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June 7, 2011

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Jeffrey A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-11170

Subject: **MHI's Amended Responses to US-APWR DCD RAI 598-4754 Revision 2 (SRP 10.02)**

Reference:
1) "REQUEST FOR ADDITIONAL INFORMATION 598-4754 REVISION 2, SRP Section: 10.02 – Turbine Generator, Application Section: 10.2, dated June 15, 2010.
2) "MHI's Response to US-APWR DCD RAI598-4754 REVISION 2" MHI Ref: UAP-HF-10210
3) "Discussion Points for the follow-up call on August 31st Public Telecom To Discuss the Responses to RAI 598-4754"

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Amended Responses to Request for Additional Information 598-4754 Revision 2." This amended response is submitted to reflect the discussion on the follow-up call on August 31, 2010 and the follow-up meeting on November 2, 2010.

Enclosed are the amended responses to 2 RAIs contained within Reference 1.

Please contact Dr. C. Keith Paulson, Senior Technical Manager, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of the submittals. His contact information is below.

Sincerely,

Y. Ogata

Yoshiki Ogata,
General Manager- APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

DO81
NRD

Enclosure:

1. Amended Responses to Request for Additional Information 598-4754 Revision 2

CC: J. A. Ciocco
C. K. Paulson

Contact Information

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Enclosure 1

UAP-HF-11170
Docket No. 52-021

Amended Responses to Request for Additional Information No. 598-4754 Revision 2

June 2011

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/7/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: **NO. 598-4754 REVISION 2**

SRP SECTION: **10.02 TURBINE GENERATOR**

APPLICATION SECTION: **10.2**

DATE OF RAI ISSUE: **6/15/2010**

QUESTION NO.: 10.02-3

RAI 10.02-5

SRP Section 10.2 specifies that turbine overspeed protection systems should include both redundancy and diversity. Additionally, operating experience insights need to be addressed in accordance with 10 CFR 52.47(a) (22) requirements. Diversity is important to minimize common-cause and common-mode failure vulnerabilities. Turbine overspeed protection for the US-APWR satisfies the SRP guidance in that both electric and mechanical turbine overspeed protection systems are provided. However, the description provided in Tier 2 Section 10.2 is insufficient for the staff to determine if common-cause and common-mode failures have been adequately considered and addressed by the design. Therefore, the following additional information is needed:

1) The description of the turbine overspeed protection systems should clearly indicate what parts are shared. For example, shared air and hydraulic dump lines and components such as trip blocks, dump valves and reservoirs should be described in the DCD. For clarity, the response should include schematic diagrams that show these flow paths, applicable components, and valves being actuated (i.e., turbine stop, control, reheat stop, intercept, and extraction nonreturn valves).

2) Common mode and common cause failure vulnerabilities that could prevent the turbine overspeed trip systems from functioning properly and are pertinent to the design should be addressed. While Tier 2 Section 10.2 indicates that the problems identified in NUREG-1275, "Operating Experience Feedback Report – Turbine-Generator Overspeed Protection Systems," have been addressed by the design, there is no discussion of design considerations that are important in this regard. A summary discussion is needed to explain how common-cause and common-mode failure vulnerabilities that are pertinent to the design have been addressed. For example, solenoid valves, steam isolation valves, hydraulic systems, air systems, and binding of mechanical trip devices have historically been problematic in this regard. Also, the potential for flow restrictions to occur in hydraulic or air system dump lines is of concern and should be addressed (especially in those cases where small diameter flow paths are used such as could be the case in trip blocks, or where redundant flow paths are not provided). Design and programmatic measures that provide assurance that these common-mode and common-cause failures are not likely to occur should be described and means to ensure

proper implementation by COL applicants should be established as appropriate.

- The use of certain materials that are not subject to corrosion, conditioning equipment, desiccants, filters and design standards are examples of design considerations that may be pertinent for addressing some common-mode and common-cause failures.

- Implementation of periodic surveillance and inspections (including diagnostic routines that assess the status of turbine generator control and overspeed protection functions), maintenance, testing, and corrective actions are examples of programmatic controls that may be applicable for assuring that common-mode and common-cause failures are prevented from occurring. For example, measures that ensure the reliable performance of components and the quality of hydraulic and air systems are pertinent in this regard.

ANSWER:

NRC Question:

1) The description of the turbine overspeed protection systems should clearly indicate **what parts are shared.** For example, shared air and hydraulic dump lines and components such as trip blocks, dump valves and reservoirs should be described in the DCD. For clarity, **the response should include schematic diagrams that show these flow paths, applicable components, and valves being actuated (i.e., turbine stop, control, reheat stop, intercept, and extraction nonreturn valves).**

Response to Question 1)

A schematic diagram which shows common parts of the turbine overspeed protection systems is provided on Fig.1. The electrical overspeed trip (EOST) detects rotation speed of the turbine shaft. In the event of reaching the setting point of the turbine speed, four (4) trip solenoid valves open to drain the emergency trip header fluid pressure and subsequently the main turbine stop, reheat stop, and extraction nonreturn valves are closed and then the turbine control and intercept valves are closed before turbine trip.
On the other hand, the mechanical overspeed trip (MOST) uses the interface piston valve for turbine trip. The interface piston valve is the key valve that connects the lubrication oil system and control oil system. It maintains the control oil pressure within the emergency trip header of the lubrication oil system during normal operation.
In the event that the speed of the turbine shaft goes up to the setting point of the MOST, the weight overcomes the spring force, actuate the MOST, and drain the autostop fluid of the manual trip header, which opens the interface piston valve to lead the control fluid within the emergency trip header to drain. After that the main turbine stop, reheat stop, extraction nonreturn valves are closed before control and intercept valves are closed, and subsequently leads to turbine trip.

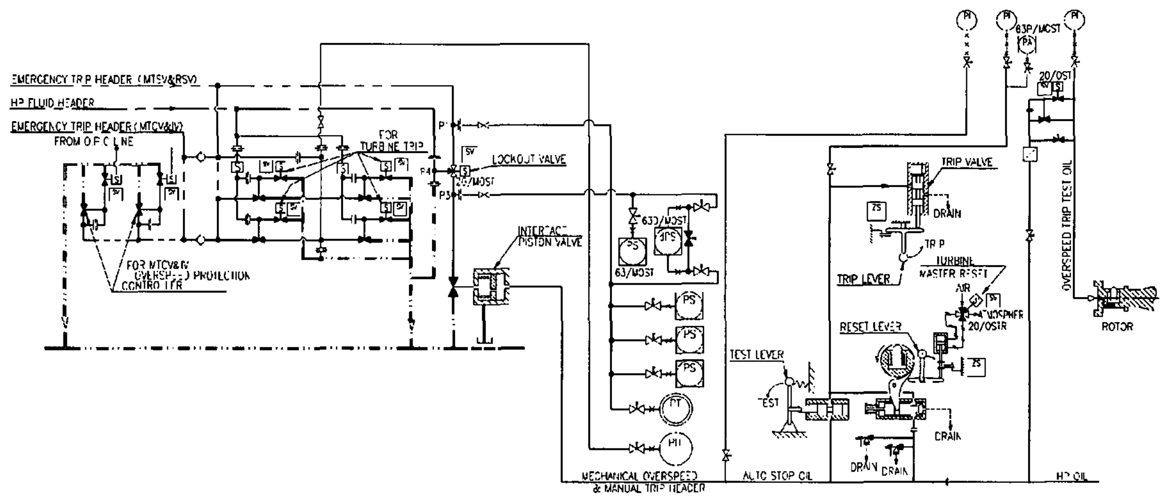


Fig.1 OVERSPEED TRIP DEVICE

Additional NRC Comments:

Figure 1 is not legible. A better diagram is needed along with a more complete description of how turbine speed control and overspeed protection are performed; how electrical emergency overspeed protection is performed; and **how mechanical emergency overspeed protection is performed.** The figure and description need to show and describe all of the major components that are used in the design, from speed sensors to turbine stop, reheat stop, turbine control, intercept, and extraction non-return valves, and everything in between (e.g., trip blocks, solenoid valves, hydraulic lines, pneumatic lines, oil reservoirs, check valves, interface valves, and so forth); **what components and flow paths are shared between the normal turbine control system and the emergency electrical and mechanical turbine overspeed protection systems.** Relative locations and vulnerability to dynamic effects such as pipe break and missile impact need to be described. For example, what are the consequences of a missile impact that renders the interface piston valve inoperable along with an assumed single active failure? Similarly, what if hydraulic lines are crimped by missile impact? **What provisions ensure that the turbine trip function will be maintained?** All of this needs to be reflected in the DCD.

MHI Response to NRC Question 1) and Additional NRC Comments:

1. Simplified schematic of the turbine control and protection system

An updated simplified schematic of the turbine control system, turbine protection system and mechanical overspeed trip (MOST) is placed in the DCD mark-up as Figure 10.2-3.
The figure shows all of the major components that are used in the design, from speed sensors to turbine stop, reheat stop, turbine control, intercept, and extraction non-return valves, and everything in between (e.g., trip blocks, solenoid valves, hydraulic lines, pneumatic lines, oil reservoirs, check valves, interface valves, and so forth).

The turbine control system includes overspeed protection controller (OPC). It is noticed that OPC is a part of turbine control system, while EOST and MOST are the system to trip the turbine in the emergency overspeed. OPC will be activated when the turbine speed is accelerated up to 103 percent or some amount of power/load unbalance is observed. Turbine speed is detected by three speed sensors. OPC does not to trip the turbine but control the turbine speed as a part

of turbine control system. Therefore, OPC will resume normal turbine operation, if the cause of turbine speed increase is dissolved.
An overspeed protection demand is sent to the OPC solenoid valves (denoted as 20-OPC1 and 20-OPC2 in Figure 10.2-3). The solenoid valves are energized and a drain path for the hydraulic fluid opens in the emergency trip header (MTCV & IV), if the turbine speed exceeds 103 percent of the rated speed. The loss of fluid pressure in the emergency trip header (MTCV & IV) causes the MTCVs and the IVs to close. When the speed returns to normal speed range following an overspeed protection controller action, the header pressure is reestablished, the MTCVs and the IVs are reopened, and the unit resumes speed control.

The turbine protection system utilizes same type of speed sensors as those for turbine control system, but those sensors are separated and independent from the sensors for OPC as is indicated in the figure.

TPS trips the turbine by opening four (4) turbine trip solenoid valves (denoted as 20-AST1, 20-AST2, 20-AST3 and 20-AST4 in Figure 10.2-3) to drain the emergency trip header fluid and subsequently all the turbine valves are closed. The turbine trip solenoid valves are opened when de-energized.

The turbine trip solenoid valves are actuated by Safety Logic System (SLS). SLS receives the turbine trip signal by hard wired line from the turbine protection system. SLS de-energize the turbine trip solenoid valves and trip the turbine in case of reactor trip or high-high SG water level and also in case that SLS receives the turbine trip signal from the turbine protection system. The turbine trip signal from the turbine protection system includes the signal of EOST.

The MOST consists of a spring-loaded trip weight mounted in the rotor extension shaft. At normal operating speed, the weight is held in the inner position by the spring. When the turbine speed reaches the trip setpoint, the centrifugal force overcomes the compression force of the spring and throws the trip weight outward striking a trigger. As the trigger moves, it unseats a cup valve which drains the mechanical overspeed and manual trip header oil. The mechanical overspeed and manual trip header can be tripped manually via a trip lever mounted on the governor pedestal. The mechanical overspeed and manual trip header is interconnected to the emergency trip header (MTSV & RSV) via the interface piston valve. When the interface piston valve is pressurized by the fluid of the mechanical overspeed and manual trip header, the drain valve remains closed and fluid pressure of the emergency trip header (MTSV & RSV) is maintained. When the fluid pressure of the mechanical overspeed and manual trip header is released by trip lever of the MOST, the interface piston valve will open the drain valve and dump the fluid of the emergency trip header (MTSV & RSV), which lead to the turbine trip.

The MOST system is activated at 110% and the TPS (EOST) is activated at 111% of the rated speed. The turbine overspeed (based on past experience) at load trip is approximately 6% of the rated speed and the maximum momentary speed will never exceed 120% of the rated speed.

2. What parts are shared and how common-cause or common-mode failures are addressed in the design?

The following components, headers and drain lines are shared by turbine protection system (EOST) and MOST (see Fig.-2);

(1) MTSVs, RSVs,
(2) Emergency trip header (MTSV&RSV),
(3) MTCVs, IVs,
(4) Emergency trip header (MTCV&IV),
(5) Check valves between the emergency trip header for (MTSV&RSV) and (MTCV&IV),
(6) A part of the trip block drain line,
(7) A part of the actuator drain line.

All the component, header and drain lines listed above are duplicated in a manner that single failure does not cause turbine overspeed exceeding design overspeed except for item 6 (a part of the drain line from the trip block) and item 7 (a part of the actuator drain line).

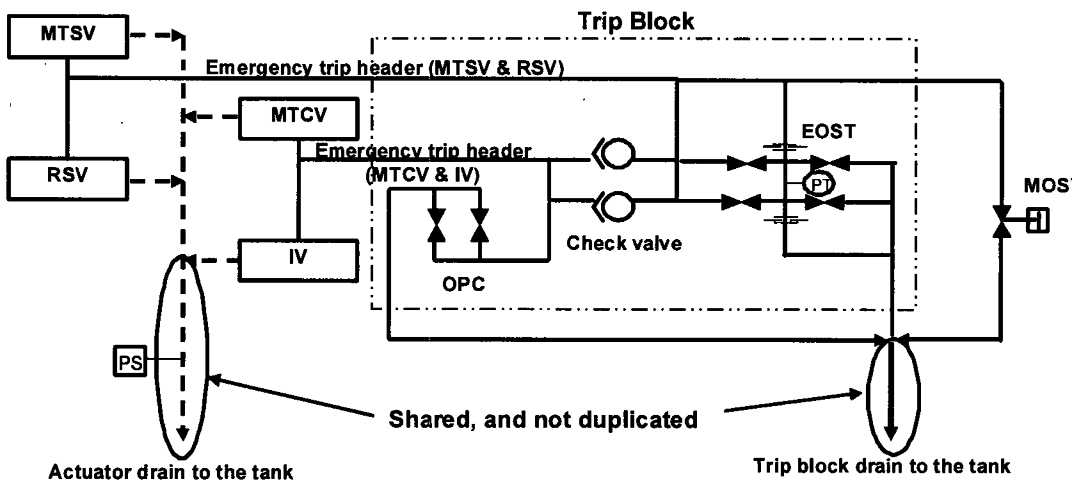


Fig.-2 components, headers and drain lines shared by TPS and MOST

A part of the drain line from the trip block and a part of drain line from the actuators are not duplicated and plugging in the lines could be the cause of common-cause failure. There is a possibility that plugging in the common drain line could cause increase in oil level and pressure in the drain line and disable all the turbine valves to close, which will remain all the turbine main valves open and could result in the turbine destructive overspeed. The hydraulic system of the TPS should be designed so that all the turbine valves can be closed even in such plugged condition. For this purpose, the following considerations are taken in the hydraulic system design;

(1) The drain pipe size and inner volume of the pipe routes after the dump valves or the solenoid valves are designed to be enough to allow draining necessary amount of oil to close MTCVs, MTSVs, RSVs, and IVs even in case that the common part of drain lines are plugged.
(2) The valve actuator drain is led from the lower chamber to the upper chamber of the actuator piston when the turbine valves rapidly close.
(3) Oil pressure of these common drain lines is continuously monitored by the pressure switch or transmitter and annunciated in the control room.

For avoiding plugging in the hydraulic system, the following countermeasures are to be taken;

(1) Although additives contained in the control fluid are considered to be the main cause of sludge deposition, the control fluid is 100% triaryl phosphate (also known as a 'natural' and 'non-additive' phosphate ester) so that sludge deposition is quite unlikely to block the pipes.
(2) Application of stainless steel pipes to the turbine control and protection system.
(3) To minimize the possibility of water intrusion to the control fluid system, air-cooled oil heat exchangers are adopted.
(4) To minimize oxygen and water content in the control fluid system and to avoid oil degradation, fuller's earth filters are installed in high pressure oil supply line.
(5) To keep cleanliness of the control fluid and keep ingredient less than allowable, appropriate filters are installed in supply and return lines. Polishing pump and polishing filter can be operated for such case as new oil is supplemented.

(6) In addition to the above countermeasures, control fluid should be subject to periodical sampling and testing to confirm that all the control parameters are within allowable range. Sampling and testing shall be done based on the manufacture's recommendation and suitable actions shall be taken in accordance with manufacture's standards if necessary (see Table 10.2-5 in DCD Mark up).

Fail-safe design concept is also taken into consideration as is indicated below;

(1) Because the solenoid valves of the trip block are designed to close by energizing, the emergency trip headers oil pressure is decreased by the loss of electrical power source. No.5 extraction check valve is designed to close by the loss of air supply system.
(2) Oil supply and drain lines are potentially broken or stricken by turbine missiles followed by oil pressure reduction in these lines. All turbine valves are designed to be kept open when control oil pressure or emergency trip header pressure is held at design pressure. All turbine valves are, therefore, closed at such unexpected oil pressure drop as mentioned above.
(3) Therefore, any failure of the electrical power sources, high pressure oil supply system and the air supply system does not cause loss of overspeed protection function.

There is a possibility that a software common-cause failure (CCF) could cause signal processing of EOST to be disabled. The diverse actuation system (DAS), which is completely independent from turbine control and protection system, has the function to trip the turbine manually even in case of software CCF.

Impact on DCD

A simplified schematic is available on Figure 10.2-3 in the DCD mark-up, and the explanation of the diagrams is included in Section 10.2.2.3.1.5, Section 10.2.2.3, Section 10.2.2.3.2 and Section 10.2.2.3.2.2. In addition, some parts of Section 10.2.2.3.1.3 are modified.

Protection and countermeasures against common-mode failure or common-cause failure in the turbine control, protection system and MOST are additionally described in Section 10.2.2.3.2. Also explanation how the MHI addressed against fail-safe design is added in the same Section.

As for the software common-cause failure (CCF), descriptions of Section 10.2.2.3 and Section 10.2.2.3.2.5 are changed.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

2) Common mode and common cause failure vulnerabilities that could prevent the turbine overspeed trip systems from functioning properly and are pertinent to the design should be addressed. While Tier 2 Section 10.2 indicates that the problems identified in NUREG-1275, "Operating Experience Feedback Report – Turbine-Generator Overspeed Protection Systems," have been addressed by the design, there is no discussion of design considerations that are important in this regard. **A summary discussion is needed to explain how common-cause and common-mode failure vulnerabilities that are pertinent to the design have been addressed.** For example, solenoid valves, steam isolation valves, hydraulic systems, air systems, and binding of mechanical trip devices have historically been problematic in this regard. Also, the potential for flow restrictions to occur in hydraulic or air system dump lines is of concern and should be addressed (especially in those cases where small diameter flow paths are used such as could be the case in trip blocks, or where redundant flow paths are not provided). **Design and programmatic measures that provide assurance that these common mode and common-cause failures are not likely to occur should be described and means to ensure proper implementation by COL applicants should be established as appropriate.**

Response to Question 2)

The overspeed protection system closes the main turbine stop and control valves. It consists of two completely isolated systems of the mechanical and the electrical overspeed protections. The mechanical overspeed trip system is capable of checking the overspeed protection function with maintaining the function during turbine operation at rated speed. It is recommended that testing be carried out once a month from the central control room and once a month manually at local to ensure soundness of the mechanical overspeed trip system. While, the electrical overspeed protection system consists of triple redundant speed sensors and quadruple redundant microprocessors. It can check that there is not any difference in values of speed signals from each other (reasonable check) and also it has self diagnosis function in order to ensure the soundness of the system. The final actuators of the electrical overspeed protection system are turbine trip solenoid valves, which are able to be tested during the turbine operation as described in 10.2.2.3.2.1.

Additional NRC Comments:

This was not addressed in the response or in the DCD markup. See notes on Page 10.2-3 of the response.

MHI Response to Question 2) and Additional NRC Comments:

NUREG-1275 Vol. 11,"Operating Experience Feedback Report – Turbine-Generator Overspeed Protection Systems" indicates in Section 7.3 that common-mode failure mechanisms leading to simultaneous failures are the most likely contributors to turbine overspeed events. In the same section Common-mode factors identified in the report which can contribute to potential for turbine overspeed are listed.

The following **Table – 1** describes how MHI addressed the common-mode factors identified in NUREG-1275 in its turbine control and protection system and component design.

Table – 1 How common-mode factors addressed in MHI control and protection system design

No.	Common-mode factors identified in NUREG-1275Vol. 11	MHI system and component design
(1)	Testing methods which do not detect existing failures of pressure switches and redundant SOVs (Solenoid operated valves)	(1) EOST system is composed of two pairs of two SOVs, which establishes 1 out of 2 twice logic. One pair of SOVs is called Channel 1and the other is called Channel 2. (2) Each SOV is actually tested once a month to check if the SOV opens when the SV is de-energized. Test methods for SOVs of trip block are shown in **Table – 2**. (3) For MOST, operation of the detector (movement of trip weight and trigger) is carried out once a month to check if the interface piston valve opens the isolation valve on the emergency trip drain
(2)	Degraded EHC and lube oil which can prevent proper operation of TOPS (Turbine overspeed protection system), SOVs, turbine control valves, TSVs (Turbine stop valves), etc.	(1) Although additives contained in the control fluid are considered to be the main cause of sludge deposition, the control fluid is 100% triaryl phosphate (also known as a 'natural' and 'non-additive' phosphate ester) so that sludge deposition is quite unlikely to block the pipes (2) Application of stainless steel pipes to the turbine control and protection system. (3) To minimize the possibility of water intrusion to the control fluid system, air-cooled oil heat exchangers are to be adopted. (4) To minimize oxygen and water content in the control fluid system and to avoid oil degradation, fuller's earth filters are installed in high pressure oil supply line. (5) To keep cleanliness of the control fluid and keep ingredient less than allowable, appropriate filters are installed in supply and return lines. Polishing pump and polishing filter can be operated for such case as new oil is supplemented. (6) In addition to the above countermeasures, control fluid should be the subject to periodical sampling and testing to confirm that all the control parameters are to be within allowable range. Sampling and testing shall be done based on the manufacture's recommendation and suitable actions shall be taken in accordance with manufacture's standards if necessary (see Table 10.2-5 of the DCD Mark-up). Example of MHI's Control Criteria for DEH fluid is listed in **Table – 3**.
(3)	System design with a single pressure switch, failure of which defeats redundant backup overspeed protection	(1) MHI's turbine protection system does not utilize pressure switches for the overspeed detection device to trigger the system.

Table – 1 How common-mode factors addressed in MHI control and protection system design

No.	Common-mode factors identified in NUREG-1275Vol. 11	MHI system and component design
(4)	Lack of a replacement program for SOVs which may fail due to material incompatibility, fluid contamination, etc.	(1) Replacement program for SOVs is not applied to MHI's turbine protection system because SOVs build 1 out of 2 twice logic. This configuration makes it possible so that SOVs are actually tested once a month during normal operation.
(5)	Lack of a replacement program for pressure switches which may fail due to aging effects	(1) MHI's turbine protection system does not utilize pressure switches for the overspeed detection device to trigger the system.
(6)	Steam admission valves identified by licensees as exhibiting common-mode failure characteristics	(1) Steam admission valves (MTSVs, RSVs, MTCVs and IVs) have the same type of design as the valves which have been applied to nuclear steam turbines MHI supplied in the past. (2) Steam admission valves have extensive accumulated operating hours in the same steam condition and had never exhibited common-mode failure characteristics, which is pertinent (inherited) to their design. (3) All the valves are to be quarterly tested during operation to check if test results show any precursors for sticking. (4) In addition to the above, at least one MTSV, one MTCV, one RSV, and one IV are dismantled approximately every 4 years during scheduled refueling or maintenance shutdowns. A visual and surface examination of the valve internals is conducted.

Table – 2 Test methods for SOVs of trip block

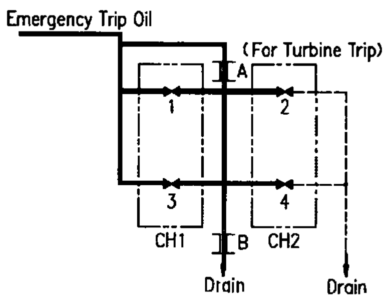
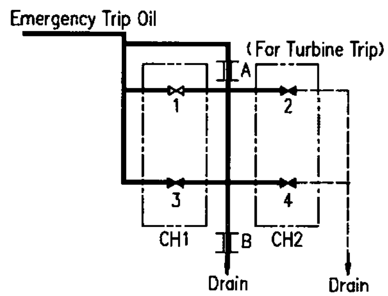
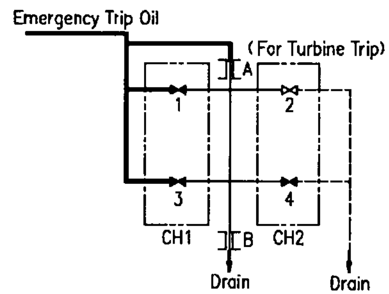
	During normal operation	During operational test of Channel 1	During operational test of Channel 2
	1. All the SOVs closed 2. Emergency Trip Oil pressure kept at design pressure (approx. 2,000 psig)	1. Channel 2 can keep emergency trip oil pressure during each SOV of Channel 1 tested.	1. Channel 1 can keep emergency trip oil pressure during each SOV of Channel 2 tested.
		 Above shows the case of SOV1 tested. SOV3 can be tested in the same manner.	 Above shows the case of SOV2 tested. SOV4 can be tested in the same manner.

Table –3 Example of MHI's Control Criteria for DEH Fluid

item	Unit	New Fluid Standard	Operation Control Standard	Method of Test	Frequency of Test			Description of Problem and Effect on Fluid Performance	Countermeasure
					On Commissioning	On Periodic Inspection/ Overhaul	In Normal Operation		
Density	Kg/dm3	≥1.13	Within ±10% of New Fluid Density	ASTM D 1298 JIS K 2249 ISO 3675 ISO 12185 IP 160	Before start, after dump test, and before commercial operation	Before re-start	Every three months	· Density is lowered when mineral oil is mixed in. Use this test to check if mineral oil is present · The presence of mineral oil can also adversely affect aeration, fire resistance and seal compatibility.	· Consider to change fluid, in the case that the value exceeds the operation control limit.
Kinematic Viscosity	mm^2/s (cSt) at 40C	38~46	Within ±10% of New Fluid Viscosity	ASTM D 445 JIS K 2283 ISO 3104 IP 71	Before start, After dump test, and before commercial operation	Before re-start	Every three months	· Variation of viscosity indicates fluid degradation or contamination · Generally, tolerance of viscosity variation is considered within ±10% of new fluid viscosity	· Consider changing fluid, in the case that the value exceeds the operation control standard value or investigate contamination.
Water Content	ppm	≤1,000	≤1,500	ASTM 203 JIS K 2275 Karl Fischer Method ISO 760	Before start, after dump test and before commercial operation	Before re-start	Every month	· Moisture in fluid produces hydrolysis and acid generation. This can catalyze further degradation of the fluid and also cause corrosion at high acid levels. No problem is expected, if acid number is maintained under 0.1	· If the level cannot be reduced to within the limit by the methods described below, consider changing the fluid. · Ensure that there are no leaks past the air breather. · Investigate and replace the desiccant if necessary

Impact on DCD

MHI's countermeasures against common-mode factors identified by NUREG-1275 are summarized in Section 10.2.2.3.2.2.
Sampling and test requirements for DEH fluid are added in Table 10.2-5.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on PRA.

6/7/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: **NO. 598-4754 REVISION 2**

SRP SECTION: **10.02 TURBINE GENERATOR**

APPLICATION SECTION: **10.2**

DATE OF RAI ISSUE: **6/15/2010**

QUESTION NO.: 10.02-4

RAI 10.2-6

SRP Section 10.2, Subsection III, specifies review considerations that pertain to the turbine-generator system. Sufficient information is needed for the reviewer to evaluate the turbine-generator systems, including subsystems and components, that are considered essential for the safe integrated operation of the facility. Additionally, operating experience insights need to be addressed in accordance with 10 CFR 52.47(a) (22) requirements. The responses that were provided to RAIs 10.2-1 through 10.2-4 and related DCD markups provided additional information and clarification concerning design features associated with the turbine-generator system. However, the information in the DCD continues to be incomplete and confusing in some respects. Consequently, additional information is needed and the description in the DCD should be revised accordingly to address the following considerations:

1) Typically, extraction steam non-return isolation valves (NRVs) must be credited to prevent the turbine from exceeding the design overspeed limit of 120 percent of rated speed following a loss of load event (given a single failure and no credit for normal speed control). However, the description does not address this consideration and identify those NRVs that must be credited in this regard, including locations where they are needed (also locations where two valves are necessary to address single failure considerations) and valve types that are used; how they interface with the turbine overspeed protection systems; and how these valves will be inspected, maintained, and tested to ensure adequate performance over the life of the plant. This information should be included in the DCD.

2) Tier 2 Section 10.2.1.2 indicates that the turbine control system is designed to trip the turbine generator upon failure of the turbine control system. However, failures that can occur and associated consequences with respect to turbine overspeed protection are not very well explained in Tier 2 Section 10.2.2.3 and additional information should be provided in this regard and the DCD should be revised as appropriate.

3) The main turbine stop and control valves are described in Tier 2 Section 10.2.2.2.1. The description indicates that a plug-type valve is used for the control valves, but the description is incomplete in that the type of valve used for the stop valves is not provided. Also, the failure mode of the turbine stop, control, reheat stop, intercept, and

extraction non-return valves upon a loss of power and impact on turbine overspeed protection should be described.

4) Tier 2 Table 10.2-2 and Tier 2 Section 10.1.2 indicate that the mechanical and electrical overspeed trip systems each close the main turbine stop and reheat stop valves. This is not entirely consistent with the description provided in Tier 2 Section 10.2.2.3 which indicates that the electrical overspeed trip system also closes the turbine control and intercept valves. Also, in order to satisfy the acceptance criteria listed in SRP Section 10.2, the mechanical overspeed trip device must also close the turbine control and intercept valves (or provide equivalent protection). However, the description of the mechanical trip function and the consequences of draining the mechanical overspeed and manual trip header are not clearly explained in this regard. Consequently, additional information is needed and the DCD should be revised accordingly to address this apparent inconsistency and to explain how the mechanical trip device satisfies the SRP acceptance criteria with respect to turbine valve closure considerations.

5) While the closure times are provided for the turbine steam admission valves and extraction NRVs in Tier 2 Table 10.2-4, the bases for these times with respect to turbine overspeed protection should be explained. The DCD also should explain how valve closure times and seat leakage will be confirmed and maintained over time and the DCD should be revised as appropriate to include this information.

6) Tier 2 Section 10.2.2.3.1 should identify the major components of the turbine control system and a simplified schematic is needed to facilitate the staff's understanding and review of this system. While the description indicates that the turbine control system is capable of preventing a turbine trip following a load rejection by closing the turbine control and intercept valves, there is not clear to what extent the turbine control system interacts with the turbine steam bypass system (described in Tier 2 Section 10.4.4) to mitigate this transient and additional information is needed in this regard. Also, Tier 2 Sections 10.2.2.3.1.4 and 10.2.2.3.1.5 refer to "OPC solenoid valves" and this acronym should be defined.

7) Tier 2 Section 10.2.2.3.1.3 refers to a DEH overspeed protection control emergency trip header for the control and intercept dump valves, and indicates that an emergency trip header is used for the stop and reheat dump valves. Further, Tier 2 Section 10.2.2.3.2.3 refers to a mechanical overspeed and manual trip header. A summary description of the arrangement, design and function of these different headers is needed to facilitate the staff's understanding and review of turbine overspeed protection features and the DCD should be revised as appropriate to include this information.

8) Tier 2 Section 10.2.2.3.1.3 indicates that the emergency trip system devices are independent of the digital electro-hydraulic control system. However, Tier 2 Section 10.2.2.3.2.2 indicates that the emergency trip header interfaces with the overspeed protection control header via a check valve. Additional information is needed to address this apparent inconsistency and the DCD should be revised as appropriate.

9) Tier 2 Section 10.2.2.3.2 indicates that turbine protective trips will cause the main stop, control, intercept, and reheat stop valves to trip. However, tripping of the extraction NRVs also should be included (relates to Item 1, above).

10) Tier 2 Section 10.2.2.3.2.1 describes the emergency trip system. To facilitate the staff's understanding and review of this system, a simplified schematic should be provided for both the backup electric and mechanical overspeed trip systems (relates to RAI 10.2-05).

11) Tier 2 Section 10.2.2.3.2.6 indicates that the emergency trip system can trip the turbine in response to a signal from the plant control system or plant safety and monitoring system (i.e., remote trip). Additional information is needed to explain where and how these remote trips are initiated, as well as how the remote trips interface with the turbine backup emergency trip system and to what extent they interface with signal conditioning and processing software as opposed to use of direct hard-wired circuits. The DCD should be revised as appropriate to include this information.

12) Tier 2 Section 3.5.1.3 indicates that the turbine control system (includes control and emergency trip functions) is fail-safe. However, the description in Tier 2 Section 10.2 does not specifically describe why the turbine control system is considered to be fail-safe and additional information should be provided in this regard and the DCD should be revised as appropriate to include this information.

13) The response to RAI 10.2-2 indicates that a software common-cause failure (CCF) can cause signal processing of the emergency back-up electrical overspeed trip system to be disabled. While the response refers to the diverse actuation system (DAS) for mitigating this situation, it does not specifically identify what actions are initiated by DAS in response to the problem. Additional information is needed to fully explain the function of DAS in this regard and the DCD should be revised as appropriate to include this information.

14) The response to RAI 10.2-3 indicates that because the turbine generator control system is not safety-related, the single failure criterion of Class 1E does not apply. Nonetheless, single failure vulnerabilities that could prevent satisfactory performance of the turbine overspeed protection function need to be identified and addressed. Consequently, additional information is needed to address any single failure vulnerabilities that exist in this regard and the DCD should be revised as appropriate to include this information.

15) The orientation of the turbine with respect to safety-related SSCs is discussed in Tier 2 Section 3.5.1.3. However, the description in the DCD is incomplete in that it does not address the orientation of the turbine with respect to those SSCs that are listed in the appendix to Regulatory Guide 1.117, consistent with the guidance provided in SRP Section 3.5.1.3 and Regulatory Guide 1.115. Therefore, additional information should be provided in this regard and the DCD should be revised as appropriate to include this information.

16) Tier 2 Section 3.5.1.3.2 and Tier 2 Section 10.2.2.1 indicate that the USAPWR acceptance limit for turbine failure probability is 1×10^{-5} per year. As shown in Table 3.5.1.3-1 of SRP Section 3.5.1.3, a turbine failure probability of 1×10^{-5} per year is specified as the acceptable limit for an unfavorably oriented turbine. However, Tier 2 Sections 3.5.1.3 and 10.2.2 both indicate that the turbine is favorably oriented which (per SRP Section 3.5.1.3) corresponds to a minimum allowable turbine failure probability of 1×10^{-4} per year. This apparent inconsistency should be explained and the DCD should be revised as appropriate.

17) Tier 2 Section 10.2.2.3.3 describes turbine generator supervisory instrumentation (TSI) and other monitors that are included in the design. Asterisks are provided to identify those monitors that are included in the TSI system, but the significance and role of TSI monitors and annunciation have not been explained. Also, while most monitors are self explanatory, the conditions that actuate the TSI failure alarm should be explained, including what the consequences of TSI failure are. The DCD should be revised as appropriate to include this information.

18) Tier 2 Section 10.2.2.3.5 indicates that the turbine trip circuitry is tested prior to unit

startup, and that the load on the turbine is reduced to facilitate control valve testing. The staff finds that the description does not adequately describe (either explicitly or by making reference to other sections of the DCD) periodic inspections and tests that will be performed to ensure that the turbine is adequately protected from exceeding 120 percent of its rated speed.

- The DCD should provide a more complete description of inspections and tests that will be performed to ensure that turbine control and overspeed protection (including electrical and mechanical remote trip functions) are adequately maintained, including (for example) a summary description of inspections and tests that will be completed while shutdown and during plant operation; inspection and test frequencies; the status of turbine overspeed protection when testing is being performed during plant operation; the status of turbine overspeed protection when abnormalities exist and/or are identified during plant operation; and diagnostic routines that will be performed to assess the status of the turbine generator control and overspeed protection systems, such as the status of speed inputs and microprocessors (note that inspections and tests relate to programmatic controls for addressing common-cause and common-mode failure considerations as discussed in RAI 10.2-5).

- Tier 2 Section 3.5.1.3 indicates that inservice inspection programs will be maintained as outlined under Item 4 of the Acceptance Criteria provided in SRP Section 3.5.1.3, Paragraph II. However, the description is incomplete in that it also should include inservice testing programs in accordance with the SRP guidance. Consequently, the DCD should be revised to address this consideration.

ANSWER:

NRC Question:

1) Typically, extraction steam non-return isolation valves (NRVs) must be credited to prevent the turbine from exceeding the design overspeed limit of 120 percent of rated speed following a loss of load event (given a single failure and no credit for normal speed control). However, the description does not address this consideration and identify those NRVs that must be credited in this regard, including locations where they are needed (also locations where two valves are necessary to address single failure considerations) and valve types that are used; how they interface with the turbine overspeed protection systems; and how these valves will be inspected, maintained, and tested to ensure adequate performance over the life of the plant. This information should be included in the DCD.

Response to Question 1)

Section 10.2 in DCD regarding extraction nonreturn valve will be revised to add more explanation. Non-return valves are served on extraction steam piping to protect from water induction by checking reverse flow into turbine. In view of turbine overspeed protection, the piping volume between the non-return valve and the turbine extraction connection must be minimized as practical, in order to reduce stored energy in extraction piping entering into the turbine during transient condition.
The nonreturn valve is swing type and is equipped power assisting actuator as backup for prompt and certain valve movement when fluid flow is zero. This actuator is initiated by turbine trip.
The valve disc is free to swing, and closes if flow is zero or reverse direction. Because of fluid flow force, it does not fully close when the flow direction is normal. Therefore the closure time refers to actuator closing time which is described in Table 10.2-4 in DCD rev.2.

The actuator closure time is tested prior to commercial operation (i.e. demonstration test by manufacturer). Valve test is conducted prior to each startup to confirm proper movement. During plant normal operation, the valve test is conducted periodically by direct observation of valve arm movement (partial close) as described in Section 10.2.3.5 in DCD rev.2. Valve seat is confirmed by seat surface check.

Additional NRC Comments:

1) Discussion points for the response to this item are:

- Where are non-return valves needed to prevent turbine overspeed, what are single failure considerations, how are valves actuated (also relates to 1) of Question 10.02-3 (RAI 10.02-5) above)? (**Additional NRC Comment-1**)
- Response indicates that testing is described in Section 10.2.3.5 of DCD, Rev. 2; need to confirm. Also, is testing consistent with SRP guidance for frequency? (**Additional NRC Comment-2**)
- Response indicates that the valve seat is confirmed by seat surface check. Is this described in DCD and is it consistent with SRP guidance for frequency? (**Additional NRC Comment-3**)
- What assurance is there that these tests will be implemented by COL applicants; is there a COL action item? (**Additional NRC Comment-4**)

MHI Response to Additional NRC Comment-1:

Each one extraction non-return valve is installed in extraction steam lines to the number three (3), four (4), six (6) and seven (7) feedwater heaters (see Fig.-3). These are located near the turbine as practical as possible. Single failure of these valves does not cause turbine overspeed (120% of rated speed) upon loss of load.
Two extraction non-return valves are installed in series in the extraction steam line to the number five (5) feedwater heater (Deaerator), which has a large amount of water for protection from single failure of this valve.

The extraction non-return valve is a swing type non-return valve. The valve disc can be opened/closed freely so that it keeps open during normal flow and closes when no flow or reverse flow occurs.
The non-return valve is equipped with spring powered assisting actuator as backup to assure prompt valve closure movement when fluid flow is zero (see Fig.-3). The spring force assists the valve to close, but normally, the pressure from the air cylinder is not applied to the spring force, thus the valve disc remains free. When the solenoid valve in air line to the cylinder is open, the air pressure is released and the spring force applies to the disc toward close. The solenoid valve is activated by turbine trip signal, low load, or level high of relevant feedwater heater. Although the spring force is applied toward disc closure, the disc keeps open partially if there is steam flow in the normal direction.
Only one of the non-return valves in the line to #5 heater has interface to Turbine Protection System. In the air line of this valve, there are two types of valves installed in series to release the cylinder air pressure. One is the solenoid valve which is the same as the other non-return valves mentioned above. The other is the air pilot valve which is activated by the pressure drop of emergency trip header fluid.

Impact on DCD

This description of extraction non-return valve is summarized and included in Section 10.2.2.2.8 of the DCD mark-up. In addition, description in the last paragraph of Section 10.2.2.3.2.6 is modified, and arrangement of extraction non-return valve is added as Figure 10.2-2.

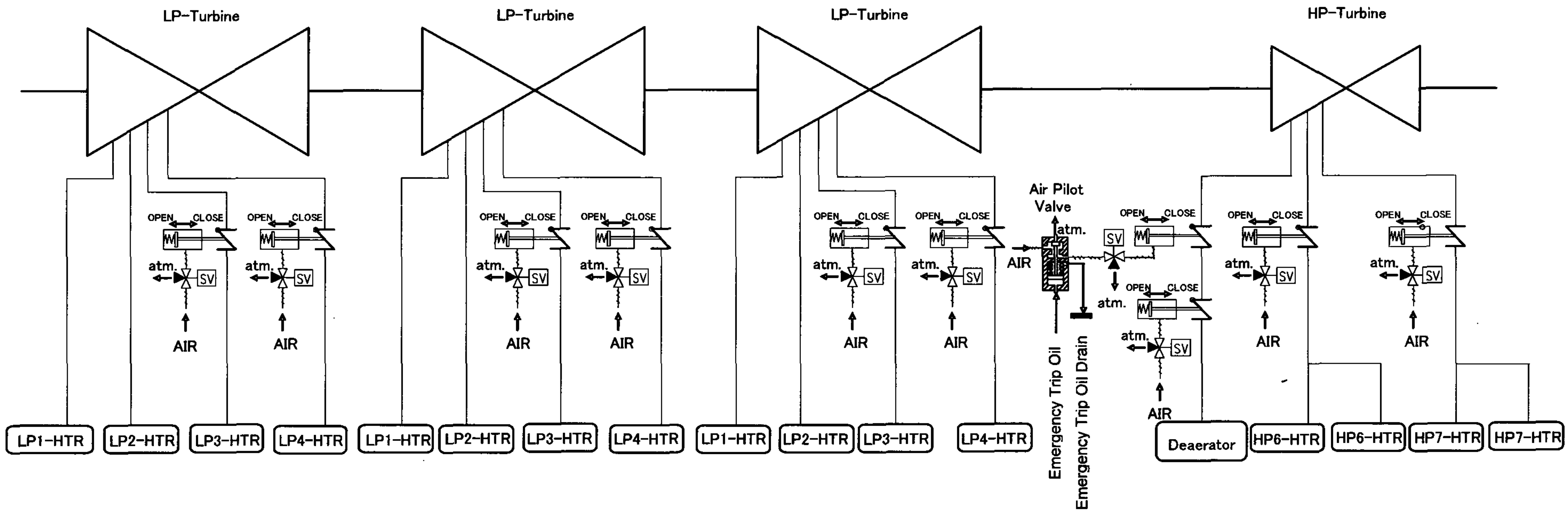


Fig.-3 Arrangement of extraction non-return valves

MHI Response to Additional NRC Comment-2 and 3:

The inspection of the non-return valves is conducted approximately every 4 years during scheduled refueling or maintenance shut down. The inspections including valve surface check are conducted in accordance with the vender's instruction (see Table 10.2-5 of the DCD mark-up).

Extraction non-return valves are tested at an interval recommended by the vender during normal operation. The tests are conducted locally by releasing air pressure allowing the spring closure mechanisms to close the valves. Closure of each valve is confirmed by direct observation of the valve arm movement (see Table 10.2-5 of the DCD mark-up).

Impact on DCD

The inspection and testing of the extraction non-return valves is included in Section 10.2.3.5 in DCD Rev.2 are modified.
The inspection and testing requirement for overspeed trip device are summarized in Table 10.2-5 of DCD mark-up.

MHI Response to Additional NRC Comment-4:

COL 10.2(1) of Section 10.2.5 of DCD Rev.2 requires the COL applicant to establish an inservice inspection program. The aforementioned inspection of the extraction non-return valves should be included in the procedure

Impact on DCD

Inspection and test plan for extraction non-return valves are summarized and included in Section 10.2.3.5 and Table 10.2-5

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

2) Tier 2 Section 10.2.1.2 indicates that the turbine control system is designed to trip the turbine generator upon failure of the turbine control system. However, failures that can occur and associated consequences with respect to turbine overspeed protection are not very well explained in Tier 2 Section 10.2.2.3 and additional information should be provided in this regard and the DCD should be revised as appropriate.

Response to Question 2)

The overspeed protection system has to cut off steam automatically and rapidly to stop it from entering the turbine in order to prevent overspeed during operation and any damage due to other abnormal factors from occurring.
Operation timing regarding overspeed shall be 1.11x and less of rated speed. For the activation of the overspeed protection system, please refer to the Response to Question 4).

Additional NRC Comments:

2) Discussion points for this response are:

- The design and operation of the turbine control system needs to be explained.
- The response indicates that operation timing regarding overspeed shall be 1.11x and less of rated speed. This needs to be explained.

MHI Response to NRC Question 2) and Additional NRC Comments:

Fail-safe design of the turbine control and protection system;

MHI's concept of fail-safe design in the turbine control and protection system is already given in the last part of MHI's response to RAI 10.02-5, Question 1) as follows.

Fail-safe design concept is also taken into consideration as is indicated below;

(1) Because the solenoid valves of the trip block are designed to close by energizing, the emergency trip headers oil pressure is decreased by the loss of electrical power source. No.5 extraction check valve is designed to close by the loss of air supply system.

(2) Oil supply and drain lines are potentially broken or stricken by turbine missiles followed by oil pressure reduction in these lines. All turbine valves are designed to be kept open when control oil pressure or emergency trip header pressure is held at design pressure. All turbine valves are, therefore, closed at such unexpected oil pressure drop as mentioned above.

(3) Therefore, any failure of the electrical power sources, high pressure oil supply system and the air supply system does not cause loss of overspeed protection function.

Diversity of the equipment;

In addition to the fail-safe concept in the system design, diversity of the system and equipment is also taken into consideration in MHI's turbine control and protection system as is explained below.

The control function consists of the turbine control system, the turbine protection system and turbine supervisory instrument system. These systems have the individual cabinets located in the non-class 1E I&C room in the auxiliary building.

The cabinets for the turbine control system have the function of speed control including overspeed protection controller (OPC) and load control.
The cabinets for the turbine protection system have the function to trip the turbine when the turbine is under abnormal condition including the turbine overspeed. The cabinets for turbine protection system are independent from the cabinets for the turbine control system. Also electric speed sensors for EOST are independent from those for the turbine control system.
In addition, the mechanical overspeed trip (MOST) exists independently from EOST. MOST consists of only the mechanical equipment.

Operation timing of overspeed protection system

As for the operation timing regarding overspeed protection systems, refer to RAI 10.02-05 1).

Impact on DCD

Description regarding fail-safe design is summarized and included in Section 10.2.2.3.2 of the DCD mark-up. Description regarding diversity is summarized and included in Section 10.2.2.3 of the DCD mark-up.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

3) The main turbine stop and control valves are described in Tier 2 Section 10.2.2.2.1. The description indicates that a plug-type valve is used for the control valves, but the description is incomplete in that the type of valve used for the stop valves is not provided. Also, the failure mode of the turbine stop, control, reheat stop, intercept, and extraction non-return valves upon a loss of power and impact on turbine overspeed protection should be described.

Response to Question 3)

A plug-type valve is used for the stop valves and it will be indicated in the description of Tier 2 Section 10.2.2.2.1. At a loss of power, a trip solenoid valve opens to drain control fluid of the trip header. At a loss of the pressure in the trip header fluid, the main stop, reheat stop, and extraction non-return valves close. A check valve which interfaces with the overspeed protection control header opens to reduce the pressure in the overspeed control header and closes the control and intercept valves, which is a fail-safe function which leads to a turbine trip.

Additional NRC Comments:

3) The response is incomplete since it is not clear how the non-return valves interface with the turbine emergency trip system (electrical and mechanical) (Additional NRC Comment-1).

   It is also not clear what solenoid valve and check valve is being referred to in the response, and the consequences of a single active failure of these components has not been explained. This relates to 1) of Question 10.02-3 (RAI 10.02-5) above (Additional NRC Commnent-2).

   How the check valve will be tested and the frequency needs to be addressed (Additional NRC Comment-3).

MHI Response to Question 3) and Additional NRC Comments:

The type of valve used for the stop valves;

A plug-type valve is used for the stop valves and it will be indicated in the description.

Impact on DCD

The type of main turbine stop valve is described in Section 10.2.2.2.1.

Failure Mode of MTSV, MTCV, RSV, IV at a loss of power;

The turbine protection system (TPS) is designed to be fail-safe. Loss of electric power or loss of control oil pressure due to some reasons such as turbine missile impact on the control and protection system result in all the main valves to be closed. MHI's concept of fail-safe design in the turbine control and protection system is already given in the last part of MHI's response to RAI 10.02-5, Question 1).
Detail explanation is added in Section 10.2.1.2, and 10.2.2.3.2.

Impact on DCD

This description is indicated in the 7th bullet of Section 10.2.1.2 and the 9th and the last part of Section 10.2.2.3.2.

MHI Response to Additional NRC Comment-1:

This response is included in the response to RAI 10.02.6 1). One of the non-return valves in the extraction line to #5 heater has interface with the Turbine Protection System (see Fig. – 3). The emergency trip header is connected to the air pilot valve for #5 extraction non-return valve. The air pilot valve is activated by draining of the emergency trip header fluid.

Impact on DCD

The interface of non-return valve and the turbine protection system is included in Section 10.2.2.2.8 of the DCD mark-up.

MHI Response to Additional NRC Comment-2 (see Fig. 10.2-3 in the DCD mark-up):

The emergency trip header (MTSV & RSV) pressure is established under the condition that the turbine trip solenoid valves which are contained in the trip block are energized (closed). The solenoid valves are arranged to have redundancy and have the test device. The emergency trip header (MTSV &RSV) is connected to the emergency trip header (MTCV &IV) through the redundant check valves.
Therefore, a single failure of these components (SOVs or check valves) does not cause malfunction of the overspeed protection function.

Impact on DCD

Detail explanation of the turbine control and protection system is described in Section 10.2.2.3.2 and Figure 10.2-3

MHI Response to Additional NRC Comment-3:

The inspection and maintenance of the redundant check valves are conducted during periodic inspections.

Impact on DCD

This description is indicated in Section 10.2.2.3.2.2.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

4) Tier 2 Table 10.2-2 and Tier 2 Section 10.1.2 indicate that the mechanical and electrical overspeed trip systems each close the main turbine stop and reheat stop valves. This is not entirely consistent with the description provided in Tier 2 Section 10.2.2.3 which indicates that the electrical overspeed trip system also closes the turbine control and intercept valves. Also, in order to satisfy the acceptance criteria listed in SRP Section 10.2, the mechanical overspeed trip device must also close the turbine control and intercept valves (or provide equivalent protection). However, the description of the mechanical trip function and the consequences of draining the mechanical overspeed and manual trip header are not clearly explained in this regard. Consequently, **additional information is needed and the DCD should be revised accordingly to address this apparent inconsistency and to explain how the mechanical trip device satisfies the SRP acceptance criteria with respect to turbine valve closure considerations.**

Response to Question 4)

The mechanical and electrical overspeed trip systems also close the turbine control and intercept valves as well. Tier 2 Table 10.2-2 and Tier 2 Section 10.1.2 will be revised.
The mechanical overspeed trip system trips the unit via the interface piston valve. The interface piston valve is normally closed by the autostop oil pressure in the manual trip header of the lubricating oil system. A spring-loaded overspeed trip weight is provided on the turbine shaft. It defeats the spring force in the event that the speed of turbine shaft reaches to the setting speed of the overspeed trip and actuates the mechanical overspeed trip system to release autostop fluid of the manual trip header to drain. When the autostop fluid pressure decreases down to a certain level or less, the interface piston valve opens to lead the control fluid to drain. At a loss of the trip header pressure, the main stop and reheat stop valves close. **Check valves** which interface with the overspeed protection control header open to reduce the pressure of the overspeed control header and close the control and intercept valves to lead a turbine trip.

Additional NRC Comment

The response is incomplete since the non-return valves have not been included. Also, it is not clear what check valve the response is referring to and the consequences of a single active failure need to be explained. This relates to 1) of Question 10.02-3 (RAI 10.02-5) above. How the check valve will be tested and the frequency needs to be addressed.

MHI Response to Question 4) and Additional NRC Comment:

The purpose and function of MOST and EOST is to close all the main turbine valves including MTSVs, RSVs, MTCVs, IVs and one of the non-return valves (NRVs) in No.5 extraction line. There are two emergency trip headers. One header is to trip MTSVs, RSVs & NRVs and the other header is to trip MTCVs & IVs as is indicated in Fig.10.2-3 of the DCD mark-up. Those two headers are interconnected with each other through two redundant check valves so that emergency trip header (MTCV & IV) fluid should be drained if the emergency trip header (MTSV & RSV) fluid drained. There exist two check valves in parallel between two emergency trip headers in order to avoid a loss of check valve function.

Since the descriptions in Section 10.1.2 and Table 10.2-2 are misleading, these sections and tables will be revised correctly.

Impact on DCD

Some parts of Section 10.1.2 and Table 10.2-2 are modified in compliance with our response. In regards to the extraction non-return valves, Section 10.2.2.2.8 is added.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

5) While the closure times are provided for the turbine steam admission valves and extraction NRVs in Tier 2 Table 10.2-4, the bases for these times with respect to turbine overspeed protection should be explained.
The DCD also should explain how valve closure times and seat leakage will be confirmed and maintained over time and the DCD should be revised as appropriate to include this information.

Response to Question 5)

As for non-return valve, see the above Response to question 1).

Additional NRC Comments:

The response did not address the question.

MHI Response to Question 5) and Additional NRC Comments:

Quick closure of the steam valves prevents turbine overspeed. Valve closing time of MTSV, MTCV, RSV and IV shall be equal or less than the closing time listed in the Table 10.2-4 for the purpose that the turbine speed does not hit turbine trip set point (110 percent of rated speed) at OPC activation and does not hit turbine design overspeed at turbine trip. Those closing times should be confirmed to be equal or less than specified time during pre-operational test prior to fuel loading and start-up test in the field.
The turbine valve closing time and valve position is also confirmed during periodic inspections, and maintained by controlling the closing spring force, the clearance between sliding surfaces, and so on.
The seat leakage is confirmed by contact check between the valve plug and the seat, and maintained by lapping or machining to control the contact area.

As for extraction non-return valve, the closure time in the Table 10.2-4 refers to the actuator closing time as replied in item 10.2.6 -1) of UAP-H-10210. This time is practically minimum value for actuator operation.
The extraction non-return valves actuator closure time is tested prior to commercial operation (i.e. demonstration test by manufacturer). Valve seat surface is confirmed during periodical shutdown.

Impact on DCD

The description of valve closing time limitation and how limitation time is decided is added in Section 10.2.2.3.2.
Valve seat surface check interval and inspection interval of valve closing time are additionally described in Table 10.2-5.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

6) Tier 2 Section 10.2.2.3.1 should identify the major components of the turbine control system and a simplified schematic is needed to facilitate the staff's understanding and review of this system. While the description indicates that the turbine control system is capable of preventing a turbine trip following a load rejection by closing the turbine control and intercept valves, there is not clear to what extent the turbine control system interacts with the turbine steam bypass system (described in Tier 2 Section 10.4.4) to mitigate this transient and additional information is needed in this regard.
Also, Tier 2 Sections 10.2.2.3.1.4 and 10.2.2.3.1.5 refer to"OPC solenoid valves" and this acronym should be defined.

Response to Question 6)

Tier 2 Section 10.2.2.3.1 describe the turbine control system as DEH control system. The non-safety digital MELTAC platform is applied to DEH control system same as other plant control and monitoring systems (PCMS).
Also Tier 2 Section 10.2.2.3.1 describe that the DEH system employs three electric speed inputs whose signals are processed in redundant microprocessors and that the steam valves are positioned by DEH control system.
As for the other mechanical component related to the turbine control system, please refer to Response to question 1) of RAI 10.02-5. OPC stands for Overspeed Protection Controller and it has been included in DCD chapter 10 ACRONYMS.
As for the turbine bypass control, the function is described in DCD section 7.7.1.1.11. The function of turbine bypass control is included in the reactor control system and not interacted by the turbine control system.

Additional NRC Comments:

The response does not identify what the components of the turbine control system are and how they function to control turbine speed, including modes of operation and what happens on a loss of load (including what happens to the steam going to the turbine). This relates to 1) of Question 10.02-3 (RAI 10.02-5) above.

MHI Response to Question 6) and Additional NRC Comments:

OPC stands for Overspeed Protection Control and a part of TCS, not a part of turbine protection system. When load rejection occurred, the turbine speed began to increase and SOVs in OPC system (denoted as 20-OPC1 and 20-OPC2 in Fig.10.2-3 of the DCD mark-up) are opened to mitigate the increase in turbine speed. At the same time, main steam is bypassed to the condenser to mitigate transient effect in reactor coolant system by opening the turbine bypass valves. If the turbine speed successfully saturated, MTCVs and IVs began re-opening to keep controlling the turbine speed.
Additional sentence explaining the function of the turbine bypass system during such phenomenon added in Section 10.2.2.3.1.5.

Impact on DCD

As for the function of the turbine bypass system with respect to overspeed protection, a short explanation is added in section 10.2.2.3.1.5.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

7) Tier 2 Section 10.2.2.3.1.3 refers to a DEH overspeed protection control emergency trip header for the control and intercept dump valves, and indicates that an emergency trip header is used for the stop and reheat dump valves. Further, Tier 2 Section 10.2.2.3.2.3 refers to a mechanical overspeed and manual trip header. A summary description of the arrangement, design and function of these different headers is needed to facilitate the staff's understanding and review of turbine overspeed protection features and the DCD should be revised as appropriate to include this information.

Response to Question 7)

DCD Section 10.2.2.3.2.3 "Overspeed Trip Functions and Mechanisms" will be revised to facilitate the understanding and review of turbine overspeed protection features.

Additional NRC Comment:

The response does not provide sufficient information. This relates to 1) of Question 10.02.3 (RAI 10-.02-5) above.

MHI Response to Question 7) and Additional NRC Comments:

As described in response to RAI10.2-5 1), the oil pressure of the mechanical overspeed & manual trip header decreases if MOST operates, and the interface piston valve opens. The oil pressure of the emergency trip header (MTSV & RSV) decreases when the interface piston valve opens.

The solenoid valves of trip block (denoted as 20-AST1 through 4 in Fig.10.2-3 of the DCD mark-up) opens if EOST operates, and decreases the emergency trip header (MTSV & RSV) oil pressure.

The emergency trip header (MTCV &IV) oil pressure decreases through the redundant check valves when the emergency trip header (MTSV & RSV) oil pressure decreases.

Because the air pilot valve for #5 extraction non-return valves is connected the emergency trip header (MTSV & RSV), the air pilot valve is opened. Therefore, all turbine main valves and #5 extraction non-return valve are closed in response to the trip signal from EOST and MOST.

"The DEH overspeed protection control emergency trip header" should be replaced by "the emergency trip header (MTCV & IV)". Description in Section 10.2.2.3.1.3 will be revised.

Impact on DCD

The description of trip header that MOST and EOST utilize is included in Section 10.2.2.3.2.2 of the DCD mark-up. In addition, the description in Section 10.2.2.3.1.3 is revised as above.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

8) Tier 2 Section 10.2.2.3.1.3 indicates that the emergency trip system devices are independent of the digital electro-hydraulic control system. However, Tier 2 Section10.2.2.3.2.2 indicates that the emergency trip header interfaces with the overspeed protection control header via a check valve. Additional information is needed to address this apparent inconsistency and the DCD should be revised as appropriate.

Response to Question 8)

DCD Section 10.2.2.3.1.4 "Valve Control" will be revised to describe that the emergency trip system devices are independent of the DEH control system.

Additional NRC Comments:

The response does not provide sufficient information. This relates to 1) of Question 10.02-3 (RAI 10.02-5) above.

MHI Response to Question 8) and Additional NRC Comment:

Overspeed protection controller for MTCV &IV is connected to trip block via redundant check valves. From view point of an I&C system, I&C parts of TPS is independent of the DEH system. Because the description in Section 10.2.2.3.1.3 is misleading, the description of this section will be revised.

Impact on DCD

The description in Section 10.2.2.3.1.3 is revised.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

9) Tier 2 Section 10.2.2.3.2 indicates that turbine protective trips will cause the main stop, control, intercept, and reheat stop valves to trip. However, tripping of the extraction NRVs also should be included (relates to Item 1, above).

Response to Question 9)

See the above response to the Response to question 1).

Additional NRC Comment:

The information in the response is not fully reflected in the DCD - see 4) above and the DCD markup notes.

MHI Additional Response:

Extraction non-return valve will be added in Section 10.2.2.3.2 of DCD.

Impact on DCD

Extraction non-return valve is added in the first sentence of Section 10.2.2.3.2 of DCD mark-up.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

10) Tier 2 Section 10.2.2.3.2.1 describes the emergency trip system. To facilitate the staff's understanding and review of this system, a simplified schematic should be provided for both the backup electric and mechanical overspeed trip systems (relates to RAI 10.2-05).

Response to Question 10)

Please refer to Response to the Response to question 1) of RAI 10.02-05. A simplified schematic for the backup electric and mechanical overspeed trip systems is shown in Fig.10.2-3 of the DCD mark-up.

Additional NRC Comment:

The response does not provide sufficient information. This relates to 1) of Question 10.02-3 (RAI 10.02-5) above.

MHI Response to Question 10) and Additional NRC Comment:

Please refer to MHI's response to RAI 10.02-05 1).

NRC Question:

11) Tier 2 Section 10.2.2.3.2.6 indicates that the emergency trip system can trip the turbine in response to a signal from the plant control system or plant safety and monitoring system (i.e., remote trip). Additional information is needed to explain where and how these remote trips are initiated, as well as how the remote trips interface with the turbine backup emergency trip system and to what extent they interface with signal conditioning and processing software as opposed to use of direct hard-wired circuits. The DCD should be revised as appropriate to include this information.

Response to Question 11)

As described in DCD 7.3.1.11 and Figure 7.3-4, the turbine trip solenoid valves are actuated by SLS (Safety Logic System). As described in DCD Table 7.3-2 and Figure 7.3-3, SLS receive the turbine trip signal by hardwired line from the turbine protection system. SLS de-energize the turbine trip solenoid valve and trip the turbine in case of reactor trip or high-high SG water level and also when SLS receive the turbine trip signal from the turbine protection system. The turbine trip signal from the turbine protection system includes the signal of the emergency backup electrical overspeed trip which is described in DCD 10.2.2.3.2.3.

Additional NRC Comment:

The response did not address remote turbine trips (mechanical and electrical). Also, the information that was provided relates to 1) of Question 10.02-3 (RAI 10.02-5) above and needs to be included in the response.

MHI Additional Response:

The turbine trip manual switch is located on the operator console in the main control room (see Chapter 7, Table 7.1-1). The signal of the turbine trip switch is transferred to the SLS through TPS de-energizing the turbine trip solenoid valves and trips the turbine. The interface between SLS and TPS is hardwired. As SLS is safety related system, the SLS is located in the separate room from the turbine control system and the TPS.
There is also a turbine trip manual switch, which is part of diverse actuation system (DAS) and independent of the TPS. This system therefore can be functioned even in the case of software common cause failure (see Chapter 7, Subsection 7.8.1.1.1).

Impact on DCD

This description is summarized and included in Section 10.2.2.3.2.5 of the DCD mark-up and Figure10.2-3.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

12) Tier 2 Section 3.5.1.3 indicates that the turbine control system (includes control and emergency trip functions) is fail-safe. However, the description in Tier 2 Section 10.2 does not specifically describe **why the turbine control system is considered to be fail-safe** and additional information should be provided in this regard and the DCD should be revised as appropriate to include this information.

Response to Question 12)

As described in DCD 10.2.2.3.1.1, the turbine is tripped automatically by the turbine protection system in the event that both of redundant microprocessor of DEH system fail to perform their function. As shown in DCD 10.2.2.3.2.2, the turbine trip solenoid valves are energized when closed. Therefore, loss of power for the turbine trip solenoid valves will open the valves and the turbine will trip. Above description is the base for Tier 2 Section 3.5.1.3.

Additional NRC Comment:

The response is incomplete since **all failure modes** are not addressed. For example, what happens if a missile impacts the hydraulic lines and cause the lines to become crimped? What happens if sludge accumulates in the hydraulic lines and causes the lines to become blocked? What happens if only one of the microprocessors fails? How is a failure of a microprocessor detected? The "fail-safe" designation needs to be fully justified and explained in the DCD. Also, the use and function of microprocessors relates to 1) of Question 10.02-3 (RAI 10.02-5) above.

MHI Additional Response:

Oil pipes could be potentially broken by the missile strike. In such events, oil pipes could be ruptured and oil will leak (spout) and main valves are designed to be fully closed (Fail Safe). When oil pipes are plugged or clogged, high pressure oil is not supplied to each main valve and control system. This causes the main valves to close and the turbine is to be tripped.

As for control fluid, basically, sludge will not block oil pipes. Although additives contained in the control oil are considered to be the main cause of sludge deposition, the control oil used in this line is 100% triaryl phosphate (also known as a 'natural' phosphate ester) therefore, sludge deposition is quite unlikely to block the pipes. In addition, maintenance of foreign substances is conducted once in three months to satisfy SAE 5 class (detail explanation concerning this matter is included in MHI answer to RAI 10.02-5 2) and Table – 3 of this document).

When only one of the microprocessor fails, another microprocessor will start and continue the process control. An alarm will be initiated in this case. This process is described in the last paragraph of DCD 10.2.2.3.1.1.

As for the self diagnosis function of microprocessor, it is explained in detail in MHI topical report "Safety System Digital Platform -MELTAC-MUAP-07005 which has been already submitted to NRC.

Impact on DCD

Additional explanation on how the turbine protection system is designed in respect to fail-safe in Section 10.2.1.2 and Section 10.2.2.3.2 DCD mark-up.

There is an explanation about the actions when the microprocessor fails during operation in Section 10.2.2.3.1.1.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

13) The response to RAI 10.2-2 indicates that a software common-cause failure (CCF) can cause signal processing of the emergency back-up electrical overspeed trip system to be disabled. While the response refers to the diverse actuation system (DAS) for mitigating this situation, it does not specifically identify what actions are initiated by DAS in response to the problem. Additional information is needed to fully explain the function of DAS in this regard and the DCD should be revised as appropriate to include this information.

Response to Question 13)

As explained in the response to RAI 10.2-2, a software common-cause failure (CCF) can cause signal processing of the emergency back-up electrical overspeed trip system to be disabled. The diverse actuation system (DAS) provides monitoring, control and actuation of safety and non-safety systems required to cope with abnormal plant conditions concurrent with a CCF that disables all functions of the PSMS and PCMS. The DAS includes an automatic actuation function, human system interface (HSI) functions located at the diverse HSI panel (DHP), and interfaces with the PSMS and PCMS. The manual actuation for turbine trip is also provided in the DHP. Refer to DCD in the first place 7.8 for more detail. Therefore, the operator can trip the turbine manually in case of CCF by means of the manual actuation in the DHP. In addition, it is clear that the mechanical overspeed trip system is valid in case of CCF.

Additional NRC Comment:

The information in the DCD and provided in the response to this item is needs clarification with respect to the DAS, since the DAS does not perform a mitigation function. The common-cause failure is mitigated by the mechanical overspeed trip system, plus manual trip capability is available.

MHI Additional Response:

Since DAS also includes manual trip function, it is explained in our reply.
As explained in our previous reply, Both Mechanical Overspeed Trip and manual trip will be OK even if a software common-cause failure (CCF) happens.

Impact on DCD

The brief explanation is added in Section 10.2.2.3 DCD mark-up.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

14) The response to RAI 10.2-3 indicates that because the turbine generator control system is not safety-related, the single failure criterion of Class 1E does not apply. Nonetheless, single failure vulnerabilities that could prevent satisfactory performance of the turbine overspeed protection function need to be identified and addressed.
    Consequently, additional information is needed to address any single failure vulnerabilities that exist in this regard and the DCD should be revised as appropriate to include this information.

Response to Question 14)

As described in DCD 10.2.2.3.1, DEH system employs three electric speed inputs whose signals are processed in redundant microprocessors. As described in DCD 10.2.2.3.2.3, the emergency overspeed trips consist of a mechanical and an electrical trip. Also, the electrical overspeed trip system has separate, redundant speed sensors. Therefore, there is no singe failure vulnerability in the turbine overspeed protection function.

Additional NRC Comment:

The information provided in the response needs to be included in the response to 1) of Question 10.02-3 (RAI 10.02-5) above and in the DCD.

MHI Additional Response:

Our previous reply refers to the description in the DCD.
Therefore, the information in our previous reply has already been included in DCD.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

15) The orientation of the turbine with respect to safety-related SSCs is discussed in Tier 2 Section 3.5.1.3. However, the description in the DCD is incomplete in that it does not address the orientation of the turbine with respect to those SSCs that are listed in the appendix to Regulatory Guide 1.117, consistent with the guidance provided in SRP Section 3.5.1.3 and Regulatory Guide 1.115. Therefore, additional information should be provided in this regard and the DCD should be revised as appropriate to include this information.

Response to Question 15)

Safety-related SSCs are addressed as stated in DCD Subsection 3.5.1.3.1. Per MHI's amended response to RAI 323-2071, Revision 1, (UAP-HF-10143, dated May 24, 2010) question 3.5.1.3-3, Subsection 3.5.1.3.1 has been revised to clarify the strike zone with respect to the turbine generator orientation to safety-related SSCs. In addition, Subsection 3.5.1.3.2 has been revised to state the estimated probability of damage from a turbine failure in a favorable orientation is shown to be more conservative than RG 1.115 criteria. The markups for Subsections 3.5.1.3.1 and 3.5.1.3.2 will be updated as shown below to address the orientation of the turbine generator with respect to SSCs listed in the appendix of RG 1.117 consistent with the guidance in RG 1.115. As such, Subsection 3.5.5 will be revised to add reference to RG 1.117.

Additional NRC Comment:

The response and DCD markup are incomplete and need clarification since all SSCs of interest as listed in RG 1.117 are not safety-related. The description needs to be clear that this non-safety-related equipment is also not located within the low trajectory turbine missile strike zone.

MHI Additional Response:

The response of this item is revised as follows.
Safety-related SSCs are addressed as stated in DCD Subsection 3.5.1.3.1. Per MHI's amended response to RAI 323-2071, Revision 1, (UAP-HF-10143, dated May 24, 2010) question 3.5.1.3-3, Subsection 3.5.1.3.1 has been revised to clarify the strike zone with respect to the turbine generator orientation to safety-related SSCs. In addition, Subsection 3.5.1.3.2 has been revised to state the estimated probability of damage from a turbine failure in a favorable orientation is shown to be more conservative than RG 1.115 criteria. The markups for Subsections 3.5.1.3.1and 3.5.1.3.2 will be updated as shown below to address the orientation of the turbine generator with respect to <u>safety-related and non-safety related</u> SSCs listed in the appendix of RG 1.117 consistent with the guidance in RG 1.115. As such, Subsection 3.5.5 will be revised to add reference to RG 1.117.

Impact on DCD

This response is described in Section 3.5.1.3.1 of DCD mark-up.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

16) Tier 2 Section 3.5.1.3.2 and Tier 2 Section 10.2.2.1 indicate that the USAPWR acceptance limit for turbine failure probability is 1 x 10-5 per year. As shown in Table 3.5.1.3-1 of SRP Section 3.5.1.3, a turbine failure probability of 1 x 10-5 per year is specified as the acceptable limit for an unfavorably oriented turbine. However, Tier 2 Sections 3.5.1.3 and 10.2.2 both indicate that the turbine is favorably oriented which (per SRP Section 3.5.1.3) corresponds to a minimum allowable turbine failure probability of 1 x 10-4 per year. This apparent inconsistency should be explained and the DCD should be revised as appropriate.

Response to Question 16)

US-APWR maintains conservative lower probability of turbine missile generation of 1.0E-5 per year. This missile generation probability supports an unfavorably oriented layout by maintaining an acceptably low probability of missile damage (1.0E-7) to safety-related SSCs located within the missile strike zone, and is conservative for a COLA that includes a favorably oriented layout. MHI's amended response to RAI 323-2071 dated May 24, 2010 (UAP-HF-10143, ML101470208) reflects this approach to provide flexibility for turbine orientation with respect to site-specific safety-related SSCs.

Additional NRC Comment

Comment on response: This approach appears to require COL applicants to implement more rigorous maintenance and surveillance schedules than that required for favorably oriented turbines.

MHI Additional Response:

Yes, certainly.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

17) Tier 2 Section 10.2.2.3.3 describes turbine generator supervisory instrumentation (TSI) and other monitors that are included in the design. Asterisks are provided to identify those monitors that are included in the TSI system, but the significance and role of TSI monitors and annunciation have not been explained. Also, while most monitors are self explanatory, the conditions that actuate the TSI failure alarm should be explained, including what the consequences of TSI failure are. The DCD should be revised as appropriate to include this information.

Response to Question 17)

TSI is the turbine supervisory instrument which is identified as the special system, and other monitoring items are implemented by ordinary instrumentation. Therefore, the role and significance of TSI is same as other monitoring system. Since TSI is the independent system, the failure alarm of TSI is provided in order to give the operator the caution and it is described in DCD 10.2.2.3.3.

Additional NRC Comment:

The response is incomplete since the conditions that initiate the TSI failure alarm are not listed. These conditions also need to be included in the DCD.

MHI Additional Response:

TSI is the turbine supervisory instrument which is identified as the special system to monitor rotation component. TSI has the self diagnosis function to detect the failure or the power supply failure. TSI failure alarm is initiated and indicated in the main control room when the self diagnosis function of TSI detects the failure or the power supply failure is detected.

Impact on DCD

The description of TSI is added in Section 10.2.2.3.3 of DCD mark-up.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

NRC Question:

18) Tier 2 Section 10.2.2.3.5 indicates that the turbine trip circuitry is tested prior to unit startup, and that the load on the turbine is reduced to facilitate control valve testing. The staff finds that **the description does not adequately describe (either explicitly or by making reference to other sections of the DCD) periodic inspections and tests that will be performed to ensure that the turbine is adequately protected from exceeding 120 percent of its rated speed.**

The DCD should provide a more **complete description of inspections and tests that will be performed to ensure that turbine control and overspeed protection (including electrical and mechanical remote trip functions) are adequately maintained, including (for example) a summary description of inspections and tests** that will be completed while shutdown and during plant operation; inspection and test frequencies; the status of turbine overspeed protection when testing is being performed during plant operation; the status of turbine overspeed protection when abnormalities exist and/or are identified during plant operation; and diagnostic routines that will be performed to assess the status of the turbine generator control and overspeed protection systems, such as the status of speed inputs and microprocessors (note that inspections and tests relate to programmatic controls for addressing common-cause and common-mode failure considerations as discussed in RAI 10.2-5).

- Tier 2 Section 3.5.1.3 indicates that inservice inspection programs will be maintained as outlined under Item 4 of the Acceptance Criteria provided in SRP Section 3.5.1.3, Paragraph II. However, the description is incomplete in that it also **should include inservice testing programs** in accordance with the SRP guidance. Consequently, the DCD should be revised to address this consideration.

Response to Question 18)

DCD Section 10.2.2.3.2.2 "Overspeed Trip Functions and Mechanisms", DCD Section 10.2.2.3.2.3 "Test Blocks", DCD Section 10.2.2.3.5 "Inspection and Testing Requirements" will be revised to describe the information of testing of the protective device.

Additional NRC Comment:

- The response is incomplete since all the items referred to were not addressed.
- Need to confirm that the guidance specified by SRP Sections 3.5.1.3 and 10.2 is properly implemented, especially frequencies that are specified.
- What ensures that the test program will be implemented by COL applicants? Is there a COL action item?

MHI Additional Response:

The inspection and test requirement for overspeed trip device are summarized in Table 10.2-5 of DCD mark-up. Test frequency is properly implemented in accordance with guidance in SRP Section 3.5.1.3 and 10.2.
The backup function is MOST when the trip block trip test or the electrical overspeed trip test is testing. The backup function is EOST when the mechanical overspeed trip test is testing. MOST and EOST prevent the turbine overspeed event when other test items are testing.

Impact on DCD

The description in Section 10.2.2.3.5 is revised.
The inspection and test requirement for the overspeed trip device are summarized in Table 10.2-5 of DCD mark-up.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

3.5.1.3.1 Geometry

As defined by "Protection Against Low-Trajectory Turbine Missiles", RG 1.115, Rev. 1 (Reference 3.5-6), current evidence suggests low trajectory turbine missile strikes are concentrated within an area bounded by lines inclined at 25 degrees to the turbine wheel planes and passing through the end wheels of the low pressure stages.

The T/G is located south of the nuclear island with its shaft oriented along the north-south axis. In this orientation, the R/B, PCCV, PS/B, and safety-related and non-safety related SSCs defined by the guidance and examples in RG 1.117 (Reference 3.5-19) within the same unit are located outside the high velocity and low trajectory missile strike zone as defined by RG 1.115 (Reference 3.5-6). The T/G and associated equipment with respect to essential safety-related SSCs are shown in figures found in Section 1.2.

The COL Applicant is responsible to assess the orientation of the T/G of this and other unit(s) at multi-unit site for the probability of missile generation using the evaluation of Subsection 3.5.1.3.2.

3.5.1.3.2 Evaluation

Protection against damage from turbine missiles to safety-related SSCs is provided by the orientation of the T/G, by the robust turbine rotors, and by the redundant and fail-safe turbine design control system as described in Section 10.2. The rotor design, material selection, preservice and inservice programs and redundant control system support a very low probability of turbine missile generation. The turbine rotor design is discussed in Subsection 10.2.3, in which material selection, fracture toughness/fracture analysis is discussed. Description of the inservice inspection and testing program that will be used to maintain an acceptably low probability of missile generation is also given in Subsection 10.2.3.

The probability of unacceptable damage resulting from turbine missiles, P_4, is expressed as the product of (a) the probability of turbine failure resulting in the ejection of turbine rotor (or internal structure) fragments through the turbine casing, P_1; (b) the probability of ejected missiles perforating intervening barriers and striking safety-related SSCs, P_2; and (c) the probability of struck SSCs failing to perform their safety function, P_3.

Mathematically, $P_4 = P_1 \times P_2 \times P_3$ where RG 1.115 (Reference 3.5-6) considers an acceptable risk rate for P_4 as less than 10^{-7} per year. For the geometry of Subsection 3.5.1.3, the product of P_2 and P_3 is estimated as 10^{-2} per year, which is a more conservative estimate than for a favorably oriented single unit and in conformance with the guidance in SRP Section 3.5.1.3. This conservative estimation provides the flexibility for the orientation of site-specific SSCs of concern based on the guidance of RG 1.117 (Reference 3.5-19) and RG 1.115 (Reference 3.5-6). The determination of P_1 (probability of turbine failure resulting in the ejection of turbine rotor (or internal structure) fragments through the turbine casing) is strongly influenced by the program for periodic inservice testing and inspection. Criteria as described in NUREG-0800 Standard Review Plan 3.5.1.3, Table 3.5.1.3-1 (Reference 3.5-7) correlates P_1 to operating cases necessary to obtain P_4 in an acceptable risk rate of 10^{-7} per year, where P_1 is less than $P_4 / (P_2 \times P_3)$ or

ACRONYMS

ANSI	American National Standards Institute
AOO	anticipated operational occurrence
ASME	American Society of Mechanical Engineers
ASSS	auxiliary steam supply system
ASTM	American Society for Testing and Materials
ATC	automatic turbine control
ATWS	anticipated transient without scram
AVT	all volatile treatment
B.A.	boric acid
CCF	common-cause failure
CCW	component cooling water
CDS	condensate system
CFS	condensate and feedwater system
COL	Combined License
CPS	condensate polishing system
CTW	cooling tower
CWS	circulating water system
DAS	diverse actuation system
DBA	design-basis accident
DEH	digital electro-hydraulic
ECCS	emergency core cooling system
ECP	electrical corrosion potential
EFW	emergency feedwater
EFWS	emergency feedwater system
EOST	electrical overspeed trip
EPRI	Electric Power Research Institute
FAC	flow-accelerated corrosion
FATT	fracture appearance transit temperature
FMEA	failure modes and effects analysis
FLB	feedwater line break
FWS	feedwater system
GDC	General Design Criteria
GSS	gland seal system
HEI	Heat Exchange Institute
HPT	high-pressure turbine
IST	inservice testing
IV	Intercept valve

ACRONYMS AND ABBREVIATIONS (CONTINUED)

JAPEIC	Japan Power Engineering and Inspection Corporation
LRB	last rotating blade
LOCA	loss-of-coolant accident
LOOP	loss of offsite power
LPT	low-pressure turbine
LWMS	liquid waste management system
M/D	motor-driven
MCES	main condenser evacuation system
MFBRV	main feedwater bypass regulation valve
MFCV	main feedwater check valve
MFIV	main feedwater isolation valve
MFRV	main feedwater regulation valve
MOST	mechanical overspeed trip
MS/R	moisture separator/reheaters
MSBIV	main steam bypass isolation valve
MSCV	main steam check valve
MSDIV	main steam drain line isolation valve
MSDV	main steam depressurization valve
MSIV	main steam isolation valve
MSLB	main steam line break
MSR	maximum steaming rate
MSRV	main steam relief valve
MSRVBV	main steam relief valve block valve
MSS	main steam supply system
MSS-SP	manufacturer standardization society-standard practice
MSSV	main steam safety valve
MTCV	main turbine control valves
MTSV	main turbine stop valve
non-ESW	non-essential service water
NPSH	net positive suction head
NSSS	nuclear steam supply system
OLM	on-line maintenance
OPC	overspeed protection controller
RCS	reactor coolant system
RHRS	residual heat removal system
RSV	reheat stop valve
SBLOCA	small break loss of coolant accident

ACRONYMS AND ABBREVIATIONS (CONTINUED)

SBO	station blackout
SCIS	secondary side chemical injection system
SG	steam generator
SGBDS	steam generator blowdown system
SGTR	steam generator tube rupture
SGWFCV	steam generator water filling control valve
SLS	safety logic system
SRHV	spent resin holding vessel
SSC	structures, systems, and component
SSE	safe-shutdown earthquake
SSS	secondary sampling system
SWMS	solid waste management system
T/D	turbine-driven
T/G	turbine-generator
T/B	turbine building
TBS	turbine bypass system
TBV	turbine bypass valves
TCS	turbine component cooling water system
TDS	total dissolved solids
TPS	turbine protection system
TSI	turbine supervisory instrument
URD	Utility Requirements Document
VWO	valve wide open

4,466 MW_t. The principal turbine-generator conditions and the rated NSSS conditions are listed in Table 10.1-1. The turbine cycle systems have been designed to meet the rated conditions for the NSSS.

Instrumentation systems are designed for the normal operating conditions of the steam and condensate/feedwater systems. The systems are designed for safe and reliable control and incorporate requirements for performance calculations and periodic heat balances. Instrumentation for the secondary cycle is also provided to meet recommendations by the turbine supplier and ANSI/ASME TDP-2-1985 (Reference 10.1-1), "Recommended Practices for the Prevention of Water Damage to Steam Turbines Used for Electric Power Generation".

10.1.2 Protective Features

Loss of External Electrical Load and/or Turbine Trip Protection

In the event of turbine trip, steam is bypassed to the condenser via the turbine bypass valves and, if required, to the atmosphere via the air-operated relief valves. Steam relief permits energy removal from the reactor coolant system. Load rejection capability is discussed in Subsections 10.4.4 and 15.2.1.

Overpressure Protection

Spring-loaded safety valves are provided on main steam lines, in accordance with the ASME Code, Section III (Reference 10.1-2). The pressure relief capacity of the safety valves is such that the energy generated at the high-flux reactor trip setting can be dissipated through this system. The design capacity of the main steam safety valves equals or exceeds 105 percent of the NSSS design steam flow at an accumulation pressure not exceeding 110 percent of the main steam system design pressure. Overpressure protection for the main steam lines is a safety-related function. The main steam safety valves are described in Subsection 10.3.2.3.2.

In addition, the shell sides of the feedwater heaters and the moisture separator/reheaters are provided with overpressure protection in accordance with ASME Code, Section VIII, Division 1 (Reference 10.1-3), or equivalent standards.

Loss of Main Feedwater Flow Protection

The emergency feedwater pumps provide feedwater to the steam generators for the removal of sensible and decay heat whenever main feedwater flow is interrupted, including loss of offsite electric power. This system is described in Subsection 10.4.9.

Turbine Overspeed Protection

During normal operations, a turbine control system, which is usually called the digital electro-hydraulic (DEH) system, provides speed control, acceleration and overspeed protection of the turbine. The ~~DEH~~ turbine control system has two modes of operation. The first maintains the desired speed during normal operation. The second mode is the overspeed protection control which operates if the normal speed control fails or ~~upon~~

during a load rejection. Additional protection is provided by ~~an emergency trip~~ the turbine protection system (TPS) which continuously monitors critical turbine parameters on a multi-channel basis~~,~~ and trips the turbine in the event that speeds in excess of overspeed protection control trip set points are reached. Emergency overspeed trip consists of a mechanical and an electrical trip. Mechanical overspeed trip (MOST) device drains emergency trip header (MTSV&RSV) oil and closes the main turbine stop valves, the main turbine control valves, the reheat stop valves, the intercept valves and ~~the reheat valves~~ one of the extraction non-return valves in the No.5 extraction line ~~and reheat valves~~ if the turbine speed exceeds 110 percent of the rated speed. The electric overspeed trip (EOST) system closes the ~~main stop and reheat stop valves (2-out-of-3 trip logic)~~ same valves as of MOST if the turbine speed exceeds 111 percent of rated speed. This system is described in Subsection 10.2.2.3.

Turbine Missile Protection

Turbine rotor integrity minimizes the probability of generating turbine missiles and is discussed in Subsection 10.2.3. Turbine missiles are addressed in Subsection 3.5.1.3. The favorable orientation of the turbine-generator directs potential missiles away from safety-related equipment and structures.

Radioactivity Protection

Under normal operating conditions, there are no radioactive contaminants of operational concern present in the steam and power conversion system. However, it is possible for the system to become contaminated through steam generator tube leakage. In this event, radiological monitoring of the main condenser air removal system, the gland seal system, the steam generator blowdown system, and the main steam lines will detect contamination and alarm high radioactivity concentrations. A discussion of the radiological aspects of primary-to-secondary system leakage and limiting conditions for operation is ~~contained~~ described in Chapter 11. The steam generator blowdown system described in Subsection 10.4.8 serves to limit the radioactivity level in the secondary cycle, below the operational limits.

Flow Accelerated Corrosion Protection

Flow accelerated corrosion (FAC) resistant materials are used in steam and power conversion systems for components exposed to two-phase flow where significant erosion can occur. Factors considered in the evaluation of FAC include system piping and component configuration and geometry, water chemistry, piping and component material, fluid temperature, and fluid velocity.

In addition to material selection, pipe size and layout may also be used to minimize the potential for FAC in systems with two-phase flow condition. To maintain a noncorrosive environment, the secondary side water chemistry (see Subsection 10.3.5) uses an all volatile chemistry for pH adjustment and corrosion prevention chemicals. Steam and power conversion systems are designed to facilitate inspection and FAC monitoring programs.

10.2 Turbine-Generator (T/G)

10.2.1 Design Bases

10.2.1.1 Safety Design Bases

The T/G does not serve a safety-related function and therefore has no nuclear safety design basis. Classification of the equipment and components of the T/G in regard to the seismic and quality group is provided in Section 3.2.

The T/G could be a potential source of high-energy turbine missiles, which could cause damage to safety-related equipment or systems. The turbine is designed to minimize the possibility of turbine missile generation as discussed in Subsection 10.2.3. The turbine control system, TPS and main valves arrangement is designed to minimize the possibility of turbine missile generation and is discussed in Subsection 10.2.2 in detail.

10.2.1.2 Non-Safety Power Generation Design Bases

The following is a list of the major design features of the T/G:

- The T/G is designed for base load operation and for load follow operation.
- The T/G is designed for electric power production consistent with the capability of the reactor and the reactor coolant system.
- The gross generator output at the rated thermal power of the reactor and at VWO condition is shown in the heat balance diagrams in Figure 10.1-2 and Figure 10.1-3 respectively.
- The T/G is designed to trip automatically under abnormal conditions such as overspeed greater than 110~~%~~ percent of the rated speed. The turbine control system is designed to control the rotating speed within the range which does not activate the ~~emergency trip system~~ TPS, and is also designed to trip the T/G ~~at the failure of the control system~~ when the control system fails. The redundant ~~emergency trip~~ overspeed trip system is designed to prevent rotating speed from exceeding design overspeed.
- The T/G is designed to allow periodic on-line testing on the main valves (main turbine stop valve (MTSV), main turbine control valves (MTCV), reheat stop valve (RSV) and Intercept valve (IV)), ~~emergency trip~~ overspeed trip system and other protection devices.
- The system and component arrangement is designed so that any single component failure will not cause ~~exceeding~~ to exceed the design overspeed.
- The turbine control and the TPS are designed to be fail-safe. Loss of electric power or loss of control oil pressure due to some reasons such as turbine missiles impact on the system result in all the main valves to close.

- The system is designed to provide proper drainage of related piping and components to prevent water induction into the main turbine.

- ~~Nonreturn valves are served on extraction steam piping to prevent water induction by checking reverse flow into turbine. Each valves is swing type and is equipped actuator as backup to assist closure action. In view of turbine overspeed protection, the piping volume between the nonreturn valve and the turbine extraction connection must be minimized as practical.~~

- The moisture separator/reheaters (MS/Rs), MS/R drain tanks, generator stator cooling water demineralizer, stator cooling water tank, seal oil drain regulator, lubricant oil cooler and accumulator are designed to ASME Code Section VIII requirements (Reference 10.2-1). The other parts are designed to the T/G manufacturer's standards.

10.2.2 Description

10.2.2.1 General Description

The T/G is an 1800rpm tandem compound six exhaust flow unit consisting of one double-flow high-pressure turbine (HPT x 1), three double-flow low-pressure turbines (LPT x 3), a generator, two sets of external moisture separator/reheaters (MS/Rs), exciter, controls, and auxiliary subsystems (see Figure 10.2-1). The major design parameters of the T/G and auxiliaries are presented in Table 10.2-1. The flow diagram Figure 10.3-4 shows the stop, control, intercept, and reheat stop valves.

The T/G and associated piping, valves, and controls are located completely within the turbine building. There are no safety-related systems or components located within the turbine building. The probability of a destructive overspeed condition and missile generation, assuming the recommended inspection and test frequencies, is less than 1 x 10^{-5} per year in accordance with NUREG-800 SRP Subsection 3.5.1.3, turbine missiles (Reference 10.2-2). In addition, the orientation of the T/G is such that a high-energy missile to be directed at an approximately 90 degree angle away from safety-related structures, systems, and components. The layout drawings that show the general arrangement of the T/G and associated equipment in relation to essential safety-related SSC are shown in Section 1.2, Figure 1.2. Failure of the T/G equipment does not preclude safe shutdown of the reactor. The T/G components and instrumentation associated with protecting the T/G from an overspeed condition are accessible under operating conditions.

The T/G foundation is a reinforced concrete structure. The T/G foundation and equipment anchorage are designed to the same seismic design requirement as the turbine building. See Section 3.7 for additional information on seismic design requirements.

10.2.2.2 Component Description

The T/G train consists of one double-flow high-pressure turbine, three double-flow low-pressure turbines and one generator. Two external MS/Rs with two stages of reheating are located on each side of the T/G centerline. The single direct-driven generator is water-cooled and rated at 1,900 MVA at 0.9 PF. Other related system components include a complete T/G bearing lubrication oil system, a ~~Digital electro-hydraulic (DEH)~~ turbine control system with supervisory instrumentation, a turbine gland seal system (see Subsection 10.4.3), overspeed protective devices, turning gear, a stator coil cooling water system, H_2 & CO_2 gas control system and seal oil system, a rectifier section, and a voltage regulator.

10.2.2.2.1 Main Turbine Stop Valve and Main Turbine Control Valves (MTSV & MTCV)

The function of the MTSV is to quickly shut off the main steam flow to the turbine when the MTSVs receive~~s~~ a trip signal. The main function of the MTCV is to regulate the main steam flow to the turbine through the control system.

Main steam from the steam generators (SGs) enters the high-pressure turbine through four horizontally-mounted plug-type MTSVs and four plug-type MTCVs. Main steam flow through one MTSV is combined with main steam flow from the other MTSVs in the steam chamber. Two MTCVs, located in the steam chamber, direct the main steam flow to the high-pressure turbine inlet stage. There are two sets of steam chambers that are located on both sides of high-pressure turbine casing.

MTSVs are operated in on-off mode by a signal from the ~~emergency trip system~~ TPS or solenoid valve for testing.

The MTSV incorporates a pilot valve. When the turbine is started, the MTCVs are fully open and the pilot valve of the MTSV is operated with full arc admission so that the turbine parts can be uniformly heated during the start-up process.

The s~~S~~team strainer~~s are~~ is located at the inlet of each MTSV.

10.2.2.2.2 High-Pressure Turbine (HPT)

The main steam enters the HPT through the four MTCVs and the lead pipes and expands across several stationary and rotating blades axially in both the governing and generator side directions. The HPT has two extraction connections. One extraction connection supplies heating steam to both the No. 7 (final) high-pressure feedwater heaters and first stage reheater while the other extraction connection supplies heating steam to the No. 6 high-pressure feedwater heaters. Steam is exhausted to the external MS/Rs through exhaust connection taps and cross-under pipes. Part of the HPT exhaust steam is supplied to the deaerating feedwater heater.

The HPT rotor is machined from an alloy steel forging (mono block design). A separate extension shaft, which is bolted to the governor end of the rotor, carries the main oil pump and overspeed trip weight.

After assembly of the HPT rotor, the high speed balance test and overspeed test up to 120% is carried out to confirm the integrity of the HPT rotor.

10.2.2.2.3 External Moisture Separator/Reheaters (MS/R)

MS/Rs employ a two-stage reheater. The first stage reheater uses the extraction steam from the high-pressure turbine and the second stage reheater uses a portion of the main steam supply to reheat the steam to a superheated condition. The reheated steam flows through a separate reheat stop valve and intercept valve (RSV and IV) in each of six cross-over pipes leading to the inlets of the three low-pressure turbines.

The external MS/Rs use multiple banks of chevron-skip vanes (shell side) for moisture removal. The moisture removed by the external moisture separator is drained to a moisture separator drain tank and is pumped to the deaerator (deaerating feedwater heater).

Condensed steam in the reheater (tube side), which is drained to the reheater drain tank, flows into the shell side of the No. 6 and 7 feedwater heaters, and cascades to the deaerator (deaerating feedwater heater).

10.2.2.2.4 Reheat Stop Valves and Intercept Valves (RSV and IV)

One pair of RSV and IV is installed in each cross-over pipe from the external moisture separator/reheater to the low-pressure turbines. There are a total of six pairs of RSVs and IVs.

The RSV is a butterfly-type valve and operated in on-off mode to prevent the T/G from exceeding design overspeed in response to the signal from the ~~emergency trip system~~ TPS. The IV is also a butterfly-type valve and is operated through the turbine control system.

10.2.2.2.5 Low-Pressure Turbine (LPT)

There are three double flow LPTs with 74-inch last stage blades. Reheated steam enters each of the LPTs through the RSV and the IV and expands in the blade path axially through stationary and rotating blades.

The fourth, fifth, sixth and seventh extraction points of the LPT supply steam to the low-pressure feedwater heaters No. 4, 3, 2, and 1, respectively.

Moisture is removed at a number of locations along the blade path. Drainage holes drilled through the blade rings provide moisture removal from blade rings located in high moisture zones. The effectiveness of moisture removal at these locations is enhanced by moisture non-return catchers which trap a large portion of the water from the blade path and direct it to the moisture removal system.

The LPT rotors are machined from an alloy steel forging (mono block design).

After assembly of the LPT rotor, the high speed balance test and overspeed test up to 120% is carried out to confirm the integrity of the LPT rotor.

10.2.2.2.6 Generator

10.2.2.2.6.5 H_2 & CO_2 Gas Control System

The H_2 & CO_2 gas control system supplies, maintains, and removes the hydrogen (H_2) gas and carbon dioxide (CO_2) gas to and from the generator.

The hydrogen gas is used as a cooling medium in the generator, and the carbon dioxide gas is used during filling and removal of the hydrogen gas to and from the generator to prevent the air and the hydrogen gas from mixing. The hydrogen gas and carbon dioxide gas are supplied from a Bulk Gas Storage system.

10.2.2.2.6.6 Stator Coil Cooling Water System

For the stator coil water-cooled turbine generator, heat loss generated in the stator coil is removed by circulating high-purity water ("stator cooling water") inside the hollow conductor of the stator coil. The high-purity water is cooled in water-to-water heat exchangers by circulating water from TCS.

The stator coil cooling water system provides the high-purity demineralized water to the generator stator coils.

10.2.2.2.7 Exciter

The excitation system is a static exciter with a solid-state voltage regulator. Excitation power is obtained from the exciter transformer, which is connected to the main generator circuit. The static exciter consists of three parts: exciter transformer, ac and dc bus duct, and a rectifier. The exciter rectifiers are arranged in a full-wave bridge configuration and protected by a series-connected fuse.

10.2.2.2.8 Extraction non-return valve

Non-return valves are installed in the extraction steam piping to prevent water induction by preventing reverse flow into the turbine as well as to prevent overspeed of the turbine if the extraction steam flow reverses towards the turbine such as load rejection. One extraction non-return valve is installed in No.3, No.4, No.6, and No.7 extraction lines to No.3, No.4, No.6, and No.7 feedwater heaters respectively. Because the stored amount of water in the deaerator is large, two extraction non-return valves are installed in series in the No.5 extraction line to the deaerator to prevent the turbine from serious damage by water induction. Non-return valves are not installed in the No.1 and No.2 extraction lines to No.1 and No.2 feedwater heaters respectively, since the pressure and the stored energy are relatively lower than that of other extraction lines. These non-return valves are located near the turbine casing as practical as possible to mitigate the increase in turbine overspeed. (see Figure 10.2-2)

The extraction non-return valves are swing type and close without any assistance if there is a reverse flow in the extraction line. Each non-return valve is equipped with a spring and an air cylinder. Normally, the pressure in the air cylinder pushes the piston back to the spring so that the valve disc remains free. When a solenoid valve in the air line to the air cylinder releases the air pressure in response to a turbine trip signal, the spring force assists the non-return valve to close. The air is supplied from the instrument air system and its quality meets to pneumatic equipment as discussed in section 9.3.1.1.2.

For the first non-return valve in No. 5 extraction line, the air pilot valve is equipped in the air line in addition to the solenoid valve in series. This pilot valve is activated when the pressure of the emergency trip header (MTSV & RSV) is released.

When the turbine trip signal actuates, a solenoid valve in each extraction non-return valve is de-energized and allows the air cylinder to assist then non-return valve to close. The air pilot valve of the No.5 extraction non-return valve also functions with the pressure drop of the emergency trip header (MTSV&RSV) to activate the air cylinder for redundancy.

Since the non-return valve is closed by free movement of its own disc without any assistance if there is no flow in the extraction line, there is no common-cause failure (CCF) for the non-return valves. As a part of its fail safe design, in case of air system failure such as loss of air supply or loss of power, the cylinder air will be released to assist closing. Release air from the solenoid valves are discharged locally and are not collected. The extraction non-return valves are arranged so that the turbine does not reach its design overspeed in the case of single valve failure.

10.2.2.3 Control Function

The control function consists of the turbine control system (which is usually called the DEH system), the TPS and turbine supervisory instrument (TSI) system. These systems have individual cabinets located in the non-class 1E I&C room in the auxiliary building.

The turbine control system has the function of speed control including overspeed protection controller (OPC) and load control and so on.

The TPS has the function to trip the turbine when the turbine is under abnormal condition. The electrical overspeed trip (EOST) is a part of the TPS. Electric speed sensors for EOST are independent from the ones for the turbine control system. There is a possibility that a software CCF could cause signal processing of the EOST to be disabled. The diverse actuation system (DAS), which is completely independent from the turbine control and protection system, has the function to trip the turbine manually even in the case of software CCF.

In addition to the turbine control system and TPS, the steam turbine is equipped with MOST. The MOST consists of only mechanical and hydraulic equipment and is independent from EOST. This configuration provides assurance that the vulnerability against common-mode and common-cause failures can be avoided.

10.2.2.3.1 Turbine Control System

The T/G is equipped with a ~~DEH~~ turbine control system that combines the capabilities of a redundant microprocessor and high-pressure hydraulics to regulate steam-flow through the turbine. The ~~DEH~~ turbine control system allows speed control, load control, and automatic turbine control (ATC) which may be used, either for control or for supervisory purposes, at the option of the plant operator.

The ~~DEH~~ turbine control system employs three electric speed sensors that are independent from the TPS, ~~inputs~~ whose signals are processed in redundant microprocessors. Valve-opening actuation is provided by a hydraulic system that is independent of the bearing lubrication system. Valve-closing actuation is provided by springs and steam forces in the event of a reduction in or relief of fluid pressure. The system is designed so that loss of fluid pressure, for any reason, leads to valve-closing and a consequent turbine trip.

Steam valves are provided in a series of pairs. The valves are positioned by the ~~emergency trip~~ turbine control system and ~~DEH system~~ the TPS.

10.2.2.3.1.1 Speed Control

The speed control function of the ~~DEH~~ turbine control system provides speed control, acceleration, and overspeed protection. The speed control function produces a speed error signal, which is fed to the load control function. The speed error signal is derived by comparing the desired speed with the actual speed of the turbine at steady-state conditions or by comparing the desired acceleration rate with the actual acceleration rate during startup.

The speed select algorithm receives three speed signals, performs a medium signal selector, compares the result to the speed reference signal, and transmits the error signal to the speed controller demanding the appropriate speed. The failure of one speed input generates an alarm and the turbine continues operating using proper speed signals. Failure of two or more speed inputs also generates an alarm and the turbine will be tripped automatically.

The ~~DEH~~ turbine control system consists of two redundant microprocessors and a redundant power supply.~~, one~~ One microprocessor is in ~~the~~ control mode and the other is in ~~the~~ standby mode. If the one microprocessor in the control mode fails, the other one in ~~the~~ standby mode takes over automatically. If the ~~one~~ microprocessor in the standby mode fails, the other one maintains control. The turbine is tripped automatically in the event that both of ~~them~~ the microprocessors fail to perform their function or both of the redundant power supplies fail.

10.2.2.3.1.2 Load Control

The load control function of the ~~DEH~~ turbine control system develops signals that are used to regulate the unit load. Signal outputs are based on a proper combination of speed error and actual load (turbine megawatt) reference signals.

Steam-flow is not controlled directly but rather by turbine megawatt and valve position. Under normal conditions, the turbine requests a certain megawatt load target. Through a coordinated mode of control, the turbine valves adjust the steam flow from the steam generators supplied to the turbine.

10.2.2.3.1.3 Valve Control

The flow of the main steam entering the high-pressure turbine is controlled by four main turbine stop valves (MTSVs) or four main turbine control valves (MTCVs). Each MTSV is controlled by electro hydraulic servo actuators in response to the signals from the ~~DEH~~ turbine control system. When the turbine is placed in operation, the MTSVs are fully opened and the MTCVs are modulated. The function of the MTSVs is to shut off the steam flow to the turbine when required. The MTSVs are closed by ~~actuation of the emergency trip system devices~~ the signals from the TPS. ~~These devices are independent of the DEH system.~~

The MTCVs are positioned by electro hydraulic servo actuators in response to the signals from the ~~DEH~~ turbine control system. When the turbine speed reaches the rated speed using the MTSVs, the MTCVs are fully open. During turbine operation, the MTCVs are modulated by the ~~DEH~~ turbine control system and MTSVs are fully open, MTCVs and MTSVs are completely closed on turbine trip.

The reheat stop and intercept valves (RSVs & IVs), located in the cross-over pipes at the inlet to the low-pressure turbines, control steam-flow to the low-pressure turbines. During normal operation of the turbine, the RSVs and IVs are fully open. The IVs are controlled by electro hydraulic servo actuators in response to the signals from the ~~DEH~~ turbine control system during startup and normal operations and they close rapidly on a loss of turbine load and turbine trip. The RSVs close completely on turbine overspeed and turbine trip.

The MTSVs, MTCVs, RSVs and IVs have dump valves connected to the hydraulic portion of their respective valve actuators. Opening a dump valve causes the connected ~~control or stop~~ valve to rapidly close. The dump valve actuators are connected to trip headers and open in response to loss of pressure in the connected emergency trip header. The ~~control and intercept~~ dump valves of the MTCVs and IVs are connected to the ~~DEH overspeed protection control~~ emergency trip header (MTCV & IV) and the ~~stop and reheat stop~~ dump valves of the MTSVs and RSVs are connected to the emergency trip header (MTSV & RSV). ~~In the event of OPC actuation, only the control fluid pressure of DEH overspeed protection control header is decreased via a check valve. Therefore, the emergency trip system is independent of the DEH overspeed protection system.~~

When the OPC is activated, only the fluid pressure of the emergency trip header (MTCV & IV) is released by the redundant solenoid valves (denoted as 20-OPC1 and 20-OPC2 in Figure 10.2-3). As the emergency trip header (MTCV & IV) is connected to the other emergency trip header (MTSV & RSV) through redundant check valves, OPC signal does not close MTSV and RSV and the turbine control system tries to maintain the turbine plant in operation.

10.2.2.3.1.4 Power/Load Unbalance

A power/load unbalance circuit initiates fast closing of the MTCVs and the IVs under load rejection conditions that might lead to rapid rotor acceleration and consequent overspeed.

Valve action occurs when the power/load unbalance exceeds the load by 30 percent or more. LPT inlet steam pressure is used as a measure of turbine power. Generator current is used as a measure of generator load to provide discrimination between a loss of load incident and an electric system fault.

When a power/load unbalance condition is detected, the OPC solenoid valves are quickly energized to close the MTCVs and the IVs. When the condition clear, the power/load unbalance circuitry resets automatically, and the OPC solenoid valves are reset.

10.2.2.3.1.5 Overspeed Protection

The ~~DEH~~ turbine control system has two modes of operation to protect the turbine against overspeed. The first mode is the speed control which maintains the desired speed as discussed in Subsection 10.2.2.3.1.1. The second mode is the overspeed protection control which operates if the normal speed control should fail or upon a loss of load. An overspeed protection demand is sent to the OPC solenoid valves ~~for MTCVs and IVs~~ (denoted as 20-OPC1 and 20-OPC2 in Figure 10.2-3). The solenoid valves are ~~is~~ energized and a drain path for the hydraulic fluid opens in the ~~overspeed protection control header~~ emergency trip header (MTCV & IV), if the turbine speed exceeds 103 percent of the rated speed. The loss of fluid pressure in the emergency trip header (MTCV & IV) causes the MTCVs and the IVs to close. If the speed falls below rated speed following an ~~overspeed protection controller~~ OPC action, the header pressure is reestablished, the MTCVs and the IVs are reopened, and the unit resumes speed control. During turbine-generator load reduction, the turbine bypass system provides the capability to bypass the steam from the steam generator to the main condenser to minimize transitional effects in the reactor coolant system. Refer to Table 10.2-2 for a description of the sequence of events following a full loss of load and the nominal trip set points. ~~An emergency trip system is also provided to trip the turbine in the event that speed in exceeds of the overspeed protection trip points.~~

Redundancy is built into the overspeed protection control in the turbine control system. The failure of a single OPC solenoid valve will not disable the turbine speed control capability. Loss of hydraulic pressure in the turbine control system causes the turbine to trip. Therefore, damage to the overspeed protection components results in the closure of the valves and the interruption of steam-flow to the turbine.

The TPS provides the capability to trip the turbine in the event where the rotating speed is exceeds the overspeed protection trip set points. The TPS ~~emergency trip system~~ is discussed in Subsection 10.2.2.3.2~~.1~~.

~~Redundancy is built into the overspeed protection control in the DEH system. The failure of a single OPC solenoid valve will not disable the trip functions. Loss of hydraulic pressure in the emergency trip system causes the turbine to trip. Therefore, damage to the overspeed protection components, results in the closure of the valves and the interruption of steam-flow to the turbine.~~

~~Quick closure of the steam valves prevents turbine overspeed. Valve closing times are given in Table 10.2-4.~~

10.2.2.3.1.6 Automatic Turbine Control (ATC)

The ATC provides safe and proper startup and loading of the turbine generator. The ATC programs monitor the applicable limits and precautions during turbine operation even if the ATC mode is not selected by the operator. When the operator selects ATC mode, the programs both monitor and control the turbine. The ~~DEH~~ turbine control system uses the computer to scan, calculate, make decisions, and take positive action during turbine operation.

The ATC is capable of automatically:

- Changing speed
- Changing acceleration
- Generating speed holds
- Changing load rates
- Generating load holds

The thermal stresses in the rotor are calculated by the ATCs programs based on actual turbine steam and metal temperatures as measured by thermocouples or other temperature measuring devices. Once the thermal stress (or strain) is calculated, it is compared to the allowable value, and the difference is used as an index of the permissible first stage inlet temperature variation. This permissible temperature variation is translated in the computer program as an allowable speed or load or rate of change of speed or load.

The values of some parameters are stored for use in the prediction of their future values or rates of change. These predictions are used to initiate corrective measures before alarm or trip points are reached.

The rotor stress (or strain) calculations used in the ATC program, and its decision-making counterpart, are the primary control inputs during turbine operation. They allow the unit to operate with relatively high acceleration until the program predicts that the stress valves are about to approach their limit. It these limits are about to be reached then a lower acceleration value is selected and, if the condition persists, a speed hold is generated. The same philosophy is used on load control in order to maintain positive control of the loading rates.

The ATCs programs are stored and executed in a redundant distributed processing unit, which contains the function of the rotor stress programs and the majority of the ATCs logic programs. Once the turbine is reset, the ATC programs are capable of switching the turbine from turning gear to synchronous speed with supervision.

Once the turbine-generator reaches synchronous speed, the startup or speed control phase of the ATC is completed and no further action is taken by the programs. Upon closing the main generator breaker, the ~~DEH~~ turbine control automatically picks up approximately 5 percent of the rated load to prevent motoring of the generator. At this time, the ~~DEH~~ turbine control system is in load control.

The ~~DEH~~ turbine control system is equipped with a remote control interface. Selection of the remote mode provides for control of the turbine-generator from an operator console. In the remote mode, the rate of load change is controlled by the operator console.

In the combined mode of both the remote control and the ATC, the ATC allows the remote control system control of load changes until an alarm condition occurs. If the operating parameters being monitored (including rotor stress) exceed their associated alarm limit, a load hold is generated in conjunction with the appropriate alarm message. The ~~DEH~~ turbine control system generates the load hold by ignoring any further load increase or decrease until the alarm condition is cleared or until the operator overrides the alarm condition. At the same time that the ~~DEH~~ turbine control system generates the load hold based on the ATC alarm condition, the ~~DEH~~ turbine control system also informs the remote control system of its action. In the combined mode of control, both the load reference and the load rate are implicitly controlled by the remote control system while the ATC supervises the load changes with overriding control capability.

The operator may remove the turbine-generator from ATC. This action places the ATC in a supervisory capacity.

10.2.2.3.2 Turbine Protection System

When initiated, turbine protection~~ve trips,~~ system causes tripping of the main stop, control, intercept, ~~and~~ reheat stop valves and extraction non-return valves. The protective trips are:

- Low bearing oil pressure
- Low emergency trip header (MTSV&RSV) pressure
- Low condenser vacuum
- Turbine overspeed (EOST)
- Thrust bearing wear
- High exhaust hood temperature
- High shaft vibration
- Low shaft-driven lube oil pump discharge pressure
- Remote trip that accepts external trips

In regard to the turbine overspeed trip function, the steam turbine is equipped with the MOST in addition to the EOST. The MOST consists of only mechanical and hydraulic devices and is independent from the TPS including the EOST.

A description of the ~~trip system~~ TPS and the MOST for turbine overspeed is provided below.

~~**10.2.2.3.2.1 Emergency Trip System**~~

The purpose of the TPS ~~emergency trip system~~ is to detect undesirable operating conditions of the turbine-generator, take appropriate trip actions, and provide information to the operator about the detected conditions and the corrective actions. In addition, means are provided for testing the TPS ~~emergency trip~~ equipment and circuits.

The system utilizes a two channel configuration which permits on-line testing with continuous protection afforded during the test sequence. ~~A mechanical overspeed trip is also provided as described in Subsection 10.2.2.3.2.3.~~

Figure 10.2-3 shows the simplified schematic of the TPS and the MOST. ~~The emergency trip system includes the emergency trip control block, trip solenoid valves, the mechanical overspeed trip device, speed sensors, and a test panel. These items and the function of the overspeed trips are described in the following three subsystems.~~

The TPS trips the turbine by opening four (4) turbine trip solenoid valves (denoted 20-AST1-20-AST4 in Figure 10.2-3) to drain the emergency trip header fluid and subsequently all the turbine valves are closed. The turbine trip solenoid valves are opened when de-energized.

The turbine trip solenoid valves are actuated by Safety Logic System (SLS) (see Chapter 7, Subsection 7.3.1.11 and Figure 7.3-4). The SLS receives the turbine trip signal by hard wired line from the TPS (see Chapter 7 Table 7.3-2 and Figure 7.3-3). The SLS de-energize the turbine trip solenoid valves and trip the turbine in case of reactor trip or high-high SG water level and also in case that the SLS receives the turbine trip signal from the TPS. The turbine trip signal from the TPS includes the signal of the EOST. The SLS is safety-related system.

The TPS cabinet consists of quadruple redundant microprocessors and redundant power supplies. Each microprocessor corresponds to each turbine trip solenoid valve. The TPS cabinet will output four independent turbine trip commands (Normally Close Contact) from the output module to turbine trip solenoid valves via Power Interface (PIF) module of SLS (see Chapter 7, Subsection 7.3.1.11 for the interface between SLS and turbine trip solenoid valve.). When the microprocessor fails or both redundant power supplies to the microprocessor fails, the turbine trip command of the failed microprocessor is initiated (Contact Open) then the SLS de-energize the corresponding turbine trip solenoid valve. Therefore, the TPS cabinet is designed as a fail-safe system.

Main stop valves (MTSVs) and reheat stop valves (RSVs) are arranged at the inlet of the HPT and LPTs respectively to shut off the steam flow to the turbines at an event such as sudden loss of electrical load during operation. The MTCVs and IVs are arranged in series with the MTSVs and RSVs respectively so that any single damage or malfunction of the valves does not fail to interrupt steam flow to the turbines. All the valves are equipped with suitably sized dump valves to release cylinder oil pressure to nil and to close the valves within the closing time specified in Table 10.2-4. MTSVs and RSVs are closed by oil pressure reduction in the emergency trip header (MTSV & RSV), while MTCVs and IVs are closed by oil pressure reduction in the emergency trip header (MTCV & IV) which is independent and separated from the emergency trip header (MTSV & RSV).

Since the emergency trip header (MTCV & IV) is connected to the emergency trip header (MTSV & RSV) through the redundant check valves, MTCVs and IVs, which are arranged in series with MTSVs and RSVs respectively, are also closed by the oil pressure reduction in the emergency trip header (MTSV & RSV).

Quick closure of the steam valves prevents turbine overspeed. Valve closing time of MTSV, MTCV, RSV and IV is equal or less than the closing time listed in the Table 10.2-4 for the purpose that the turbine speed does not hit the turbine trip set point (110 percent of rated speed) at OPC activation and does not hit turbine design overspeed at turbine trip. Those closing times will be confirmed to be equal or less than specified time during pre-operational test prior to fuel loading and start-up test in the field.

MOST and EOST release the fluid pressure of the emergency trip header (MTSV & RSV) and consequently the fluid pressure of the emergency trip header (MTCV & IV) through the redundant check valves in the event that turbine rotation speed reaches 110 and 111 percent respectively. Detail explanation of MOST and EOST function and trip mechanism is given in Section 10.2.2.3.2.2.

MTSVs, RSVs, emergency trip header (MTSV & RSV), MTCVs IVs, emergency trip header (MTCV & IV), check valves between emergency trip header for (MTSV & RSV) and (MTCV & IV), a part of the trip block drain line and a part of the actuator drain line are shared by the MOST and the EOST. All the equipments/headers listed above are duplicated in a manner that single failure does not cause the turbine overspeed to exceed the design overspeed except for a part of the drain line from the trip control block and a part of the actuator drain line.

A part of the drain line from the trip control block and the actuators is not duplicated and plugging in the lines could be the cause of common-cause failure. There is a possibility that plugging in the common drain line could cause increase in oil level and pressure in the drain line and disable all the turbine valves to close, which will leave all the turbine main valves open and could result in turbine destructive overspeed. The hydraulic system of the TPS is designed so that all the turbine valves can be closed even in such plugged condition. For this purpose, the following considerations are taken in the hydraulic system design;

- The drain pipe volume after the dump valves or the solenoid valves is designed to have enough volume to dump enough amount of oil that is required to close MTCVs, MTSVs, RSVs, and IVs at emergency conditions.
- The valve actuator drain is led from the lower chamber to the upper chamber of the actuator piston when the turbine valves rapidly close.
- Oil pressure of these common drain lines is continuously monitored by the pressure switch or transmitter and annunciated in the control room.

For avoiding plugging in the hydraulic system, the following countermeasures are to be taken;

- Although additives contained in the control fluid are considered to be the main cause of sludge deposition, the control fluid is 100% triaryl phosphate (also known as a 'natural' and 'non-additive' phosphate ester) so that sludge deposition is quite unlikely to block the pipes.
- Application of stainless steel pipes to the turbine control and protection system.
- To minimize the possibility of water intrusion to the control fluid system, air-cooled oil heat exchangers are to be adopted.
- To minimize oxygen and water content in the control fluid system and to avoid oil degradation, fuller's earth filters are installed in high pressure oil supply line.
- To keep cleanliness of the control fluid and ingredient less than allowable, appropriate filters are installed in the supply and return lines. Polishing pump and polishing filter can be operated for such case as new oil is supplemented.
- In addition to the above countermeasures, control fluid should be subject to periodical sampling and testing to confirm that all the control parameters are within allowable range. Sampling and testing shall be done based on the manufacture's recommendation and suitable actions shall be taken in accordance with manufacture's standards if necessary (see Table 10.2-5).

Fail-safe design concept is also taken into consideration as indicated below;

- Because the solenoid valves of the trip control block are designed to close by energizing, the emergency trip headers oil pressure is decreased by the loss of electrical power source. No.5 extraction check valve is designed to close by the loss of air supply system.
- Oil supply and drain lines are potentially broken or stricken by turbine missiles followed by oil pressure reduction in these lines. All turbine valves are designed to be kept open when control oil pressure or emergency trip header pressure is held at design pressure. All turbine valves are therefore closed at such unexpected oil pressure drop as mentioned above.
- Therefore any failure of the electrical power sources, high pressure oil supply system and the air supply system does not cause loss of over speed protection function.

The function of the overspeed trips are described in the following three subsystems.

10.2.2.3.2.~~2~~ 1 ~~Emergency~~ Trip ~~Control~~ Block

The emergency trip header pressure is established when the turbine trip solenoid valves are energized ~~when closed~~. The valves are arranged in two channels for testing purposes, the odd numbered pair corresponds to channel 1, and the even numbered pair corresponds to channel 2. This convention is followed throughout the TPS ~~emergency trip system~~ in designating devices; i.e., channel 1 devices are odd-numbered, and channel 2 devices are even-numbered. Both valves in a channel will open to trip that channel. At least one solenoid valve in both channels must open before the trip header pressure reduces to close the turbine steam inlet valves. Each tripping function of the solenoid valves ~~electrical emergency trip system~~ can be individually tested from the operator/test panel without tripping the turbine by separately testing each channel of the appropriate trip function. The solenoid valves ~~may be individually~~ are to be tested once a month (Table 10.2-5). ~~Spool-type solenoid valves are not used in the emergency trip control block.~~

A trip signal from the SLS ~~of the emergency trip system~~ opens a drain path for the hydraulic fluid in the emergency trip header (MTSV & RSV). The loss of fluid pressure in the trip header causes the MTSVs ~~main stop~~ and the RSVs ~~reheat stop valves~~ to close. Also, redundant check valves to ~~in~~ connect~~ion with~~ emergency trip header for (MTCV & IV) and (MTSV & RSV)~~the overspeed protection control header~~ open to drop the pressure in the ~~overspeed protection control~~ emergency trip header (MTCV & IV) and cause the MTCVs and IVs ~~control and intercept valves~~ to close. ~~The control and intercept valves are redundant to the main stop and reheat stop valves respectively.~~

10.2.2.3.2.~~3~~ 2 Overspeed Trip Functions and Mechanisms

The emergency overspeed trips consist of a mechanical and an electrical trip. The MOST ~~mechanical emergency overspeed trip~~ actuates before the EOST ~~electrical emergency trip~~. The emergency overspeed trip set points are identified in Table 10.2-2.

The ~~mechanical overspeed trip~~ MOST device consists of a spring-loaded trip weight mounted in the rotor extension shaft. At normal operating speed, the weight is held in the inner position by the spring. When the turbine speed reaches the trip setpoint, the centrifugal force overcomes the compression force of the spring and throws the trip weight outward striking a trigger. As the trigger moves, it unseats a cup valve which drains the mechanical overspeed and manual trip header. The mechanical overspeed and manual trip header can be tripped manually via a trip lever mounted on the governor pedestal. The mechanical overspeed and manual trip ~~are installed equipment for hydraulic test which can test without overspeed of the turbine shaft. If it is tested on site, trip weight will fall out after opening manual test valve with pulling a lever and mechanical overspeed trip equipment will be operated. After operating, trip operation can be confirmed because hydraulic pressure which detect mechanical overspeed trip is decreased rapidly. The mechanical overspeed and manual trip is tested remotely from the center online. If the test solenoid valve for the overspeed trip is excited after making the mechanical overspeed trip system a test mode with the lockout solenoid valve, trip weight will be operated. After operating, trip operation can be confirmed because automatic stop oil and hydraulic pressure which detect mechanical overspeed trip is decreased.~~ header is interconnected to the emergency trip header (MTSV & RSV) via the interface piston valve. When the interface piston valve is pressurized by the fluid of the mechanical overspeed and manual trip header, the drain valve remains closed and fluid pressure of the emergency trip header (MTSV & RSV) is maintained. When the fluid pressure of the mechanical overspeed and manual trip header is released by trip lever of the MOST, the interface piston valve will open the drain valve and dump the fluid of the emergency trip header (MTSV & RSV), which lead to the turbine trip.

MOST system is equipped with on-line test facilities, which can test the functions of the system without overspeeding the actual turbine shaft. This test is to be conducted periodically once a month during normal operation (Table 10.2-5). During MOST on-line testing, EOST keeps detecting turbine speed and is to trip the turbine in case that the turbine speed exceeds the trip set point.

The ~~electrical overspeed trip~~ EOST system has separate, redundant speed sensors and provides backup overspeed protection utilizing the trip solenoid valves in the ~~emergency~~ trip ~~control~~ block to drain the emergency trip header. The hydraulic fluid in the emergency trip header ~~and overspeed protection control headers~~ is independent of the bearing lubrication system to minimize the potential for contamination of the fluid.

As described above, MOST and EOST are separated functionally and physically except for a part of the trip block drain line and a part of the actuator drain line. As described in Section 10.2.2.3.2, the failure of these drain lines does not prevent the valves from rapidly closing.

~~The emergency trip header of the control fluid system and the manual trip header of the lubricating oil system are interconnected via the interface piston valve. The interface piston valve is normally closed under the autostop fluid header pressure of the manual trip header of the lubricating oil system, which establishes the control fluid pressure in the emergency trip header of the control fluid system.~~

The speed control and overspeed protection function of the ~~DEH~~ turbine control system combined with the TPS (including the EOST) ~~emergency trip system and electrical~~ and MOST ~~mechanical overspeed trips~~ provide a level of redundancy and diversity at least equivalent to the recommendations for turbine overspeed protection found in III.2 of the Standard Review Plan (NUREG-0800) Section 10.2 (Reference 10.2-3).

Additionally, the issues and problems with overspeed protection systems and common-mode factors identified in NUREG-1275 (Reference 10.2-4) have been addressed. The countermeasures against the common-mode factors are summarized as follows; ~~(Reference 10.2-4).~~

- The TPS does not utilize pressure switches for the overspeed detection device to trip the turbine and there is no need to detect existing failures of pressure switches.
- Solenoid block for the EOST has four solenoid operated valves and established 1 out of 2 twice logic. This configuration makes it possible to test each solenoid operated valve to detect if there are any difficulties or failures to open the solenoid valves.
- The MOST system including trip weight, trigger mechanism and operation of interface piston valve can also be tested during operation.
- Those EOST and MOST tests during operation shall be carried out once a month.

- Hydraulic fluid for turbine control and protection system shall be sampled and tested every three months to confirm that all the control parameters of the fluid are within the allowable range specified in the manufacturer's standard.

10.2.2.3.2.~~4~~3 Test Blocks

Low bearing oil pressure, Low main oil pump discharge pressure and Low condenser vacuum are each sensed by separate test block instrumentation. Each test block assembly consists of a steel test block, two pressure indications, two manual valves, two solenoid valves, and four pressure switches. Each assembly is arranged into two channels. The assemblies, mounted on the governor pedestal, are connected to pressure sensors mounted in a nearby terminal box. The assemblies have an orifice on the system supply side and are connected to a drain or vent on the other side. An orifice is provided in each channel so that the measured parameter is not affected during testing. An isolation valve on the supply side allows the test block assembly to be serviced.

If the medium (pressure or vacuum) reaches a trip set_point, then the pressure sensors cause the emergency trip header mechanism to operate. When functionally testing an individual trip device, the medium is reduced to the trip set_point in one channel either locally through the hand test valves or remotely from the trip test panel via the test solenoid valves.

10.2.2.3.2.~~5~~ 4 Thrust Bearing Trip Device

Three sets of position pickups, which are part of the turbine supervisory instrument package, monitor movement of a disc mounted on the rotor near the thrust bearing collar. Axial movement of this collar is reflected in the movement of the disc. Excessive movement of the disc is an indication of thrust bearing wear. Should excessive movement occur, supervisory instrument modules close and initiate a turbine trip.

10.2.2.3.2.~~6~~ 5 Remote Trip

~~The emergency trip system can also trip the turbine in response to a signal from theplant control system or plant safety and monitoring system.~~ The turbine trip manual switch is located on the operator console in the main control room (see Chapter 7, Table 7.1-1). The signal of the turbine trip switch is transferred to the SLS through the TPS de-energizing the turbine trip solenoid valves and trips the turbine. As the SLS is a safety-related system, the SLS is located in the separate room from the turbine control system and the TPS.

There is also a turbine trip manual switch, which is part of the DAS and independent of the TPS. This system therefore can be functioned even in the case of software common cause failure (see Chapter 7, Subsection 7.8.1.1.1).

10.2.2.3.2.~~7~~ 6 Other Protective Systems

Additional protective features of the turbine and steam system are:

- Moisture separator reheater safety relief valves

- Rupture diaphragms located on each of the low-pressure turbine cylinder covers
- Turbine water induction protection systems on the extraction lines. The extraction line isolation valves and non-return valves close, and drain valves open, following a turbine trip signal.

10.2.2.3.3 Turbine Generator Supervisory Instrumentation

The turbine-generator is provided with turbine supervisory instrumentation including monitors for the following:

- Speed*
- MTSV position
- MTCV position
- RSV and IV positions
- Temperatures as required for controlled starting, including:
  - Steam chest inner surface
  - Steam chest outer surface
  - First-stage inlet lower inner surface
  - Cross-over pipe downstream of RSV No. 1
  - Cross-over pipe downstream of RSV No. 2
  - Cross-over pipe downstream of RSV No. 3
  - Cross-over pipe downstream of RSV No. 4
  - Cross-over pipe downstream of RSV No. 5
  - Cross-over pipe downstream of RSV No. 6
- Casing and shaft differential expansion*
- Vibration of each bearing*
- Shaft eccentricity*
- Bearing metal temperature
- Bearing oil temperature

Alarms are provided for the following abnormal conditions:

- High vibration*
- Turbine supervisory instruments failure alarm*

Note: * mark monitors are included in the TSI System.

TSI is the turbine supervisory instrument which is identified as the special system to monitor rotation component. TSI has a self diagnostic function to detect failure or power supply failure. The TSI failure alarm will be initiated and indicated in the main control room when the self diagnosis function of the TSI detects failure or power supply failure.

Others are for monitoring. Indications of the following miscellaneous parameters are provided:

- Main steam throttle pressure
- Steam seal supply header pressure
- Steam seal condenser vacuum
- Bearing oil header pressure
- Bearing oil coolers coolant temperature
- ~~DEH~~ Turbine control fluid header pressure
- ~~DEH~~ Turbine control fluid temperature
- Cross-over pressure
- Moisture separator drain tank level
- First-stage inlet pressure
- High-pressure turbine exhaust pressure
- Extraction steam pressure, each extraction point
- Low-pressure turbine exhaust hood pressure
- Exhaust hood temperature for each exhaust

Generator supervisory instruments are provided, with sensors and/or transmitters mounted on the associated equipment. These indicate or record the following:

- Stator winding temperature (three detectors per phase)

- Stator coil cooling water temperature (one detectors per coil)
- Hydrogen cooler inlet and outlet gas temperature (two detectors at each point)
- Hydrogen gas pressure
- Hydrogen gas purity
- Generator ampere, voltage, and power

Additional generator protective devices are listed in Table 10.2-3.

10.2.2.3.4 Plant Loading and Load Following

The T/G control system has the same loading and load following characteristics as the control system described in Section 7.7.

10.2.2.3.5 Inspection and Testing Requirements

Major system components are readily accessible for inspection and are available for testing during normal plant operation. Turbine trip circuitry is tested prior to unit startup. To test control valves with minimal disturbance, the load is reduced to that capable of being carried with one control valve closed.

~~The information of testing of the protective device is described in the following section:~~

~~Emergency trip test Section 10.2.2.3.2.2~~

~~EOST test~~	~~Included in Section 10.2.2.3.2.2~~
~~MOST test~~	~~Section 10.2.2.3.2.3~~
~~Low Bearing oil Trip Test~~	~~Section 10.2.2.3.2.6~~
~~Low Vacuum Trip Test~~	~~Section 10.2.2.3.2.6~~
~~Low MOP Discharge oil Trip Test~~	~~Section 10.2.2.3.2.6~~

Inspection and test requirements for the overspeed trip device are shown in Table 10.2-5. In addition, the testing frequency of turbine valve testing that influences the possibility of turbine missile generation is described in Section 10.2.3.5.

10.2.3 Turbine Rotor Integrity

Turbine rotor integrity is provided by the integrated combination of material selection, rotor design, fracture toughness requirements, tests, and inspections. This combination results in a very low probability of a condition that could result in a rotor failure. For the verification that actual rotor material properties satisfy the material properties assumed and used in the turbine missile calculations, mechanical properties including fracture toughness are to be verified by the tests to conform to the applicable material specifications of turbine missile calculations. (Reference 10.2-9)

10.2.3.1 Materials Selection

Fully integral turbine rotors are made from ladle refined, vacuum deoxidized Ni-Cr-Mo-V alloy steel by processes that maximize the cleanliness and toughness of the steel. The lowest practical concentrations of residual elements are obtained through the melting process. The turbine rotor material complies with the chemical property limits of ASTM A470 (Reference 10.2-5). The specification for the rotor steel has lower limitations than indicated in the ASTM standard (Reference 10.2-5) for phosphorous, sulphur, aluminum and antimony. This material has the lowest fracture appearance transit temperatures (FATT) and the highest Charpy V-notch energies obtainable on a consistent basis from water-quenched Ni-Cr-Mo-V material at the sizes and strength levels used. Charpy tests and tensile tests are in accordance with ASTM, A370 (Reference 10.2-6). A minimum of three Charpy test specimens are tested using the impact test criteria that satisfy ASTM A470 Grade C (Class 6).

The production of steel for the turbine rotors starts with the use of high-quality, low residual element scrap. An oxidizing electric furnace is used to melt and dephosphorize the steel. Ladle furnace refining is then used to remove oxygen, sulphur, and hydrogen from the rotor steel. The steel is then further degassed using a process whereby steel is poured into a mold under vacuum to produce an ingot with the desired material properties. This process minimizes the degree of chemical segregation since silicon is not used to deoxidize the steel.

10.2.3.2 Fracture Toughness

Suitable material toughness is obtained through the use of materials described in Subsection 10.2.3.1 to produce a balance of material strength and toughness to provide safety while simultaneously providing high reliability, availability, and efficiency during operation. The restrictions on phosphorous, sulphur, aluminum, antimony, tin, argon, and copper in the specification for the rotor steel provides for the appropriate balance of material strength and toughness. The impact energy and transition temperature requirements are more rigorous than those given in ASTM A470 Class 6 or 7 and their equivalents.

Stress calculations include components due to centrifugal loads and thermal gradients where applicable. Fracture toughness will be at least $200\text{ksi}\cdot\text{in}^{1/2}$ ($220\text{MPa}\cdot\text{m}^{1/2}$). For the purpose of conservative evaluation, fracture analysis is to be done using ~~a~~ fracture toughness with margin against minimum expected values on the rotors. The material fracture toughness needed to maintain this conservative margin is verified by mechanical property tests on material taken from the rotor.

The rotor is evaluated for fracture toughness by criteria that include the design duty cycle stresses, number of cycles, ultrasonic examination capability and growth rate of potential flaws. Conservative factors of safety are included to account for the amount of uncertainty in the potential or reported ultrasonic indications of flaws, rate of flaw growth (da/dN versus dK) and the duty cycle stresses and number.

center of the rotors satisfied the rotor material specification requirements. Forgings for no-bore rotors are provided by suppliers who have been qualified based on bore material performance.

All the low-pressure turbine rotating blades are attached to the rotor using christmas tree, side entry type root.

10.2.3.5 Inservice Inspection

The inservice inspection program for the LP turbine provides assurance that rotor flaws that might lead to brittle failure of a rotor at speeds up to design speed will be detected. This inspection includes disassembly of the turbine at equal or less than 10-year intervals during plant shutdowns coincident with the inservice inspection schedule required by IWA-2430 of the 2007 Edition with 2008 Addenda of Section XI, Division 1 ASME Boiler & Pressure Vessel Code. Inspection of parts that are normally inaccessible when the turbine is assembled for operation (couplings, coupling bolts, turbine rotors, and low pressure turbine blades) is conducted.

The maintenance and inspection program plan for the turbine assembly and valves is based on turbine missile probability calculations, operating experience of similar equipment and inspection results. The turbine missile generation probability due to rotor material failure below design overspeed was submitted in Reference 10.2-9. The analysis of missile generation probability due to failure of the overspeed protection system is used to determine turbine valve test frequency and is described in Reference 10.2-10. The maintenance and inspection program includes the activities outlined below:

- This inspection consists of visual, surface, and volumetric examinations as indicated below:
  - Each rotor, stationary and the rotating blade path component is inspected visually and by magnetic particle testing on its accessible surfaces. Ultrasonic inspection of the side entry blade grooves is conducted. These inspections are conducted at intervals equal or less than 10 years for both high-pressure and low-pressure turbines.
  - A 100 percent surface examination of couplings and coupling bolts is performed.
  - The fluorescent penetrant examination is conducted on nonmagnetic components.
- At least one main steam stop valve, one main steam control valve, one reheat stop valve, and one intercept valve are dismantled approximately every 4 years during scheduled refueling or maintenance shutdowns. A visual and surface examination of the valve internals is conducted. If unacceptable flaws or excessive corrosion are found in a valve, the other valves of the same type are inspected. Valve bushings are inspected and cleaned and bore diameters are checked for proper clearance.
- Main stop valves, control valves, reheat stop and intercept valves may be tested with the turbine online. The ~~DEH~~ turbine control test panel is used to stroke or partially stroke the valves.

- Turbine valve testing is performed at quarterly intervals. The quarterly testing frequency is based on nuclear industry experience that turbine-related tests are the most common cause of plant trips at power. Plant trips at power may lead to challenges of the safety-related systems. Evaluations show that the probability of turbine missile generation with a quarterly valve test is less than the evaluation criteria.

- Inspection of e~~E~~xtraction non-return valve~~s~~ is conducted approximately every 4 years during scheduled refueling of maintenance shutdown. The inspection is conducted in accordance with the vendor's instruction, which includes valve seat surface check and valve maintenance if necessary ~~are tested prior to each startup~~. (see Table 10.2-5)

- Extraction non-return valves are tested at intervals recommended by the vendor during normal operation. The test is conducted locally by releasing air pressure ~~stroking the valve full open with air, then equalizing air pressure,~~ allowing the spring closure mechanism to close the valve. Closure of each valve is verified by direct observation of the valve arm movement. (see Table 10.2-5)

The Combined License Applicant is to establish a turbine maintenance, ~~and~~ inspection and test procedure prior to fuel load.

10.2.4 Evaluation

Components of the turbine-generator are conventional and typical of those which have been extensively used in other nuclear power plants. Instruments, controls, and protective devices are provided to confirm reliable and safe operation. Redundant, fast actuating controls are installed to prevent damage resulting from overspeed and/or full load rejection. The control system initiates turbine trip upon reactor trip. Automatic low-pressure exhaust hood water sprays are provided to prevent excessive hood temperatures. Exhaust casing rupture diaphragms are provided to prevent low-pressure cylinder overpressure in the event of loss of condenser vacuum. The diaphragms are flange mounted and designed to maintain atmospheric pressure within the condenser and turbine exhaust housing while passing full flow.

Since the steam generated in the steam generators is not normally radioactive, no radiation shielding is provided for the turbine-generator and associated components. Radiological considerations do not affect access to system components during normal conditions. In the event of a primary-to-secondary system leak due to a steam generator tube leak, it is possible for the steam to become contaminated. Discussions of the radiological aspects of primary-to-secondary leakage are presented in Chapters 11.

10.2.5 Combined License Information

COL 10.2(1) Inservice Inspection

The Combined License Applicant is to establish a turbine maintenance, ~~and~~ inspection and test procedure prior to fuel load.

Table 10.2-2 Turbine Overspeed Protection

Percent of rated Speed (Approximate)	Event (see note)
100	Turbine initially is at valves wide open. Full load is lost. Speed begins to rise. When the breaker opens, the load drop anticipator immediately closes the control and the intercept valves if the load at the time of separation is greater than 30 percent.
101	Control and intercept valves begin to close.
103	The overspeed protection controller closes the control and the intercept valves until the speed drops below 103 percent.
110	The mechanical overspeed trip device drains emergency trip oil and closes the main turbine stop, the main turbine control, the intercept, ~~and~~ the reheat and extraction non-return valves.
111	The electrical overspeed trip system closes the main stop, the main turbine control, the intercept, ~~and~~ the reheat stop and extraction non-return valves based on a two-out-of-three trip logic system.

Note:

Following the above sequence of events, the turbine will approach but not exceed the design overspeed (120 percent of the rated speed).

Table 10.2-5 Inspection and Test Requirement for Overspeed Trip Device

Test item	Confirmation item	Test or Inspection frequency
Trip block test	• Operation of trip solenoid valves	Once/month
Mechanical overspeed trip test	• Operation of eccentric weight and interface piston valve	Once/month
Electrical overspeed trip test	• Operation of trip solenoid valves	Once/month
Turbine Valve test	• Operation of MTSVs and MTCVs	Once/3 months
	• Operation of RSVs and IVs	Once/3 months
	• Operation of non-return valves	Vendor's recommendation
Turbine control fluid sampling and testing	• Items specified in manufacture's standard	Vendor's recommendation
Valve inspection	• Seat surface check of MTSVs and MTCVs	Approx. every 4 years during scheduled refueling of maintenance shutdown
	• Seat surface check of non-return valves	Approx. every 4 years during scheduled refueling of maintenance shutdown
	• Closure times of MTSVs, MTCVs, RSVs and IVs	Approx. every 4 years during scheduled refueling of maintenance shutdown

Note:
The above mentioned tests are carried out during operation. Valve inspections are carried out during scheduled refueling or maintenance shut down.

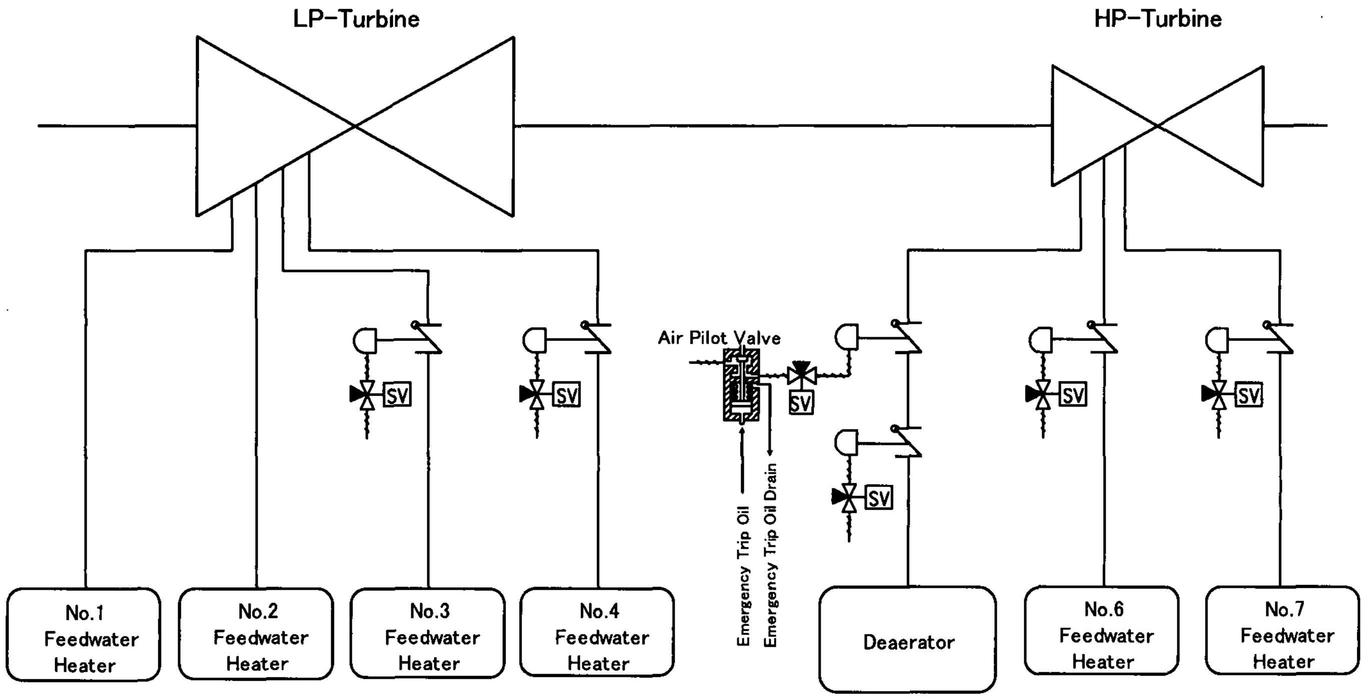


Figure 10.2-2 Arrangement of extraction non-return valves

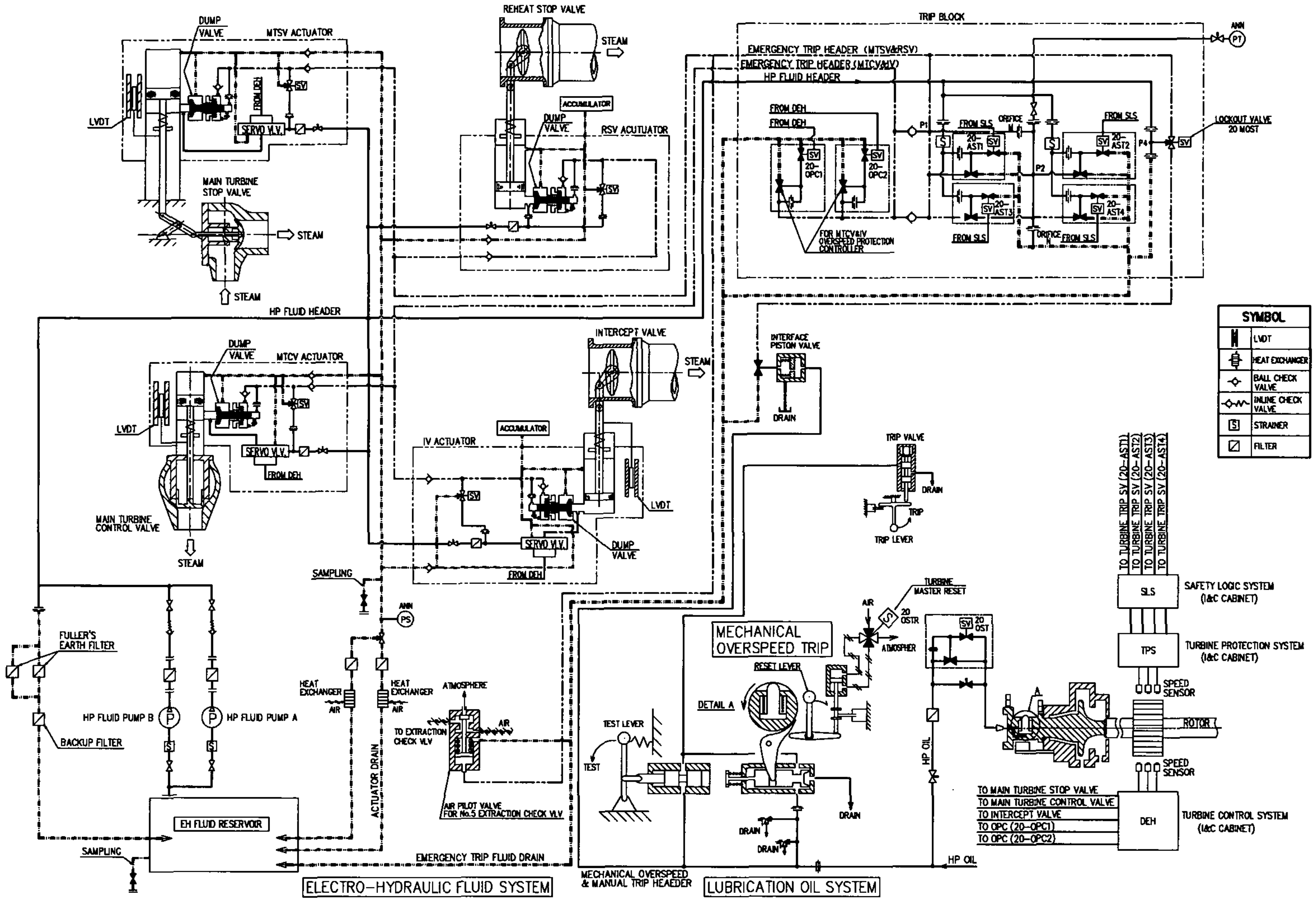


Figure 10.2-3 Simplified shematic of turbine control and protection system