A detail analysis of brittle rupture probability of low pressure turbine disks is presented in Reference 1.

10.2.3.3 High Temperature Properties

→(DRN 04-719, R14)

Since the steam at the turbine stop valve only has a temperature of 517.6°F for Waterfored 3, it is not considered that creep processes will occur on the HP rotors and therefore, stress rupture properties are not relevant.

Analysis for ductile burst due to overspeed, fracture resulting from high cycle fatigue cracking, and fracture from low cycle fatigue cracking are given in Reference 3.

←(DRN 04-719, R14)

10.2.3.4 Turbine Disk Design

The turbine is designed to withstand normal conditions, anticipated transients, and accidents resulting in a turbine trip without loss of structural integrity. A record search for compliance with Branch Technical Position MTEB10-1 has not been performed, because the turbine has been manufactured and placed in storage prior to issuance of the Branch Position. However, the turbine is designed to the following criteria:

a) The highest anticipated speed from loss of load is less than 110 percent of rated speed. The turbine is designed for 120 percent of rated speed. The Branch Position requires design overspeed five percent above the highest anticipated speed.

b) At 115 percent of rated speed, the average tangential stress in low-pressure discs or high-pressure rotors due to centrifugal force, interference fit, and thermal gradients do not exceed 0.75 of the minimum specified yield strength of the materials.

c) The rotors are designed so that the response levels at the natural critical frequency of the turbine shaft assemblies are controlled between 0 speed and 20 percent overspeed, so as to cause no distress to the unit during operation.

d) The bore of the high-pressure rotors can be inspected in-service with the rotors removed from the cylinder. The rims of the low-pressure discs can also be inspected. There are, however, no reliable methods for in-service inspection keyways and bores without disassembling.

10.2.3.5 Preservice Inspection

The preservice inspection and test methods applied during the manufacturing process assure that the product complies with the specifications.

The low pressure turbine rotor body and disk are heat treated nickel-chromium-molybdenum-vanadium alloy steel procured to specifications that define the manufacturing method, heat treating process, and the test and inspection methods. Specific tests and test documentation, in addition to dimensional requirements, are specified for the forging manufacturer.

Inspection and tests for the low pressure turbine rotor body which are conducted at the forging manufacturer's plant include:

a) A ladle analysis of each heat of steel for chemical composition is to be within the limits defined by the specification.

b) Following preliminary machining and heat treatment for mechanical properties but prior to stress relief, all rotor diameters and faces are subjected to ultrasonic tests defined in detail by a Westinghouse specification which exceeds the requirements of ASTM A 418-64.

c) After all heat treatment has been completed, the rotor forging is subjected to a thermal stability test defined by a Westinghouse specification which is more restrictive than the requirements of ASTM A 472-69.

d) The end faces of the main body and the fillet areas joining the body to the shaft ends of the machined forging are subjected to a magnetic particle surface inspection as defined by ASTM A 275-71.

e) After the bore of the rotor is finished machined, the bore is given a visual examination followed by a wet magnetic particle inspection defined in detail by a Westinghouse specification which exceeds the requirements of ASTM A 275-71.

f) Utilizing specimens removed from the rotor forging at specified locations, tensile, Charpy V Notch impact and Fraction Appearance Transition Temperature (FATT) properties are determined following the test methods defined by ASTM A 370-67.

After the rotor body is finished machined at Westinghouse, the rotor surface is given a fluorescent magnetic particle examination as defined by a Westinghouse specification which is similar to ASTM E 138-63.

Inspection and tests for the low pressure turbine rotor disks which are conducted at the forging manufacturer's plant include:

a) The ladle analysis of each heat of steel is to be within the composition limits defined by the specification.

b) After all heat treatment, rough machining and stress relief operations, the hub and rim areas of the completed disk forging are subjected to ultrasonic examinations. These ultrasonic tests are defined by a Westinghouse specification which exceeds the requirements of ASTM A 418-64.

c) The tensile, Charpy V Notch impact and FATT properties are determined from specimens removed from the disks at specific locations. The test method used for determining these mechanical properties are defined by ASTM A 370-67.

After the disks are finished machined at Westinghouse, the disk surfaces except blade grooves are given a fluorescent magnetic particle examination as defined by a Westinghouse specification which is similar to ASTM E 138-63.

After the preheated disks are assembled to the rotor body to obtain the specified interference fit, holes are drilled and reamed for axial locking pins at the rotor and disk interface. These holes are given a fluorescent penetrant inspection defined by a Westinghouse specification which is similar to ASTM E 165-65.

Prior to shipping, each fully bladed rotor is balanced and tested to 120 percent of rated speed in a shop heater box.

→(DRN 04-719, R14)

The high pressure turbine rotor has the same basic material composition as the low pressure rotors. This nickel-chromium-molybdenum-vanadium alloy steel forging is procured, processed, and subjected to the following tests:

a) Ladle analysis

b) Ultrasonic tests

c) Tensile and impact mechanical properties

d) Heater box and 120 percent speed test

←(DRN 04-719, R14)

10.2.3.6 In-service Inspection

Various parameters for the turbine generator and accessories are recorded and alarmed in the main control room and logged on the plant monitoring computer. A full compliment of controls and instruments are provided in order that the turbine-generator may be started, operated, tested, and shutdown from the main control room.

Periodic turbine generator inspections, including inspections and tests of the main steam stop and control valves and reheat stop and control valves, will be performed on Waterford 3 with the goal of maximizing turbine generator reliability and efficiency and thus minimizing long-term power generation costs.

Factors that determine the timing of inspections include:

a) Operating symptoms: vibration, abnormal pressures and temperatures, loss of capability, increase in heat rate, etc.

b) Mode of Operation: number of start-ups, cyclic or base loading, etc.

c) Findings from prior inspections both in-house and at other utilities,

d) Recommendations of the turbine-generator manufacturer.

The purpose of these inspections are to search for, correct, and minimize the causes of items, such as:

a) Wear: bearings, gears, linkages, valve parts, packings, spill strips, hydrogen seals, collector rings, etc.

b) Erosion: solid particle in dry regions, moisture in wet regions.

c) Depositions: collections in the stream path that result in loss of capability or efficiency and possible exposure to undesirable chemicals.

d) Distortions and misalignment.

e) Cracking: thermal or fatigue.

f) Mechanical damage: buckets, diaphragms, stator core, etc.

g) Contamination of fluid systems.

h) Reduction in integrity of insulation on stator bars, field winding, or core laminations.

i) Loosening of generator hardware, blocking, supports, core, etc.

j) Generator contamination (oil or dirt) blocking of ventilation passages.

k) Excessive heating in electrical systems.

l) Excitation system electrical and mechanical problems.

When the turbine is disassembled, a visual, a magnetic particle and an ultrasonic examination is made externally on accessible areas of the high pressure rotor, low pressure turbine blades and low pressure discs. The coupling bolts are visually examined.

The methodology used to calculate the sizes of the critical cracks in the low pressure rotor discs and the frequency of inspection is described in Westinghouse's document IOPRO3 entitled "Calculation Method for Critical Crack Size" and its attachment "L. P. Turbine Disc Information."

→(DRN 06-722, R15)

a) Throttle, governor, reheat stop and interceptor valves are inspected after initial start-up of a turbine. As per the following program some valves are inspected 12-15 months after start-up, others 24-27 months, and the remainder 36-39 months so that all valves are inspected at least once in the 39 months of operation following initial start-up. After this initial inspection program is completed, valves are inspected as described in Technical Requirements Manual Section 3/4.3.4.

b) Functional test of the turbine steam inlet valves is performed as described in Technical Requirements Manual Section 3/4.3.4. This test can be made while the unit is carrying load. The purpose of the test is to insure proper operation of throttle, governor, reheat stop and the interceptor valves. The operation of these valves are observed during the test by an operator stationed at the valves. Movements of the valves should be smooth and free. Jerky or intermittent motion may indicate a buildup of deposits on shafts.

←(DRN 06-722, R15)

These frequent in-service inspections, coupled with a comprehensive monitoring program during operation, will assure efficient and reliable turbine generator performance over the life of the plant.

10.2.3.7 SYSTEM AND OPERABILITY REQUIREMENTS

→(DRN 06-722, R15)

Operability requirements are imposed to ensure that the turbine overspeed protection instrumentation and the turbine speed control valves are OPERABLE and will protect the turbine from excessive overspeed. Protection from turbine excessive overspeed is required since excessive overspeed of the turbine could generate potentially damaging missiles which could impact and damage safety related components, equipment, or structures. Operability requirements are contained in Technical Requirements Manual Section 3/4.3.4.

←(DRN 06-722, R15)

→(DRN 06-722, R15)

←(DRN 06-722, R15)

10.2.4 EVALUATION

The steam generated in the two steam generators is not normally radioactive. Only in the event of primary-to-secondary system leakage (due to steam generator tube leak) is it possible for the SPCS to become radioactively contaminated. In this event, monitoring of condenser air discharge will detect any contamination. A full discussion of the radiological aspects of primary-to-secondary leakage, including anticipated operating concentrations of radioactive contaminants, means of detection of radioactive contamination, anticipated releases to the environment, and limiting conditions for operation, are included in Chapters 11 and 12.

A description of the protection provided by bypassing and dumping main steam to the condenser and atmosphere in case of sudden load rejection by the turbine-generator is included in Subsection 10.4.4. A description of the protection provided by exhausting steam to the atmosphere through the safety valves in the event of a turbine generator trip and coincident failure of the SBS is given in Section 10.3.

→(DRN 05-861, R14)

The expected speed rise of the turbine unit upon a breaker opening at the maximum expected load is less than the design limit of 120% based on the failure of the OPC. With successful operation of the OPC, the expected speed rise would be less.

←(DRN 05-861, R14)

The overspeed protection devices showing provided redundancy is shown in Table 10.2-2.

SECTION 10.2: REFERENCES

1. "Analysis of the Probability of the Generation and Strike of Missiles from a Nuclear Turbine" by Westinghouse Electric Corporation Steam Turbine Division Engineering, dated March, 1974.

→(DRN 04-719, R14)

2. “Turbine Missile Report for Entergy Operations Waterford Unit 3,” Siemens Westinghouse Power Corporation, CT-27326, Revision No. 0, September 27, 2002.

3. “Missile Generation Risk Assessment for Original and Retrofit Nuclear HP Rotors,” Siemens Westinghouse Power Corporation, EC-02262, December 17, 2002.

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←(DRN 04-719, R14)

TABLE 10.2-1 Revision 11-A (02/02)

EXTRACTION STEAM VALVE ARRANGEMENTS
FOR TURBINE OVERSPEED PROTECTION

Heaters	Extraction Point	Description of Extraction Valves	Motor Operated Valve Closure Times
1A, 1B & 1c	HP Turbine	One power assisted check valve and one motor operated valve, both located at the turbine.	120 secs.
→(DRN 00-873)			
2A, 2B & 2C	Cross-Under Piping	One power assisted check valve and one motor operated valve, both located at extraction points.	152 secs.
←(DRN 00-873)			
3A, 3B & 3C	LP Turbine	3-motor operated valves, one located at each heater, and three power assisted check valves each located at the turbine.	100 secs.
4A, 4B & 4C	LP Turbine	3-motor operated valves, one located at each heater, and six power assisted check valves with two valves located at the turbine extraction point.	152 secs.
5A, 5B & 5C	LP Turbine	There are no valves in extraction lines to these heaters. The heaters are located in the condenser.	-
6A, 6B & 6C	LP Turbine	There are no valves in extraction lines to these heaters. The heaters are located in the condenser.	-

TABLE 10.2-2

TURBINE OVERSPEED PROTECTION DEVICES

	Set Point	Control Description	Overspeed Control System	Hydraulic Fluid Drain Valves	Redundancy
Main Speed Control Loop	Rated Speed	When unit exceeds rated speed the governor and interceptor valves move to the closed position.	DEH*		Normal speed control and overspeed protection analogue signal is developed from 2 out of 3 redundant inputs.
Overspeed Protection Controller (Breaker Status)	30% load + Open Breaker	At 30% higher load and the main breaker opens, the governor and the interceptor valves close rapidly.	DEH*	20-1/OPC and 20-2/OPC	The redundant hydraulic fluid drain valves are energized for rapid closure of all governor interceptor valves.
Overspeed Protection Controller	103%	The governor and interceptor valves close rapidly when unit exceeds 103% of rated speed.	Overspeed* Protection Controller	20-1/OPC and 20-2/OPC	Two redundant hydraulic fluid drain valves are energized for rapid closure of all governor and interceptor valves.
Mechanical Overspeed Trip	111%	At 111% of rated speed all turbine steam valves close rapidly	Eccentric weight opens the Mechanical Overspeed and Manual Trip Device and thus drains the Auto Stop Oil Header	Auto Stop Oil Header Drain Vlave and 20/ET	Throttle and reheater stop valves provide redundancy for governor and interceptor valves respectively, Loss of ASO header pressure opens diaphragm operated hydraulic fluid drain valve, and, to ensure turbine trip in case of failure of ASO header drain valve to open, the low pressure switches 63-1/AST, 63-2/AST and 63-3/AST energize to open the solenoid operated hydraulic fluid drain valve 20/ET.
Electric Overspeed Trip	111.5%	At 111% of rated speed plus 10 rpm, all turbine steam valves close rapidly	Overspeed Protection* Controller drains the Auto Stop Oil Header by energizing to open the redundant valves 20-1/AST and 20-2/AST.	Auto Stop Oil Header Drain Valve and 20/ET	Throttle and reheater stop valves provide redundancy for governor and interceptor valves respectively. Loss of ASO header pressure opens diaphragm operated hydraulic fluid dram valve, and, to ensure turbine trip in case of failure of ASO header drain valve to open, the low pressure switches 63-1/AST, 63-2/AST and 63-3/AST energize to open the solenoid operated hydraulic fluid drain valve 20/ET.
Remote Manual Trip		Speed recording and indicating Instrumentation in the Control Room.	Drains the Auto Stop Oil Header by energzing to open the redundant valves 20-1/AST and 20-2/AST	Auto Stop Oil Header Drain Valve and 20/ET	Throttle and reheater stop valves provide redundancy for governor and interceptor valves respectively. Loss of ASO header pressure opens diaphragm operated hydraulic fluid drain valve, and to ensure turbine trip in case of failure of ASO header drain valve to open, the low pressure switches 63-1/AST, 63-2/AST and 63-3/AST energize to open the solenoid operated hydraulic fluid drain valve 20/ET.

Note: Four redundant turbine speed sensors are used to monitor turbine speed and to provide three redundant input signals to DEH and OPC.

TABLE 10.2-3 Revision 3 (12/89)

LOW PRESSURE TURBINE MATERIALS

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		DISCS					ROTORS			CYLINDERS
		1	2	3	4	5	1	2	3	
Yield Strength, psi KSI	Min	100	100	90	100	100	100	100	120	35
	Max	110	110	110	115	115				
Tensile Strength (KSI)	Min	110	110	105	110	110	115	115	135	65
	Max						130	130	150	
Elongetion in 2 in. %	Min	18	18	19	18	18	17	17	14	23
in 8 in. %	Min									19
Reduction in Area %	Min	47	47	50	47	47	50	50	40	
Impact Strength At Room Temperature - Charpy V-Notch Ft-Lbs	Min	65	65	80	50	50	40	40	25	
50% Fracture Appearance Transition Temperature (°F)	Max	-105	-105	-115	0	0	30	30	60	
Material		NiCrMoV Alloy Steel					NiCrMoV Alloy Steel			ASTM-A515-65

Note: The above listed mechanical properties have been specified to the material suppliers.
The rotors and discs were individually tested by the suppliers to be within the specified limits.

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