10.2 Turbine Generator

The information in this section of the reference ABWR DCD, including all subsections, tables and figures, is incorporated by reference with the following departures and supplements.

STD DEP T1 2.4-2

STP DEP 1.1-2 (Figure 10.2-4)

STP DEP 10.2-1 (Figure 10.2-4)

STP DEP 10.2-2

STP DEP 10.2-3

STP DEP 10.2-4

STD DEP Admin (Figure 10.2-1)

10.2.1.2 Power Generation Design Bases

STP DEP 10.2-2

Power Generation Design Basis Three*—The T-G is designed to accept a sudden loss of full load ~~without exceeding design overspeed~~* with sufficient margin to the overspeed trip*.*

Power Generation Design Basis Five*—The failure of any single component will not cause the rotor speed to exceed the ~~design speed~~* Emergency Overspeed (EOS) trip setpoint*.*

STP DEP 10.2-3

Power Generation Design Basis Six*~~—The T-G is designed to support the plant availability goals by utilizing 2/3 or 2/4 coincident trip logic for all but the vibration trips (which are at least 2/2 per bearing). Similarly, all turbine control functions which are required for power generation will use at least dual redundant controllers and triply redundant control inputs.~~* Turbine control functions required for turbine protection possess sufficient redundancy such that failure of a single component input does not compromise the integrity of the turbine protection system.

10.2.2.1 General Description

STP DEP 10.2-1

The turbine-generator consists of an 188.5 rad/s (1800 RPM) *turbine, moisture separator/reheaters, generator, exciter, controls, and associated subsystems.*

The turbine consists of a double-flow, high-pressure unit, and three double flow low-pressure units in tandem. The high-pressure unit has ~~a single stage of steam~~ extraction points for reheater reheating steam and high pressure feedwater heating. *Moisture separation and reheating of the high-pressure turbine exhaust steam is performed by* ~~*four*~~ two *combined moisture separator/reheaters (MSRs).* ~~*Two MSRs are*~~ A MSR is *located on each side of the T-G centerline. The steam passes through the low-pressure turbines, each with four extraction points for the four low-pressure stages of feedwater heating, and exhausts into the main condenser. In addition to the* moisture separators in the *external MSRs, the* ~~*turbines are designed to separate water from the steam and drain it to the next lowest extraction point feedwater heater*~~ turbine steam path has provisions for removing some additional moisture and routing it to extraction lines.

The generator is a direct driven, three-phase, 60 Hz, 188.5 rad/s (1800 RPM) *synchronous generator with a water-cooled* ~~*stator*~~ armature winding *and hydrogen cooled rotor.*

The turbine-generator uses a digital monitoring and control system which, in coordination with the turbine Steam Bypass and Pressure Control System, controls the turbine speed, load, and flow for startup and normal operations. The control system operates the turbine stop valves, control valves, and ~~*combined*~~ *intermediate* stop and intercept *valves* ~~*(CIVs)*~~*. T-G supervisory instrumentation is provided for operational analysis and malfunction diagnosis.*

Automatic control functions are programmed to protect the Nuclear Steam Supply System through appropriate corrective actions (Section 7.7).

T-G accessories include the bearing lubrication oil system, electrohydraulic control (EHC) system, turbine hydraulic system, *turning gear, hydrogen* gas control ~~*and CO2*~~ *system, seal oil system, stator cooling water system, exhaust hood spray system, turbine gland sealing system,* MSR reheater heating steam system *and turbine supervisory instrument (TSI) system.*

STD DEP Admin

The T-G unit and associated piping, valves, and ~~*controls*~~ instruments *are located completely within the Turbine Building.* ~~*There are no safety-related systems or components*~~ The safety-related instruments *located within the Turbine Building* ~~*with the exception of*~~ are *the* safety-related *Reactor Protection System (RPS) sensors on the T-G unit*~~*. The safety-related switches or transducers*~~ *used to detect fast closure of the turbine* ~~*main stop and*~~ *control valves* and closure of the main stop valves and the Leak Detection and Isolation System (LDS) sensors used to detect ~~*and high*~~ *high* main *condenser* ~~*back*~~ shell *pressure*, low main steam header pressure, and main steam line leakage. The safety-related instrumentation is ~~*are*~~ *fail safe, hence any local failure associated with the T-G unit will not adversely affect any safety-related equipment. Failure of T-G equipment cannot preclude safe shutdown of the reactor.*

STD DEP T1 2.4-2

The Turbine Building contains the safety-related electrical switchgear and trip breakers for the condensate pumps for the mitigation of a postulated feedwater line break in accordance with Subsection 8.3.1.1.1.

10.2.2.2 Component Description

STP DEP 10.2-1

Main Stop and Control Valves*—Four high-pressure main stop and control valves admit steam to the high-pressure (HP) turbine. The primary function of the main stop valves is to quickly shut off the steam flow to the turbine under emergency conditions. The primary function of the control valves is to control steam flow to the turbine in response to the turbine control system.*

*The main stop valves are operated in an open-closed mode either by the emergency trip, fast acting valve for tripping, or by a small solenoid valve for testing. The disks are totally unbalanced and cannot open against full differential pressure. A bypass is provided to pressurize the below seat areas of the four valves. Springs are designed to close the main stop valve in approximately ~~0.20~~*0.30 *second under the emergency conditions listed in Subsection 10.2.2.5.*

Each stop valve contains a permanent steam strainer to prevent foreign matter from entering the control valves and turbine.

*The control valves are designed to ensure tight shutoff. The valves are of sufficient size, relative to their cracking pressure, to require a partial balancing. Each control valve is operated by a single acting, spring-closed servomotor opened by a high pressure fire-resistant fluid supplied through a servo valve. The control valve is designed to close in approximately ~~0.20~~*0.30 *second.*

Moisture Separator Reheaters*~~—Four~~*Two *horizontal cylindrical-shell, combined moisture separator/reheaters (MSRs) are installed in the steam path between the high and low pressure turbines. The MSRs serve to dry and reheat the HP turbine steam exhaust (crossaround steam), before it enters the low-pressure turbines. This improves cycle efficiency and reduces moisture-related erosion and corrosion in the low-pressure turbines. Crossaround steam is piped into the bottom of the MSR. Moisture is removed in chevron-type moisture separators, and is drained to the ~~moisture separator drain tank and from there to the heater drain tank~~* appropriate stage of feedwater heating*. ~~The dry crossaround steam next passes upward across the reheater which is supplied with main steam. Finally, the crossaround steam is routed to the combined intermediate valves (CIVs), which are located just upstream of the low-pressure turbines inlet nozzles.The reheaters drain, via drain tanks, to the forward pumped heater drain system, which discharges to the reactor feedwater pump suction. Safety valves are provided on the MSR for overpressure protection.~~* The steam next passes upward across the two reheater stages. Heating steam to the first reheater stage is supplied by extraction steam and heating steam to the second reheater stage is supplied with main steam. Reheated steam is routed to the intermediate stop and intercept valves, which are located just upstream of the low-pressure turbine inlet nozzles. Relief valves are provided on the MSR for overpressure protection.

***Combined Intermediate* Stop and Intercept *Valves* (Intermediate Stop Valves and Intercept Valves)**— *Two combined intermediate valves (CIVs) are provided for each LP turbine, one in each steam supply line, called the hot reheat line. The* combined intermediate valves (*CIV*s) *consists of two valves—the intercept valve and the intermediate stop valve, which share a common casing. Although they utilize a common casing, these valves have entirely separate operating mechanisms and controls. The function of the CIVs is to protect the turbine against overspeed from steam and water energy stored between the main stop and control valves and the CIVs. One CIV is located on each side of each LP turbine.* Hydraulically operated intermediate stop valves (ISVs) and intercept valves (IVs) are provided in each hot reheat line just upstream of the Low Pressure (LP) turbine inlets. Upon loss of load, the intercept valves first close then throttle steam to the LP turbine, as required to control speed. The intermediate stop valves close on a turbine trip. The intermediate stop valves and intercept valves are designed to rapidly close to control turbine overspeed.

Steam from the MSRs enters the single inlet of each valve casing, passes through the permanent basket strainer, past the intercept valve and stop valve disks, and enters the LP turbine through a single inlet these valves*. The CIVs* which *are located as close to the LP turbine as possible to limit the amount of uncontrolled steam available for overspeeding the turbine. Upon loss of load, the intercept valve first closes then throttles steam to the LP turbine, as required to control speed and maintain synchronization. It is* These valves are *capable of opening against full system pressure. The intermediate stop valves close only if the intercept valves fail to operate properly. These valves are capable of opening against a pressure differential of approximately 15% of the maximum expected system pressure. The intermediate stop valve and intercept valve* and *are designed to close in approximately 0.2 second.*

Low-Pressure Turbines*—Each LP turbine receives steam from two CIVs* hot reheat lines*. The steam is expanded* expands *axially across several stages of stationary and moving buckets* blades*. Turbine stages are numbered consecutively, starting with the first HP turbine stage.*

Extraction steam from the LP turbines supplies the first four stages of feedwater heating. A fifth extraction stage may be provided to remove moisture and protect the last-stage buckets from erosion induced by water droplets. This extraction is drained directly to the condenser.

Extraction Non-return Valves*—Upon loss of load, the steam contained downstream of the turbine extractions could flow back into the turbine, across the remaining turbine stages, and into the condenser. Associated condensate could flash to steam under this condition and contribute to the backflow of steam or could be entrained with the steam flow and damage the turbines. Extraction n*N*on-return valves are installed in the* employed in selected *extraction lines to the first, second, third and, if required, forth stage of turbine extractions to guard against this backflow and the resulting potential damage due to water entrainment or overspeed condition* prevent overspeeding*.*

The non-return valves are spring assisted closure type check valves. Spring assisted non-return valves are held open with instrument air. They close on loss of air. When the air is released the springs act to close the valves. Closure time is within 2 seconds from tripping the air relay dump valve. If the air relay dump valve fails to vent the air to the non-return valve actuators, they will close on reverse steam flow.

There are thirteen (13) extraction non-return valves. Seven are located on high pressure extraction steam lines to the two No. 5 and two No. 6 feedwater heaters, the two MSRs, and the turbine gland seal evaporator. Six are located on low pressure turbine extraction lines to the three No. 3 and three No. 4 low pressure heaters. A single failure of an extraction nonreturn valve will not cause the turbine speed to exceed its design overspeed of 120% of rated speed after a full load rejection.

Non-return valves are not used on extraction lines to the three No. 1 and three No. 2 low pressure heaters and, because of the relatively low potential energy for increasing the turbine speed, are not required for turbine overspeed protection.

Generator*—The generator is a direct-driven, three-phase, 60 Hz, 188.5 rad/s* (1800 RPM)*, four-pole synchronous generator with water-cooled stator and hydrogen cooled rotor.*

The rotor is manufactured from a ~~one-piece~~ forging and includes layers of field windings embedded in milled slots. The windings are held radially by ~~steel~~ slot wedges at the rotor outside diameter. The wedge material maintains its mechanical properties at elevated temperature. The magnetic field is generated by DC power which is fed to the windings through collector rings located outboard of the main generator bearings. The rotor body and shaft is machined from a ~~single,~~ solid steel forging. Detailed examinations include:

(1) *material property checks on test specimens taken from the forging;*

(2) *photomicrographs for examination of microstructure;*

(3) *magnetic particle and ultrasonic examination;*

(4) ~~*surface finish tests of slots for indication of a stress riser*~~ residual stress measurement at vendor factory test.

STP DEP 1.1-2

STP DEP 10.2-4

Bulk Hydrogen System*—The bulk hydrogen and CO_2 system is illustrated on Figure 10.2-4. The hydrogen system is designed to provide the necessary flow and pressure at the main generator for purging carbon dioxide during startup and supply makeup hydrogen for generator leakage during normal operation.*

The bulk hydrogen system utilizes the guidelines given in EPRI report NP-5283-SR-A with respect to these portions of the guidelines involving hydrogen that do not deal *specifically with the HWC system. Specifically, the bulk hydrogen system piping and components will be located to reduce risk from their failures.* A single bulk hydrogen storage facility will be used to store hydrogen compressed gas cylinders for STP 3 & 4. *The bulk hydrogen storage is located outside ~~but near~~ the Turbine Building* and at least 100m from any safety-related building*. The hydrogen lines are provided with a pressure reducing station that limits the maximum flow to less than 100 standard cubic meters per minute before entering the Turbine Building. Equipment and controls used to mitigate the consequences of a hydrogen fire/explosion will be designed to be accessible and remain functional during the postulated postaccident condition. The design features and/or administrative controls shall be provided to ensure that the hydrogen supply is isolated when normal building ventilation is lost.*

10.2.2.3 Normal Operation

STP DEP 10.2-1

During normal operation, the main stop valves ~~and CIVs~~ , intermediate stop valves and intercept valves *are wide open. Operation of the T-G is under the control of the Electro-Hydraulic Control (EHC) System. The EHC System is comprised of three basic subsystems: the speed control unit, the load control unit, and the flow control unit. The normal function of the EHC System is to generate the position signals for the four main stop valves, four main control valves, ~~and~~ six ~~CIVs~~* intermediate stop valves and six intercept valves.

10.2.2.4 Turbine Overspeed Protection System

The information in this subsection of the reference ABWR DCD is replaced in its entirety with the following information.

STP DEP 10.2-3

The electro-hydraulic control (EHC) system provides the normal speed control for the turbine and comprises a first line of defense against turbine overspeed. This system includes the main steam control valves (CV), intermediate steam intercept valves (IV), and fast-acting valve-closing functions within the EHC system. The normal speed control unit utilizes three speed signals. Loss of any two of these speed signals initiates a turbine trip via the Emergency Trip System (ETS). An increase in speed above setpoint tends to close the control and intercept valves in proportion to the speed increase. The EHC fully shuts off steam to the high pressure turbine (HP) at approximately 105% of the turbine rated speed by closing the turbine control valves, and the EHC fully shuts off steam to the low pressure turbines (LPs) at approximately 107% of the turbine rated speed by closing the intercept valves.

Rapid turbine accelerations resulting from a sudden loss of load at higher power levels normally initiate the fast-acting solenoids via the speed control system's Power-Load Unbalance (PLU) function, to rapidly close the control valves and intercept valves irrespective of the current turbine speed. Normal speed control is supplemented by the PLU function which is implemented in the EHC, and together they form the first line of defense against turbine overspeed. The PLU uses the difference between turbine power and load indications, which are high pressure turbine exhaust steam pressure and generator current, respectively, to cause fast closure of the turbine control valves and intercept valves when the difference between power and load exceeds approximately 40%, to limit overspeed in the event of a full load rejection. A load rejection below approximately 40% power (reactor trip threshold) will not result in a PLU actuation and subsequent control valve fast closure. Instead, it will result in normal control valve closure under normal servo control to prevent turbine speed from exceeding the primary overspeed trip setpoint of 110%; and will result in opening of the turbine bypass valves for reactor pressure control.The normal speed control system, including the PLU function, is designed to limit peak overspeed resulting from a loss of full load, to at least 2% below the overspeed trip set point. Typically, this peak speed is in a range of 105-108% of rated speed, and the overspeed trip set point is typically close to 110% of rated speed. All turbine steam control and intercept valves are fully testable during normal operation. The fast closing feature, provided by action of the fast-acting solenoids, is testable during normal operation.

If the normal speed control and the PLU function should fail, the turbine primary and emergency overspeed trip devices close the steam admission valves (turbine stop, control, intermediate stop and intercept valves) and the extraction steam non-return valves through the actuation of the air relay dump valve. This turbine overspeed protection system, which includes the diverse primary and emergency turbine overspeed protection functions, comprises the second line of defense against turbine overspeed. This overspeed protection system is designed to ensure that even with failure of the normal speed control system, the resulting turbine speed does not exceed 120% of rated speed. In addition, the components and circuits comprising the turbine overspeed protection system are testable when the turbine is in operation.

The primary trip function is independent and diverse from the emergency trip function as explained below (refer to Figure 10.2-5, Turbine Overspeed Trip System Functional Diagram). Two-out-of-three logic is employed in both the primary and emergency overspeed trip circuitry. Each trip function can de-energize its associated trip pilot valve solenoids of the electro-hydraulic Emergency Trip Device (ETD). The ETD is composed of two independent trip valves, each with two normally energized fail-safe solenoids. For each trip valve, each trip pilot valve solenoid is powered from a separate power source. The solenoids de-energize in response to detection of an overspeed condition by the turbine speed control logic. De-energization of both trip pilot valve solenoids is necessary to cause the spool in their respective trip valve to reposition, which depressurizes the emergency trip fluid system, rapidly closing all steam inlet valves and indirectly closing the steam extraction nonreturn valves. Accordingly, the repositioning of only one of the two trip valves is necessary to trip the main turbine. A single electrical component failure does not compromise trip protection, and does not result in a turbine trip. Each trip valve in the ETD is testable while the turbine is in operation.

The diverse primary overspeed trip function utilizes three passive speed sensors that are separate from the active speed sensors used for normal speed control and emergency trip function. Speed sensors are diverse (passive and active sensors) between primary overspeed and emergency overspeed trip. Speed sensing for primary and emergency overspeed trip functions also use separate speed wheels (refer to Figure 10.2-5). Each speed signal for the primary trip function is compared to a speed setpoint of approximately 110% of rated speed, and produces trip signals arranged in two-out-of-three logics, to de-energize both trip pilot valve solenoids of one of the two trip valves of the ETD. Both trip pilot valve solenoids must be de-energized to trip the associated trip valve. The ETD has two redundant trip valves. Tripping of either redundant trip valve will drain the emergency trip fluid, resulting in a turbine trip.

The emergency overspeed trip function is the redundant backup electrical overspeed trip and uses three active magnetic pickups to sense turbine speed that are separate from those used by the primary overspeed trip function. The speed setpoint for the emergency overspeed trip function is approximately 111% of rated speed.

The control signals from the two turbine-generator overspeed trip functions are isolated from, and independent of, each other. The two overspeed trip functions use diverse electronic means (hardware and software/firmware) to eliminate common cause failures from rendering the trip functions inoperable. The two overspeed trip systems are installed in separate cabinets, each with redundant uninterruptable power sources.

The emergency electrical overspeed trip function uses the same turbine speed sensing techniques and the same speed sensors as the normal speed control system. The normal speed controllers and emergency overspeed protection trip controllers may be located in the same cabinet (refer to Figure 10.2-5). However, the control signals from the normal speed control system and the trip signals from the emergency overspeedprotection trip function are separate from each other. This means that the emergency overspeed protection trip function is implemented in three separate trip controllers, and that these trip controllers are separate from the normal speed controllers, so that the control signals from the two systems are isolated from, and independent of, each other. The trip output signals from the trip controllers are arranged in two-out-of-three logic to de-energize the trip pilot valve solenoids of one of the two trip valves in the ETD to cause a turbine trip. Redundant power sources are provided for the trip controllers and normal speed controllers. Loss of power to one trip controller will result in a single channel trip signal to the two-out-of-three trip logic with no turbine trip. Functional independence of the normal speed control system and the emergency overspeed trip system is assured in that failure of the normal speed controllers does not affect the ability of the emergency overspeed trip function.

The overspeed sensing devices are located in the turbine front bearing standard, and are therefore protected from the effects of missiles or pipe breakage. The hydraulic lines are fail-safe; if one were to be broken, loss of hydraulic pressure would result in a turbine trip. The ETD is also fail-safe. Each trip valve transfers to the trip state on a loss of power to both of its associated trip pilot valve solenoids, resulting in a turbine trip. These features provide inherent protection against failure of the overspeed protection system caused by low trajectory missiles or postulated piping failures.

Each turbine extraction line is reviewed for potential energy and contribution to overspeed. The number and type of extraction non-return valves required for each extraction line are specified based on the enthalpy and mass of steam and water in the extraction line and feedwater heater. Higher energy lines are provided with power-assisted closed non-return valves, controlled by an air relay dump valve, which in turn, is activated by the emergency trip fluid system. The air relay dump valve, actuated on a turbine trip, dumps air from the extraction non-return valve actuators to provide rapid closing. The closing time of the extraction non-return valves is sufficient to minimize steam contribution to the turbine overspeed event.

The following component redundancies are employed to guard against excessive overspeed:

(1) Main stop valves/control valves

(2) Intermediate stop valves/intercept valves

(3) Normal speed control/primary overspeed control/emergency overspeed control

(4) Fast-acting solenoid valves/emergency trip fluid system (emergency trip device)

(5) Speed control signals/primary overspeed trip/emergency overspeed trip

(6) Spring assisted non-return check valves where needed/ air relay dump valve for spring assisted non-return valves

The main stop valves and control valves provide full redundancy in that these valves are in series and have independent control signals and operating mechanisms. Closure of all four stop valves or all four control valves effectively shuts off all main steam flow to the HP turbine. The intermediate stop and intercept valves are also fully redundant in that they are in series and have separate control signals and operating mechanisms. Closure of either valve or both valves in each of the six sets of intermediate stop and intercept valves effectively shuts off steam flow to the three LP turbines. This arrangement is such that failure of a single valve to close does not result in a maximum speed in excess of design limits. To ensure water flashing to steam from the feedwater heaters, moisture separators/reheaters, and the gland seal evaporator does not contribute to acceleration of the turbine after a trip, spring assisted non-return check valves are installed on lines that could contain high amounts of entrained energy.

The following is a summary of the shared hydraulic components and system interfaces.

- The fluid trip system supply (FTS) provides hydraulic fluid to the trip valves. Failure of this supply line will fail safe because loss of oil pressure will cause all valves to fast close.
- The hydraulic power unit (HPU) has one central reservoir, two redundant pumps, associated filters and control valves. These pumps supply high-pressure hydraulic

fluid for the fluid trip system, normal control of turbine valves and the main steam bypass valves.

- There is one hydraulic fluid drain header for the main stop valves (MSV) and one drain header for the control valves (CV). These two headers drain to the HPU reservoir through a common drain line.
- There is one hydraulic fluid drain header for three intermediate stop valves (ISV) and three intercept valves (IV), with one common drain line to the HPU reservoir. A similar arrangement exists for the other three ISVs and three IVs.
- The hydraulic fluid drain headers and drain lines are large diameter pipes, and are arranged with the appropriate slope to drain to the HPU reservoir.
- Each pair of ISVs and IVs share a common valve body, also referred to as a CIV, but each valve has its own separate valve disk, actuator, and instrumentation. The ISVs and IVs operate separately from each other as discussed in COLA Part 2, Tier 2, Subsection 10.2.2.2.
- The trip valves and lockout valves drain emergency trip system (ETS) fluid to a common drain header, where it is drained to the HPU reservoir through a common drain pipe. The header drain will be a one-inch nominal, or greater, pipe.
- The drain header has one vent line to the HPU reservoir.
- Periodic surveillance testing of valves and trip devices ensure that the drain lines are not plugged.
- There is one air relay dump valve that controls air to the steam extraction non-return valves. Venting of the air through the air relay dump valve will enable spring assisted closure of the non-return valves. The instrument air system supplies clean and filtered air to the non-return valves and the relay dump valve. See COLA Part 2, Tier 2, Subsection 9.3.6 for more details of the instrument air system. The extraction non-return valves are check valves and, should the air fail to vent, they would close on reverse flow without the spring assist.

10.2.2.5 Turbine Protection System

STP DEP 10.2-3

In addition to the overspeed trip signals discussed, the ETS closes the main stop valves *and control valves*~~,~~ ~~*and*~~ *the* ~~*CIVs*~~ intermediate stop valves and intercept valves, and the extraction non-return valves *to shut down the turbine on the following signals.*

(1) ~~*Emergency*~~Manual *trip* ~~*pushbutton*~~switch *in* the *control room*

(2) Moisture Separator high level

(3) High condenser pressure

(4) *Low lube oil pressure*

(5) *LP turbine exhaust hood high temperature*

(6) *High reactor water level*

(7) *Thrust bearing wear*

(8) ~~*Overspeed (electrical and mechanical)*~~ Not Used

(9) ~~*Manual*~~ Manual *trip* ~~*handle on*~~ switch near the *front standard*

(10) *Loss of stator coolant*

(11) *Low hydraulic fluid pressure*

(12) ~~*Any*~~ Selected *generator trip*

(13) *Loss of EHC electrical power*

(14) *Excessive turbine shaft vibration*

(15) *Loss of two* of the three *speed signals* that are shared by the normal speed control and emergency overspeed trip functions

(16) *Loss of two pressure control channels*

All of the above trip signals except generator trips, loss of power, and *vibration and manual trips use* ~~*2/3 or 2/4*~~ two-out-of-three *coincident trip logic.*

When the ETS is activated, it overrides all operating signals and trips the main stop ~~*and*~~valves, *control valves,* ~~*and combined*~~ *intermediate* stop valves, and intercept ~~*by way of their disk/dump*~~ *valves.* The extraction non-return valves also close by venting air through the relay dump valve.

The manual trip switches in the control room and near the front standard are directly hardwired to interrupt power to the trip pilot valve solenoids, resulting in dumping of the ETS fluid and a turbine trip.

10.2.2.6 Turbine-Generator Supervisory Instruments

STP DEP 10.2-1

Although the turbine is not readily accessible during operation, the turbine supervisory instrumentation is sufficient to detect any potential malfunction. The turbine supervisory instrumentation includes monitoring of the following:

(13) ~~*Exciter*~~ Collector *air temperatures*

10.2.2.7 Testing

STP DEP 10.2-3

The ~~electrical and mechanical~~ Primary and Emergency *overspeed trip* circuits and *devices can be tested remotely at* shut down, *rated speed* and *under load, by means of controls ~~on the EHC test panel.~~*in the Main Control Room. *Operation of the overspeed protection devices under controlled, ~~overspeed~~* speed *conditions* is *checked at startup and after each refueling or major maintenance outage.* In some cases, operation of the overspeed protection devices can be tested just prior to shutdown, thus negating the need to test overspeed protection devices during subsequent startup, if no maintenance is performed affecting the overspeed trip circuits and devices.

During refueling, or maintenance shutdowns, coinciding with the in-service inspection schedule required by Section XI of the ASME Code for reactor components, at intervals defined in Subsection 10.2.3.6, at least one main steam stop valve, one turbine control valve, one intermediate stop valve, and one intercept valve are dismantled to conduct visual and surface examinations of valve seats, disks and stems. If unacceptable flaws or excessive corrosion is found in a valve, all other valves of that type are dismantled and inspected. Valve bushings are inspected and cleaned, and bore diameters checked for proper clearance.

Main stop valves and turbine control valves, intercept valves and intermediate stop valves are exercised quarterly (or as required by the missile probability analysis) by closing each valve and observing the remote valve position indicator for fully CLOSED position status. This test also verifies operation of the fast close function of each main steam stop, turbine control, intercept and intermediate stop valve during the last few percent of valve stem travel.

Access to required areas outside of the turbine shielding is provided on the turbine floor under operating conditions.

Provisions for testing each of the following devices while the unit is operating are included:

(1) Main stop valves and control valves

(2) Turbine bypass valves

(3) Low pressure turbine ~~combined~~ intermediate stop and intercept *valves ~~(CIVs)~~*

(4) ~~Overspeed governor~~ Emergency trip devices

(5) Turbine extraction nonreturn valves

(6) ~~Condenser vacuum trip system~~ Not Used

(7) ~~Thrust bearing wear detector~~ Not Used

(8) *~~Remote trip solenoids~~* Not Used

(9) *Lubricating oil pumps*

(10) *Control fluid pumps*

10.2.3.1 Materials Selection

STP DEP 10.2-2

~~Since actual levels of FATT and Charpy V-notch energy vary depending upon the size of the part, and the location within the part, etc., these variations are taken into account in accepting specific forgings for use in turbines for nuclear application. The fracture appearance transition temperature (50% FATT), as obtained from Charpy tests performed in accordance with specification ASTM A-370, will be no higher than -17.8°C for low-pressure turbine disks. The Charpy V-notch energy at the minimum operating temperature of each low-pressure disk in the tangential direction should be at least 81.4 Nm.~~

Low-pressure turbine wheel (disc) forgings are made from vacuum treated Ni-Cr-Mo-V alloy steel forgings. The fracture appearance transition temperature (50% FATT), as obtained from Charpy tests performed in accordance with ASTM A-370, will be no higher than 0ºF for low-pressure turbine wheel (disc) forgings. The Cv energy at the minimum operating temperature will be at least 60 ft-lbs for a low-pressure turbine wheel (disc) forging. A minimum of three Cv specimens will be tested in accordance with specification ASTM A-370 to determine this energy level. The determination of FATT is used in lieu of nil-ductility transition temperature methods.

Large integral rotors are also made from vacuum treated Ni-Cr-Mo-V alloy steel forgings. Their larger size limits the achievable properties. The fracture appearance transition temperature (50% FATT), as obtained from Charpy tests performed in accordance with ASTM A-370, will be no higher than +40ºF for large integral forgings. The Cv energy at the minimum operating temperature will be at least 45 ft-lbs for a large integral rotor forging. A minimum of three Cv specimens will be tested in accordance with specification ASTM A-370 to determine this energy level.

Current turbine designs utilize rotors produced from large integral forgings. Future turbine designs may include fabricated rotors produced from multiple wrought components. Acceptable material properties will be consistent with component size and fabrication method.

10.2.3.2 Fracture Toughness

STP DEP 10.2-2

Stress calculations include components due to centrifugal loads, interference fit, and thermal gradients where applicable. The ratio of material fracture toughness, KIC (as derived from material tests on each major part or rotor), to the maximum tangential stress intensity *at speeds from normal to ~~115% of rated speed~~* design overspeed *is at least ~~10 mm$^{1/2}$~~* 2 at minimum operating temperature. The fracture toughness (KIC) value is determined using a value of deep-seated FATT based on the measured FATT values from trepan specimens, and a correlation factor obtained from historical integral rotor test data.

~~Adequate material facture toughness needed to maintain this ratio is assured by destructive tests on material samples using correlation methods which are as conservative, or more so, than those presented in Reference 10.2-1. However, this method of obtaining fracture toughness, KIC, will be used only on materials which exhibit a well-defined Charpy energy and fracture appearance transition curve and strain-rate insensitive. The COL applicant will provide the test data and the calculated toughness curve to the NRC staff for review. (See Subsection 10.2.5.1 for COL license information.)~~

~~Turbine operating procedures are employed to preclude brittle fracture at startup by ensuring that metal temperatures are (a) adequately above the FATT, and (b) as defined above, sufficient to maintain the fracture toughness to tangential stress ratio at or above 10 mm$^{1/2}$.~~ Sufficient warmup time is specified in the turbine operating instruction to assure that toughness will be adequate to prevent brittle fracture during startup. Sufficient warm-up time is specified in the turbine operating instructions to ensure that the above ratio of fracture toughness to stress intensity is maintained during all phases of anticipated turbine operation.

10.2.3.3 High Temperature Properties

STP DEP 10.2-2

The operating temperatures of both *the high-pressure* and the low pressure *rotors are below the stress rupture range. Therefore, creep-rupture is not a ~~significant~~ failure mechanism.*

10.2.3.4 Turbine Design

STP DEP 10.2-2

The turbine assembly is designed to withstand normal conditions and anticipated transients, including those resulting in turbine trip, without loss of structural integrity. The design of the turbine assembly meets the following criteria:

(1) Turbine shaft bearings are designed to retain their structural integrity under normal operating loads and anticipated transients, including those leading to turbine trips.

(2) The multitude of natural critical frequencies of the turbine shaft assemblies existing between zero speed and 20% overspeed are controlled in the design and operation so as to cause no distress to the unit during operation.

(3) ~~The maximum tangential stress resulting from centrifugal forces, interference fit, and thermal gradients does not exceed 0.75 of the yield strength of the materials at 115% of rated speed.~~ The turbine rotor average tangential stress

(excluding stresses in the blade/wheel region) at design overspeed resulting from centrifugal forces, interference fit (as applicable), and thermal gradients does not exceed 0.75 of the minimum specified yield strength of the material.

(4) *The design overspeed of the turbine is* at least *5% above the highest anticipated speed resulting from a loss of load. The basis for the assumed design overspeed will be submitted to the NRC staff for review. (See Subsection 10.2.5.2 for COL license information.)*

~~*(5) The turbine disk design will facilitate inservice inspection of all high stress regions. The turbine rotor design is based on using solid forged monoblock rotors rather than shrunk-on disks.*~~

10.2.3.5 Preservice Inspection

STP DEP 10.2-1

The pre-service inspection procedures and acceptance criteria are as follows.

(1) *Forgings are rough-machined with minimum stock allowance prior to heat treatment.*

(2) *Each finished machined rotor is subjected to ~~100% volumetric (ultrasonic), and~~ surface visual examinations, using established acceptance criteria. These criteria are more restrictive than those specified for Class 1 components in the ASME Boiler and Pressure Vessel Code, Sections III and V, and include the requirement that subsurface sonic indications are either removed or evaluated to ensure that they will not grow to a size which will compromise the integrity of the unit during its service life.* Forgings undergo 100% volumetric (ultrasonic) examination subject to established inspection methods and acceptance criteria that are equivalent or more restrictive than those specified for Class I components in ASME Code Sections III and V. Subsurface sonic indications are not accepted if found to compromise the integrity of the unit during its service life. Rotor forgings may be bored to remove defects, obtain material for testing and to conduct bore sonic inspection.

(3) ~~*All finished*~~ Finished *machined* ~~*surfaces*~~ rotors *are* also *subjected to* ~~*a*~~ surface and visual examination. Specific portions, including any bores, keyways, or drilled holes, are subject to *magnetic particle test*~~*. with no flaw indications permissible*~~ Surface indications are evaluated and removed if found to compromise the integrity of the unit during its service life. All flaw indications in keyways and drilled holes are removed.

(4) *Each fully* ~~*bucketed*~~ bladed *turbine rotor assembly is* factory *spin- tested at* ~~*the highest ainticipated speed resulting from a loss of load*~~ 20% overspeed*.*

Additional preservice inspections include air leakage tests performed to determine that the hydrogen cooling system is tight before hydrogen is introduced into the generator *casing. The hydrogen purity is tested in the generator after hydrogen has been introduced. The generator windings and all motors are megger tested. Vibration tests are performed on all motor-driven equipment. Hydrostatic tests are performed on all coolers.* ~~*All piping is pressure tested for leaks. Motor-operated valves are factory leak tested and inplace tested once installed*~~ Required piping is pressure-tested for leaks.

10.2.3.6 Inservice Inspection

STP DEP 10.2-1

The inservice inspection program for the turbine assembly includes ~~*the disassembly of the turbine and*~~ *complete inspection of all normally inaccessible parts, such as couplings, coupling bolts, turbine shafts,* ~~*low-pressure turbine buckets, low-pressure and high-pressure*~~ turbine blades and turbine *rotors. During plant shutdown* (*coinciding with the inservice inspection schedule for ASME Section III components, as required by the ASME Boiler and Pressure Vessel Code, Section XI*)*, turbine inspection is performed in sections during the refueling outages so that* ~~*in 10 years*~~ a *total inspection has been completed at least once* within the time period recommended by the manufacturer*.*

The recommended maintenance and inspection program plan for the turbine assembly, valves and controls ensures that the annual turbine generator missile probabilities are maintained at or below the acceptable level (see Subsection 10.2.1).

This inspection consists of visual, ~~*and*~~ *surface* and volumetric *examinations as indicated below:*

(1) *Visual*, magnetic particle, and ultrasonic *examination of all accessible surfaces of rotors.*

(2) *Visual*, ~~*and surface*~~ magnetic particle, or liquid penetrant *examination of* ~~*all low-pressure buckets*~~ turbine blades*.*

(3) ~~*100% visual*~~ Visual and magnetic particle *examination of couplings and coupling bolts.*

The inservice inspection of valves important to overspeed protection includes the following:

(1) *All main stop valves, control valves, extraction nonreturn valves,* intermediate stop valves and intercept valves ~~*and CIVs will be*~~ are *tested under load. Test controls installed* ~~*on*~~ in *the main control room* ~~*turbine panel*~~ *permit full stroking of the stop valves, control valves, and* ~~*CIVs*~~ intermediate stop valves and intercept valves*. Valve position indication is provided* ~~*on the panel*~~ in the main control room*. Some load reduction* ~~*is*~~ may be *necessary before testing main stop* ~~*and*~~valves, *control valves,* intermediate stop valves *and* intercept valves ~~*CIVs*~~*. Extraction nonreturn valves are tested by equalizing air pressure*

across the air cylinder. Movement of the valve arm is observed ~~upon action of the spring closure mechanism~~ by the main control room valve position indication.

(2) Main stop valves, control valves, extraction nonreturn valves, ~~and CIVs~~ intermediate stop valves and intercept valves ~~will be~~ are tested by the COL applicant ~~in accordance with the BWROG turbine surveillance test program,~~ as required by the turbine missile probability analysis by closing each valve and observing by the main control room valve position ~~indicator~~ indication that ~~it~~ the valves move~~s~~ smoothly to a fully closed position. Closure of each main stop valve, control valve, ~~and CIV~~ intermediate stop valve and intercept valve during test ~~will be~~ is verified by ~~direct~~ observation of the main control room valve ~~motion~~ position indication. This test also verifies the fast closure function during the last portion of the valve travel.

Tightness tests of the main stop and control valves are performed at least once per maintenance cycle by checking the coastdown characteristics of the turbine from no load with each set of four valves closed alternately, or using warm-up steam as an indicator with the valves closed.

Extraction nonreturn valves are tested at power, using the air supply test solenoid valves, to verify operability.

During each refueling outage, the main stop valves, control valves, intermediate stop valves, intercept valves, and nonreturn valves are tested to verify their closure times are less than the times provided in FSAR Section 10.2.2.2.

The turbine overspeed protection trip devices are tested quarterly, to verify operability of these devices. The time out of service for either the primary or emergency overspeed protection system for maintenance will be specified in the appropriate maintenance procedure.

(3) All main stop valves, ~~main~~ control valves, ~~and CIVs~~, intermediate stop valves, intercept valves, and extraction nonreturn valves are disassembled and visually ~~will be~~ inspected once during the first three refueling or extended maintenance shutdowns. Subsequent inspections ~~will be~~ are scheduled ~~by the COL applicant in accordance with the BWROG turbine surveillance test program~~ as required by the turbine missile probability analysis. The inspections will be conducted for:

(a) Wear of linkages and stem packings.

(b) Erosion of valve seats and stems.

(c) Deposits on stems and other valve parts which could interfere with valve operation.

(d) Distortions, misalignment or cracks.

Inspection of all valves of one functional *type* (i.e., stop, control, intercept, nonreturn) are ~~*will be*~~ *conducted* ~~*if any unusual condition is discovered*~~ for any detrimental, unusual condition (as defined by the turbine valve in-service inspection program) if one is discovered during the inspection of any single valve.

10.2.4 Evaluation

STD DEP T1 2.4-2

STP DEP 3.5-1

The probability of a turbine missile adversely impacting SSCs important to safety will be maintained less than $1x10^{-7}$ per year as discussed in Subsection 3.5.1.1.1.3, which meets the guidelines of Regulatory Guide 1.115 for not considering turbine missile damage to specific components. Refer to Subsection 3.5.1.1.1.3 for a discussion of compliance with Standard Review Plan 3.5.1.3 and the guidelines of Regulatory Guide 1.115. Thus failure of a turbine generator should not preclude the safe shutdown of the reactor.

Since there ~~*is*~~are *no* ~~*nuclear safety-related mechanical equipment in the turbine*~~essential systems or components located in the condenser expansion joint *area and since the condenser is at subatmospheric pressure during all modes of turbine operation, failure of the joint will have no adverse effects on nuclear safety related equipment.*

10.2.5 COL License Information

10.2.5.1 Low Pressure Turbine Disk Fracture Toughness

The following site-specific supplement addresses COL License Information Item 10.1.

In accordance with 10 CFR 50.71(e), STPNOC will update the FSAR to identify the as-built turbine material property data that supports the material properties used in the turbine rotor design specified in Subsection 10.2.3.2, after procurement and prior to initial fuel load (COM 10.2-1). Operating procedures to assure sufficient turbine warm-up time as required by Subsection 10.2.3.2, are prepared in accordance with the guidelines in FSAR Section 13.5.

10.2.5.2 Turbine Design Overspeed

The following site-specific supplement addresses COL License Information Item 10.2.

The highest anticipated speed resulting from loss of load is normally in the range of 105-108% of rated speed. Turbine components are designed such that calculated stresses do not exceed the minimum material strength at 120% of rated speed. Turbine rotors are spun to a speed of 120% rated as part of factory balance verification. This is approximately 12% above the highest anticipated speed resulting from loss of load, which meets the design criteria stated in Section 10.2.3.4 Item (4). The valve closure times used in the overspeed calculation are provided in Subsection 10.2.2.2. The turbine steam admission valves are assumed to be initially at valve-wide-open positions, which are conservative. The primary overspeed trip and the emergency overspeed trip setpoints are 110% and 111%, respectively.

10.2.5.3 Turbine Inservice Test and Inspection

The following site-specific supplement addresses COL License Information Item 10.3.

Turbine inservice test and inspection requirements are discussed in Subsection 10.2.3.6.

10.2.6 References

The following supplement adds the following references.

10.2-3 Electric Power Research Institute, “Guidelines for Permanent BWR Hydrogen Water Chemistry Installations – 1987,” EPRI NP-5283-SR-A, September 1987.

10.2-4 J. Tominaga, “Analysis of the Probability of the Generation of Missiles from Fully Integral Nuclear Low Pressure Turbines,” Toshiba Technical Report UTLR-0008-P, Revision 1, September 2010.

10.2-5 K. Jibiki, “Probabilistic Evaluation of Turbine Valve Test Frequency,” Toshiba Technical Report UTLR-0009-P, Revision 1, September 2010.

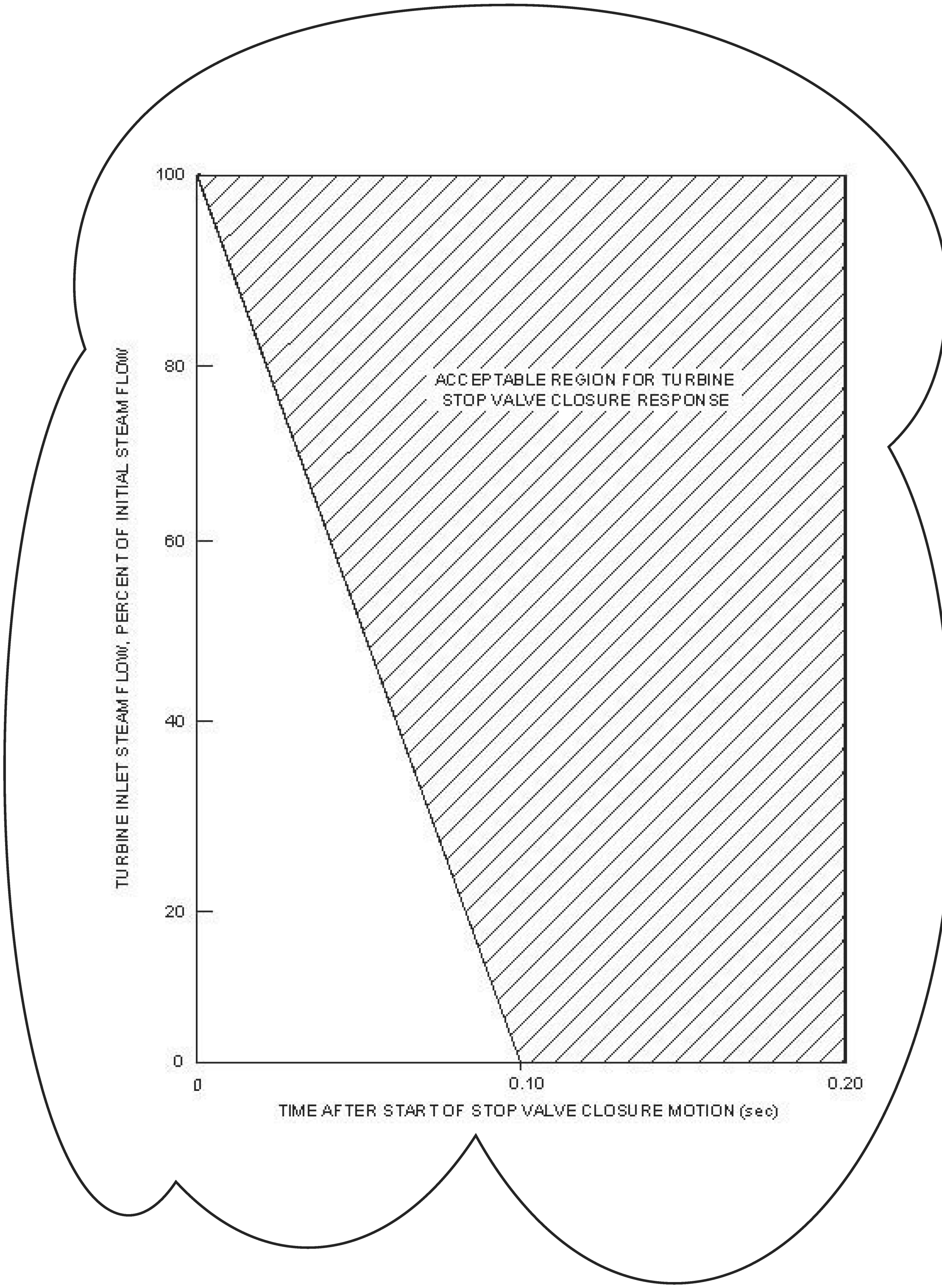

Figure 10.2-1 Turbine Stop Valve Closure Characteristic

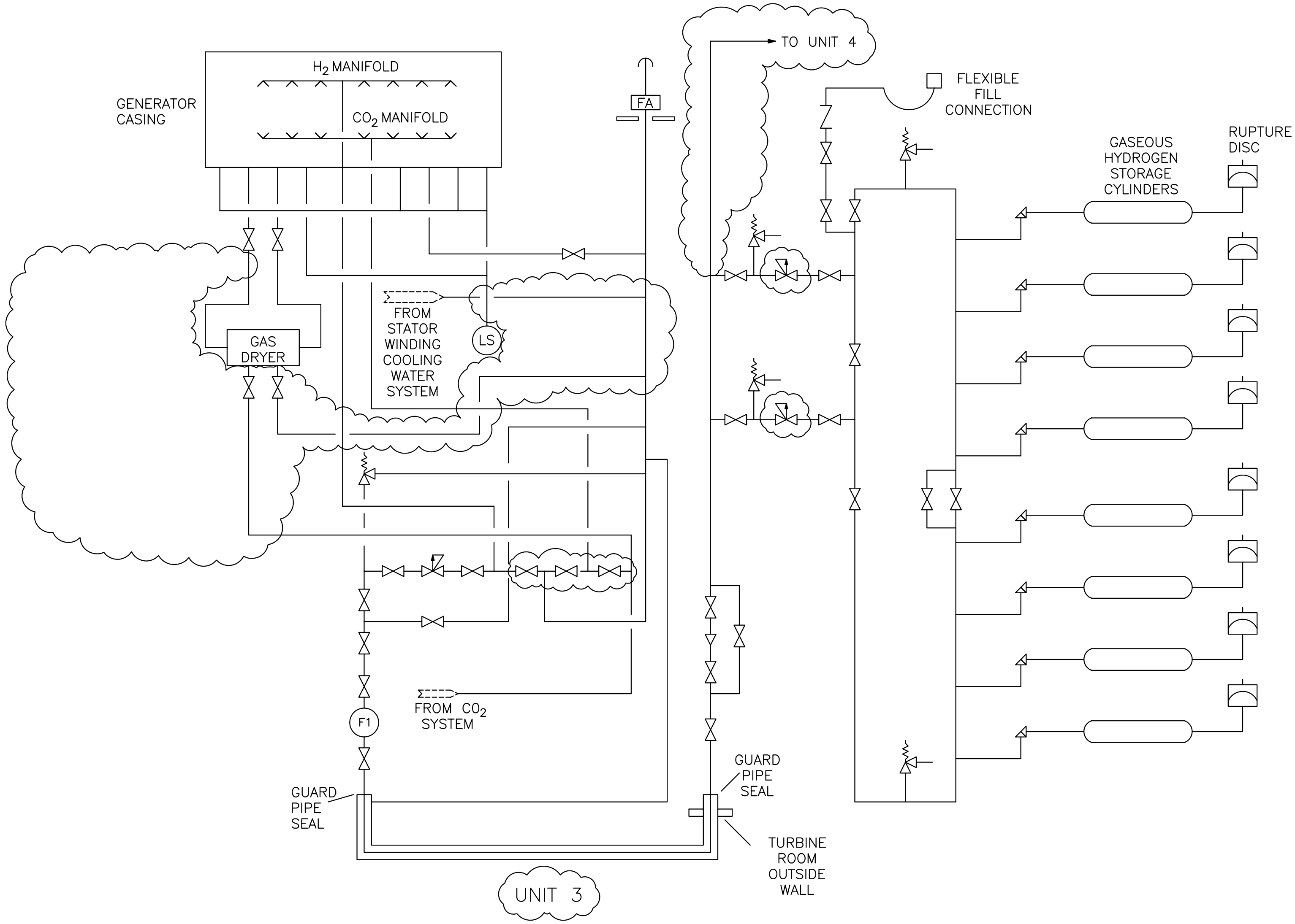

Figure 10.2-4 Generator Hydrogen and CO_2 System

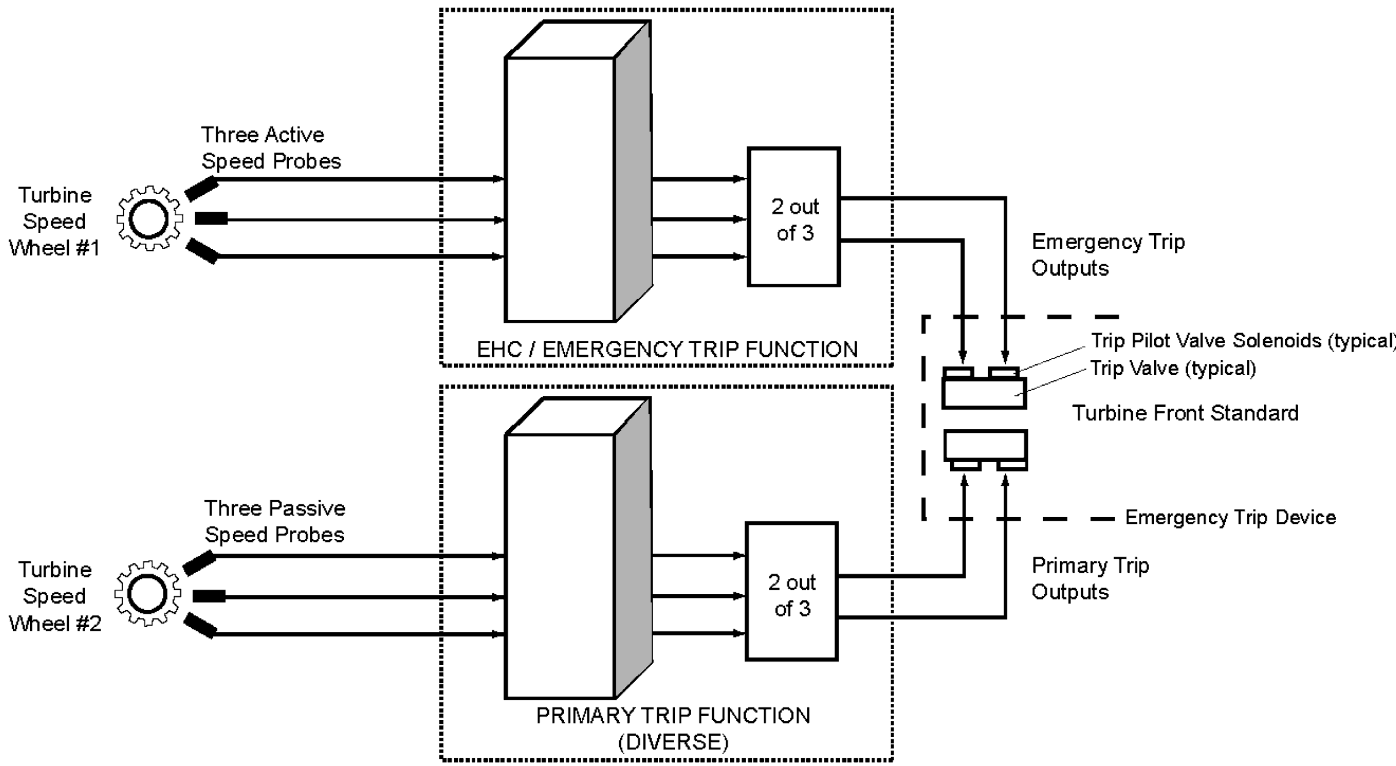

Figure 10.2-5 Turbine Overspeed Trip System Functional Diagram