Insufficient flow of steam through the HP section

Low flow of steam through the HP Turbine can be caused by either a restriction preventing steam from entering the turbine or a restriction preventing the steam from exiting the turbine. The RCA team first investigate restrictions preventing the steam from exiting the HP Turbine. Preliminary trending data indicated the HP control valves were opened enough to allow steam to enter the turbine; however, the CRH pressure was about 10psi greater than the HP Exhaust pressure. This back pressure would restrict the of flow to steam through the HP Turbine. [redacted]

The same programming control settings were in place during the startup on April 25, 2021, where the STG operated at FSNL condition for over 7 hours and did not produce the damaging temperatures in the HP Exhaust. The HP Exhaust high temperature alarm did activate as the temperature reached 974F. The HP Turbine control valves were opened a little more in April which would be expected as the HP Steam pressure and temperature were lower in April (1300psig and 920F). The HP Exhaust pressure and CRH pressure were lower, approximately 240 to 250psi, due to lower HP Steam pressure and temperature. The HP Exhaust pressure was +/-3 psi in respect to the CRH pipe pressure, which would indicate low to no flow through the HP turbine. The investigation looked for what else was different during the April startup event for the HP Exhaust temperature to be held lower. The analysis uncovered a difference in the operation of the CRH condensate drain valve. This valve is to be open while the STG is warming up, forcing the condensate build up out of the pipe and then closed once the STG is above [redacted] load. The drain valve is in the piping between the HP Exhaust and the Non-Return Valve (NRV). During the April startup, the CRH drain valve was open for the first 3 hours of FSNL operation. After the CRH drain valve was closed, the HP Exhaust temperature began to increase at a faster rate. The open CRH drain valve provided a pathway for steam to flow through the HP Turbine. During the November startup, the CRH drain valve was closed, resulting in the HP Exhaust restricted by the backpressure of the higher IP-Bypass valve pressure setting. The startup procedure refers to a separate document with a table listing the settings for the valves during the startup process. The CRH condensate drain valve is to be open and placed in manual to keep the valve open. The valve is to be placed in auto once the STG is above [redacted] load. In auto, the valve opens to drain the valve's condensate collection pot when it is full or when the turbine is tripped to provide a path for condensate as the unit cools. The CRH drain valve was placed in auto at 1:30 PM on November 8th prior to the attempted STG turbine start at 3:33 PM. The drain valve remained in auto until after the STG was manually tripped on November 10th. (Refer to Figures 10 and 11)

The Startup procedure does not contain a listing of the valve initialization configuration. It refers to a separate document for all the valves' initialization settings, requiring the operators to have that document in addition to the startup procedure. The valve initialization configuration document is not consistent in the nomenclature for the valve settings. Some of the valves are listed to be positioned in AUTO, some in MANUAL/OPEN, some in MANUAL/CLOSED, and some in OPEN. This makes the startup process difficult for a peer check unless the operators have the Auto Valve initialization configuration document with them for reference. The CRH drain valve is listed to be positioned in OPEN. For the CRH drain valve to be opened, it must be in MANUAL control. This is not designated in the startup procedure, nor the valve initiation configuration document. The requirement in the control narratives (for the valve to be opened while the STG is loaded less than [redacted] is not part of the DCS programming for the CRH drain valve when controlled in the AUTO mode. As such, the operators are called upon to perform the operation manually by placing the CRH drain valve to MANUAL control. The controls narrative states the CRH drain valve is to be closed when the STG is loaded about [redacted] The written startup procedure does not state when to close the CDH drain valves, which would be accomplished by switching the valve control from MANUAL into AUTO.

The analysis team used trend data to confirm the HP control valves were opened enough to allow steam to flow into the HP turbine. The concern was the higher main steam temperatures on November 10th may have caused increased thermal expansion of the valve stem, thereby physically closing the valve more than the controlled setting. Examination of a trend comparing the valve positions, the steam pressures and the turbine speed revealed the turbine speed increased when the HP Turbine Exhaust pipe ruptured. Indicating the relief of the back pressure allowed more steam to flow through the HP turbine. The steam control valves immediately responded by closing slightly to return the turbine speed back to its setpoint of 3,600rpm. Although the steam control valves were closed more than previous startups, they were still open enough to allow steam to enter the HP turbine. (Refer to Figure 12)

During the examination of the DCS steam control programming and the DCS logic drawings the analysis found additional discrepancies between the design expectation and the actual programming. This included incorrect control logic and incorrect settings in look-up value tables. The RCA utilized a 3rd party engineering firm to conduct a full and detailed comparison between the design expectations as expressed in the controls narratives and the actual programming of the DCS. The comparison uncovered numerous discrepancies which are provided in marked up control logic drawings. (Refer to Figures 13 and 14) Of concern are some temperature ramp rates for the main steam components being above the manufacturer's operational limits, potentially creating damaging internal stress from unequal thermal expansion.

These discrepancies affected the way the system functioned and from historical data these issues can be seen to have occurred during commissioning to the failure event. Therefore, these issues are not new to Eagle Valley. The issues and alarms have been considered normal, and historically there has been no known damage resulting from the issues. Comparison of the DCS control sheets at the time of the failure event to the original post-FAT control sheets determined the system has not been changed. It is unknown if the issues were detected or understood during commissioning, but from the lack of logic changes it does not appear anyone has attempted to remedy the problem.

[redacted] They issued a Toshiba Technical Information Letter (TTIL-KT112001X) in 2013 [redacted]

[redacted] In February 2021, Toshiba issued a Revision 1 to the TTIL [redacted] Eagle Valley leadership was unaware of either TTIL issued by Toshiba. The last Toshiba TTIL disseminated by Toshiba to Eagle Valley leadership was in August 2018. Without knowledge of the February 2021 TTIL, the recommendations contained in the TTIL were not considered for incorporation into the annual outage scheduled in April 2021 for the Eagle Valley facility.

[redacted]

[redacted]

[redacted]

[redacted] The Toshiba steam turbine was manufactured in 2015, 2 years after the publication of the TTIL Revision 0 from 2013 [redacted]

Conclusion:
The DCS programming logic for the Bypass Steam System was not in compliance with the designed operational control narrative. This deficiency did not provide the proper setpoint of the HRH pressure for proper steam flow through the HP Turbine during the STG startup process. The commissioning operational review of the Eagle Valley CCPP during construction failed to find the operational discrepancy. Eagle Valley personnel never reported an operational problem as the programming deficiency was minimized by steam flow through the open CRH condensate drain valve. With the CRH condensate drain valve not being open during the startup on November 10th, the steam flow through the HP Turbine was insufficient due to the high CRH pressure creating backpressure in the HP Exhaust piping. The TTIL Revision 1 was not implemented, [redacted].

Main steam pressure supplied to the HP section exceeded [redacted]

On November 8th, GT2 was started and set to a load of 16MW, as stated in the procedure for a cold start of the STG. The auto temperature match mode was enabled which controls the GT2 loading based on the steam turbine's 1st stage metal temperature. This temperature [redacted] is sent to the GE Mark Vie as an exhaust temperature setpoint. The GT will lower or raise its load to match this exhaust temperature setpoint. The GE Mark Vie has other parameters that will override lowering or raising the load to protect the gas turbine, which is why the minimum exhaust temperature attainable is [redacted]

When the STG would not start (due to a Profibus digital network communication issue), the auto temperature matching mode was disabled to increase the GT2 load to 90MW as directed by plant leadership. The Operations Leader stated that sitting at this load wasn't normal but was done to get the NOx emission rate in compliance with the plant's permit. The higher GT load was needed to meet the permissives for placing the Selective Catalytic Reduction system (SCR) in service. The GT must be in dry low NOx mode 6p, which is when the GT minimizes its emissions, in order to the start the SCR. The operators questioned the continued operation at the higher load, but management confirmed to maintain operating GT2 at 90MW as the repairs were expected to be completed soon and the desire was to be ready to start the STG.

On November 10th at 1:06 PM the GT2 load was lowered to 15MW, as specified in the startup procedure for a cold start of STG and the STG roll was started. GT2 load control was not returned to auto temperature match mode nor was the CRH condensate drain valves returned to manual to keep them open during the STG startup. At that time, the HP Steam temperature was at 1,035F with a pressure of 1,369psi. [redacted] Two minutes later, at 1:08 PM, GT2 load was adjusted back up to 90MW. At 1:40 PM the GT2 load was lowered to 50MW. At 2:50 PM the GT2 load was increased to 110MW and remained at that setting through the rest of the event. (Refer to Figure 15) The RCA team conducted interviews with operators and leadership but was unable to determine the reasons for the changes made to the GT2 load setting.

At 2:58 PM the HP Steam conditions reached 1,042F at 1,500psi. At 3:25 the HP Exhaust high temperature alarm displayed. The startup procedure states the GT load should be set to 16MW prior to starting the STG and then increased to 30MW after the STG is synchronized on the power grid and producing at 7.9MW load. The GT load is to be later increased to 110MW in preparation for increasing the STG load to 45MW. The STG was never synchronized and loaded, so the GT should have remained at 16MW for the entire STG startup.

There are four countermeasure actions which can be utilized in combination with each other to control the HP Steam temperature and pressure. They are:

1. Modulation of the gas turbine load
2. Turbine bypass system
3. Startup vent valve on the hot reheat section
4. Attemperator sprays in the superheater section

When the gas turbine is running, heat is being put into the HRSG. To avoid overheating the HP Steam, Reheat Steam, and Low-Pressure Steam tubes, the tubes must have steam flow. To accomplish steam flow, the turbine bypass system must be in service. This allows steam flow through the HRSG tubes. The amount of load on the gas turbine directly correlates to the heat input into the HRSG. The lower the load, the less heat input; the higher the load, the more heat input. Lowering the gas turbine load will not adequately control the HP Steam temperature and pressure.

To assist with controlling the HP Steam temperature and pressure, the turbine Bypass Steam System is used. The HP bypass valve will be used to control the temperature ramp rate of the HP drum and once the HP drum reaches [redacted], it will switch to control the HP Steam pressure. The IP bypass valve is used to control the pressure on the HRH and CRH lines.

If the turbine Bypass Steam System cannot control the temperature ramp rate or the pressure, the startup Vent Valve on the HRH is used. It will vent the HRH steam to the atmosphere. This will remove hot steam from the system, and it will increase flow through the HP and IP sections of the HRSG. This will reduce the steam temperatures and pressures of the HP Steam and reheat steam systems.

The last way to control HP Steam temperature is through the attemperator sprays. The sprays use high pressure feedwater that is injected into the HP Steam after the HRSG Superheater 1 and before HRSG Superheater 2. The sprays decrease the temperature of the HP Steam.

When the operators were asked how to lower the steam pressure and temperature, operators were either unsure or responded they did not know how. The operators stated they received some minimal training when coming over from the old coal plant (conducted by CB&I and most recently by TTP). Most of the training from CB&I was hands-on combined with some training material documents. The RCA review of the TTP developed training videos found them to be an "overview" of the plant operation but lacked the information on how to use the consoles and information displayed to operate the plant. Training manuals had been created, but the operators went through an abbreviated classroom course and training videos based on these manuals. Leadership expressed they expected the operators to review the training manuals on their own to learn the specifics behind the information presented in the training videos.

On November 10th, the control room operators had deviated from the written startup procedure. This was known by the leadership as they were giving the instructions to deviate from the GT2 starting load of 16MW. There was confusion on the priority between emissions compliance and adhering to the written startup procedure. The operators reported they are often given operational instructions from management with one operator stating, "What he wants is what he gets." meaning the control room operators are being overruled in operating the equipment. The operators refer to this as micromanagement, but the plant management views it as making sure the operators are performing their jobs correctly.

The operators feel that every startup is different, and one procedure cannot cover all the possible scenarios. Process knowledge plays a key role for personnel to understand the operational principles on which the procedures are based. Having such knowledge provides personnel with the skillset necessary to deal with scenarios that depart from the written procedure and identify the corrective actions needed to return the situation back into compliance with the procedure. A sampling review of past startups confirmed there were differences in the control settings over past events. The offset biases for the HP and IP bypass valves have been changed historically but had not been adjusted since October 2020. CRH drain valve settings would vary between auto and manual. The historical trends did not support consistency in the startup process. These factors would make it appear to the personnel each startup is unique and therefore the procedures are ineffective. The Operations Leader stated the startup on November 10th was a standard cold startup for which the startup procedure was applicable.

The procedure provided to the RCA team by the Operations Leader was one used by the secondary team assisting the Control Room Operator during the startup. There were some inconsistencies in the Control Room

Operator's statements about this use of a procedure. An assisting operator stated he observed the Control Room Operator not using a procedure when he was there on November 8th. The Control Room Operator stated he made written comments on his copy of the procedure; however, the RCA investigation was unable to acquire the procedure copy referred to by the Control Room Operator. The procedure provided to the RCA team was Revision 9 and contained revisions based on the April 25th failure. The current procedure in the documents file is Revision 13 and is dated after the November 10th incident. The Operations Leader states he provides updates to the startup procedure as needed. However, there were no records found in the Management of Change process for these changes of Revisions 9 through revision 13. Changes to procedures are covered under the current Management of Change procedure.

The copy of the startup procedure provided to the RCA was initially utilized on November 8th and then further utilized for the STG startup attempt on November 10th. There were no notes written by the operators on the copy of the startup procedure documenting the problems initiating the STG auto start up sequence. Operators stated it was customary for them to make notes of items and issues which were not in accordance with the procedure for their future reference or to propose revisions to the procedure. Had the issue been documented, it would have provided a reference point where the condition the equipment settings were left while the troubleshooting work was conducted. At the time there was no indication how long the troubleshooting effort would take. It took almost two days for the troubleshooting effort to resolve the issues preventing the STG startup sequence. Once resolved, there were no operator checks performed on the operating conditions and controls settings to confirm compliance with the procedure prior to initiating the STG startup sequence on November 10th. The HRSG and steam piping lineups per OI-SRT01 on page 4 was marked complete, but in review, the valve lineups were not completed per procedure and no notes on these deviations were recorded. The STG startup resumed as if all the startup conditions were in place, with personnel unaware the Bypass Steam System and HP Steam conditions were not ready for the STG to begin a startup.

[redacted]

Since TOSMAP allowed the STG to start [redacted], the operators believed there were no issues with the elevated steam temperature and pressure.

Conclusion:

The high pressure and temperature were the result of GT2 operating at 110MW without temperature matching mode versus 16MW with temperature matching mode as called for in the startup procedure. This was compounded by the operators' lack of the Bypass Steam System knowledge to bring the steam conditions into compliance. The Toshiba TOSMAP programming allowance for the startup of the STG [redacted] left the operators unaware of the need to take actions to lower the HP Steam temperature and pressure. The lack of actions to restore the steam system settings back into accordance with the written procedure combined with the operators' and management's lack of situational awareness for potential damage of starting the STG with conditions above the [redacted] allowed the failure mechanism of thermal damage to proceed. The DCS was not programmed to recognize when the steam conditions exceeded the design limits and prevent the STG auto startup sequence from being initiated.

Insufficient notification and response to high HP Turbine Exhaust temperature

The HP Exhaust temperature reached [redacted] and the controls system displayed a HP Exhaust high temperature alarm on the operator monitor at 3:25 PM on November 10th. Two minutes later, at 3:27 PM, the alarm acknowledgement button on the Toshiba console was pressed. However, no process adjustments were made to reduce the HP Exhaust temperature. The alarm displayed just as the automated STG startup sequence was about to initiate the high-speed thermal heat soak as the turbine speed was approaching 3,600rpm. The operators interviewed stated they did not notice the alarm, and no one remembers acknowledging the alarm. The Operations Leader stated no alarms were presented during startup although there were numerous "nuisance" alarms, which there is an ongoing project to address these. A nuisance alarm is an alarm that comes in regularly and is either not true or does not present a real problem. Operators are expected to investigate all alarms and notify management if they are unable to address them (notifications are written by whoever is able). Some alarm titles do not give a good description of the alarm condition, which does not give the operator a good understanding of the situation. Without knowing the situation, the corrective actions may not be immediately clear.

The operator station in the control room consists of two Toshiba system display monitors, two GE system display monitors and seven display monitors for the Emerson Ovation system. (Refer to Photograph 9) The HP Exhaust temperature high alarm is displayed on the Toshiba monitor and is indicated with a flashing red "Alarm" block at the top of the screen. When the operator presses the Alarm button the display monitor shows a listing of the current alarms. (Refer to Photograph 10) This allows the responding operator to diagnose the situation and implement corrective actions. The operator then has an alarm acknowledgement button that will stop the "Alarm" block from flashing. This acknowledgement button acknowledges all the alarms on the list. If the conditions for an alarm on the list has already returned to normal, that alarm will be removed from the list when the acknowledgement button is pressed. If the alarm condition remains present, the alarm will remain on the alarm list. Its only when the alarm has been acknowledged and the alarmed condition returns to normal, will the alarm automatically be removed from the list.

Alarms on the Toshiba system display monitors are not audible alarms and are not displayed on the Emerson Ovation displays as are other alarms for the plant operation. To display the Toshiba alarms on the Emerson Ovation display monitors the Toshiba alarms must be individually mapped and set up for tracking and display. A work order was entered in SAP on October 6, 2020, requesting audible alarms on the steam turbine. The reply written on October 25 stated [redacted] Mapping the Toshiba alarms into the Emerson Ovation for display and annunciation was believed not possible and therefore not investigated for the request.

Interviewed Operators could not provide specifics on the adjustments necessary to reduce the HP Exhaust temperature in the event of a high temperature alarm. The adjustments needed would have been one of, or a combination of, the following:

- [redacted]
- Reduce the GT2 load
- Manual control of HP bypass setting
- Manual control of IP bypass setting
- Open the startup vents valves on HRSG units
- Initiate a manual trip of STG

As stated previously in the report, the HP Exhaust high temperature alarm displayed almost every startup since commissioning. Operators and the Operations Leader stated that they believe the alarm is normal during startup, since it will clear shortly after the STG is online. The operators lacked appreciation for the severity of the high HP Exhaust temperature as the alarm happened often during past STG startups.

Operators and leadership stated the plant control systems trigger numerous nuisance alarms. Operators are instructed to "Write it up" as a work order in SAP. An incomplete work order was found in the maintenance management system (CMMS) requesting resolution of nuisance alarms, but no specifics were provided in the request. Operators reported being frustrated with work requests not being completed or addressed.

Over the weekend prior to the startup on November 8th, there was a facility wide stand-down meeting held in the parking lot to require communication to the control room about changes being made for troubleshooting. The operators were troubled when signals displayed on the monitors as devices in the facility were being checked in preparation for the startup and they were not made aware of the actions taking place. Those working on the final checks were instructed to carry a radio and communicate with the control room operators when they made changes. It should be noted, the lack of communication between the technicians and the control room was identified as a systemic issue in the RCA performed on the failure during the April 25 startup. The meeting resulted in communications to the operators when changes were made in the field. However, the stand down meeting did not address the coordination and control of the work effort between operational startup tasks and troubleshooting efforts.

Comments were made to the RCA team about the number of people in the control room during the November startup was higher than normal. Additional contractors and support personnel were in the control room watching the performance of the repaired generator and operation of the breakers. The environment was disruptive to the operators. One incident was reported where the Toshiba engineer verbally expressed frustration that his ability to have unobstructed contact with the Control Room Operator was not possible. Toshiba declined to provide the RCA team with any confirmation of the incident.

The Toshiba TTIL-KT112001X Rev1 recommendations had not been implemented at Eagle Valley prior to the November startup. If these recommendations had been in plac[redacted]

Conclusion:

There were no process changes made to lower the high HP Exhaust temperature when it went into an alarm condition. Several possible factors were identified for the lack of action; the alarm was dismissed as another nuisance alarm, the alarm was overlooked due to other nuisance alarms on the displayed alarm listing, the operator focus was on STG auto startup sequence screen, the alarm was accepted as a normal startup event and would resolve itself as experienced in the past, and the severity and urgency of the alarming condition for potential equipment damage was not appreciated in the OEM programming. An audible annunciator for the alarms may have increased the likelihood of the alarm being recognized; The failure to recognize and respond to the HP Exhaust high temperature condition and the lack of DCS programmed protection to automatically trip the process, allowed the damaging high temperature conditions to continue and manifest into the turbine and piping damage. [redacted]

The steam turbine operated outside parameters for an extended time with no load (FSNL)

[redacted]

When the final high-speed heat soaking was completed at 4:29 PM, the STG had already been outside of operation parameters with the HP Exhaust temperature high Alarm present since 3:25 PM. Operations continued the startup process, and the STG was ready for excitation voltage to be applied on the generator. However, the 41E Breaker controlling the excitation voltage to the generator failed to close. The Toshiba engineer reported the Toshiba controls system was sending the close signal to the breaker. AES technicians were finding there was not a signal being sent to the 41E Breaker. Troubleshooting efforts eventually found a bad micro-relay on the printed circuit board of the Toshiba output card. Once the relay was replaced, the 41E Breaker closed. This happened at 7:49 PM. Meanwhile, the HP Exhaust temperature continued to increase and had gone above the sensor's operating range when it reached 1,120F at 5:19 PM.

The next step in the STG startup sequence is to synchronize the generator with the power grid and close the 52G Breaker. The synchronize conditions were met, but the 52G Breaker would not close. Before the troubleshooting effort could resolve the issue the CRH piping ruptured at 8:44 PM. The STG was manually tripped 3 minutes later at 8:47 PM. GT2 was manually tripped within seconds of tripping the STG.

Troubleshooting efforts on the 52G Breaker the next day found a connecting wire missing from the 25A synchronize ready signal circuitry, preventing the close signal from reaching the 52G Breaker closing coil. The wire had been mistakenly removed as part of the electrical wiring verification and cleanup effort which was a corrective action from the April 25 startup failure RCA investigation.

The STG operated at FSNL condition with the HP Steam temperature above the operational limits of [redacted] (recorded temperature at 1,042F and pressure greater than 1,500psi) for 5-1/4 hours. The HP Exhaust temperature high alarm displayed about 5 minutes prior to the STG reaching 3,600rpm, full speed operation and remained active during the entire FSNL operation. The expectation was for the troubleshooting effort to be completed quickly and the desire was to have the STG ready to go into service once the repairs were completed. The attention was on the troubleshooting efforts and not on the operating conditions of the STG and the Bypass Steam System.

The 52G and 41E breakers had presented issues during the April 25 startup attempt. In preparation for the November 8th startup of the Eagle Valley plant, testing was performed to confirm the breakers were functioning properly and ready for service. Functional testing of both the 41E Breaker and the 52G Breaker was performed on November 4th and again on November 7th. The testing involved opening the breakers through Toshiba control logic commands and verify the status displayed on the operator display monitor. The closing of the breakers was done with field applied jumpers due to the complexity of the control circuits to close 41E Breaker and 52G Breaker. As such, the breaker closing operations were not done solely through the TOSMAP controls which would happen during startup operations.

Conclusion:

Operating the steam turbine at FSNL condition is not an issue. The Toshiba Auto-start sequence provides [redacted] heat soak at FSNL prior to performing the steps to synchronize to the grid. On November 10th, the steam turbine operated at FSNL for over 5 hours. The heat produced by the turbine's rotational friction, the heat from the high temperature of the incoming steam and the low steam flow through the HP turbine to remove the heat, combined to increase the HP Exhaust temperature more rapidly than a normal cold startup. As such, the extended time operating the steam turbine produced exceptionally high temperature in the exhaust piping and the HP turbine. [redacted]

Detailed Recommendations

I. **Recommendation:** Conduct an independent engineering review of controls narratives, and DCS programing logic for continuity, accuracy, and equipment protection.

Latent Root Causes Addressed:

- DCS programming did not follow control narrative.
- DCS programming allowed STG startup to be initiated when steam conditions exceed manufacturer's design parameters.
- DCS program did not contain a STG trip when equipment operating temperature exceeded manufacturer's design operating limits.
- Toshiba TTILs not disseminated to Eagle Valley leadership for review and implementation.
- Belief the automated control systems and programmed permissives would inhibit operational actions and process conditions which could damage the equipment.
- Toshiba alarms not posted on Ovation alarm display screen.
- Nuisance alarms remained unresolved.

Details:

The RCA uncovered several discrepancies between the control narratives and the DCS control logic programing. As a result, the systems did not perform as the design intended. The recommendations in the Toshiba issued TTIL KT112001X were not incorporated into the control narratives, the DCS control logic programming, nor the TOSMAP controller. It is recommended for Eagle Valley to undertake an engineering review of the DCS controls for operation of the Eagle Valley CCPP and compare it to the OEM requirements. This recommendation will need to be completed by multiple contractors.

Kiewit: Control Narratives and DCS Logic Review

- Review the control narratives are correct in the control philosophy of the associated equipment.
- Review the DCS logic is correct to match the control narratives.
- Provide a redlined set of control narrative documents identifying deficiencies for correction
- Provide a redlined set of logic drawings identifying deficiencies for correction.

Emerson: Implement DCS changes

- Review redlined documents and drawings supplied by Kiewit.
- Implement control logic program changes in the DCS.

Toshiba: Implement TTIL KT112001X Revision 1 recommendations

- Build TOSMAP logic, trips, and alarms to match the recommendations provided.

Emerson: Implement TTIL KT112001X Revision 1 recommendations

- Build DCS logic, trips, and alarms to match the recommendations provided.

AES Eagle Valley personnel

- Ensure plant leadership remains signed up to receive TTIL's through periodic audits.
- Develop a succession plan for changes in personnel to be added to the distribution list.
- Review all past TTILs to identify any others which are applicable to the Eagle Valley CCPP and implement the recommendations.

II. **Recommendation:** Construct a virtual model of the Bypass steam handling system to confirm engineering design and DCS programming provide correct functional operation.

Latent Root Causes Addressed:

- DCS programming did not follow control narrative
- Toshiba TTILs not disseminated to Eagle Valley leadership for review and implementation
- Belief the automated control systems and programmed permissives would inhibit operational actions and process conditions which could damage the equipment.

Details:

The control logic used to operate the Eagle Valley CCP steam bypass system is very complex. An effective way to confirm proper operation as well as to test operational scenarios is to utilize accurate virtual modeling. The testing can be done without the potential dangers and operating costs of performing the testing on the actual equipment. Eagle Valley should develop a virtual model of the bypass system and HRSG startup vent valve for steam control. The model will demonstrate if the engineering design is acceptable to control the main steam temperature and pressure. Upon successful demonstration, the model will be controlled using Eagle Valley's existing DCS logic. The model will show if the current design and logic are able to control the main steam temperature and pressure. Any discrepancies and corrections uncovered must be conveyed to the AES teams performing **Recommendation I** for incorporation in the control changes. This work will be performed by WSC.

WSC: Model the Bypass System

- ➢ Build a virtual model using the existing isometrics, P&ID's, and control logic of the bypass system. Simulate the bypass system running in this condition to determine if the engineering design and the DCS control are adequate.
- ➢ Determine the correct operation of the HRSG start up vent valves.
- ➢ Provide a report to AES Indiana on the findings and recommendations.

III. **Recommendation:** Review the maintenance work order system (CMMS) for any incomplete work orders pertaining to nuisance alarms.

Latent Root Causes Addressed:

- Nuisance alarms remained unresolved.

Details:

The Eagle Valley operators commented the controls systems trigger several nuisance alarms which distract them from the valid alarms. They reported the nuisance alarms in the work order system; but the nuisance alarms continue. The work order system should be reviewed to identify and resolve any incomplete work orders reporting nuisance alarms. Completion of these items should be conducted while the recovery repair work is underway and before the plant is returned into operation. The process of reporting and resolving nuisance alarms should be reviewed to ensure reports of nuisance alarms are handled in a timely manner.

IV. **Recommendation:** Perform an environmental audit to clarify emission requirements for startup.

Latent Root Causes Addressed:

- Lack of understanding on emissions Air Permit requirements and operation to meet them.
- Failure to document operational departures from written startup procedure.

Details:

The Operations Leader stated the GT load was increased in order to meet emissions level stated in the air permit. There was not a lot of clarification on what the emissions requirements were. The recommendation is to perform an audit of the previous plant emissions during startup and determine acceptable operational procedures to meet compliance.

V. **Recommendation:** Perform a recommissioning of Eagle Valley plant after repairs and program corrections are completed.

Latent Root Causes Addressed:

- Commissioning did not correct the high HP Turbine Exhaust Temp issues.
- DCS programming did not follow control narrative.
- Lack of coordination amongst multiple contractors and personnel during start up.

Details:

The DCS controls programing logic will be revised to address the findings from the engineering review. The bypass controls will be modeled and tested to confirm correct operations. Before placing Eagle Valley back into operation, it is recommended AES develop and perform a detailed operational commissioning to determine the plant performs in accordance with the design. The commissioning should test the critical systems for functional checks to ensure they operate correctly per OEM requirements. The commissioning should confirm the tuning parameters provide proper control of the process variables. It should also compare the observed plant operation to the virtual model of the Bypass Steam System. Any discrepancies between the actual plant behavior and the model should be analyzed with appropriate measures taken to ensure correct operation of the plant and an accurate operational simulation of the model for use in testing and personnel training.

VI. **Recommendation:** Perform a review of alarm history, sorting critical alarms from nuisance alarms to provide improved operator notifications of critical alarms and resolve issues causing nuisance alarms.

Latent Root Causes Addressed:

- Nuisance alarms remained unresolved
- Toshiba alarms not posted on Ovation alarm display screen.

Details:

It is recommended for a project to be implemented during the recovery work to map the critical alarms of the Toshiba TOSMAP controller into the Ovation historian. Install equipment for audible and visual notifications to the control room operators for critical alarms. Remove the nuisance alarms and develop procedures to provide notification, tracking and prompt resolution of nuisance alarms when identified by operators.

VII. Recommendation: Acquire a high-fidelity process simulator for operator training.

Latent Root Causes Addressed:

- Lack of operator knowledge of by-pass steam process and related controls logic.
- Lack of understanding on emissions Air Permit requirements and operation to meet them.
- Belief the automated control systems and programmed permissives would inhibit operational actions and process conditions which could damage the equipment.

Details:

A high-fidelity simulator will provide two main benefits: review of the current DCS logical controls and provide training to the operators. The simulator will be used as a verification that the DCS logic is correct and operates the plant within OEM specifications. It provides a simulated environment to make DCS logic changes without the risk to equipment. The simulator will also provide training to the operators. The operators will be able to simulate real world scenarios and train on how to respond to certain situations. The work for this recommendation will be completed by WSC.

VIII. Recommendation: Perform a gap analysis of the current operating procedures and revise the procedures based on the analysis findings.

Latent Root Causes Addressed:

- Failure to document operational departures from written startup procedure
- Lack of coordination amongst multiple contractors and personnel during start up
- Startup procedure did not contain stop points to confirm system response and status
- Inadequate adherence to Management of Change process
- Lack of operator knowledge of by-pass steam process and related controls logic
- Lack of understanding on emissions Air Permit requirements and operation to meet them.
- Belief the automated control systems and programmed permissives would inhibit operational actions and process conditions which could damage the equipment.

Details:

A gap analysis on the current operating procedures is needed to reveal weaknesses in the work systems at Eagle Valley CCPP which need to be addressed. Once these areas are addressed, the updated procedures will provide the operators with a correct method for starting the unit, including stop points to be completed prior to advancing in the procedure, and more detail for each sequence in the startup. The gap analysis should be completed by AES personnel and TTP, a training contractor. The findings and corrections developed in **Recommendation I**, **Recommendation II** and **Recommendation IV** must be included as part of the operating procedures updates.

To provide assurance the resulting procedures are properly updated with future changes, a review of the current Management of Change procedure should be undertaken. The review should confirm the process and approvals needed to make changes to the operating procedures. The current Management of Change procedure covers process setting changes which will last for longer than the current shift. It needs to be clarified what changes to the DCS and TOSMAP settings are subject to the Management of Change process. The review should also address measures to prevent operators from using outdated copies of the operating procedures.

IX. Recommendation: Implement a skills and knowledge assessment as well as a training program for Leaders, Operators and Technicians.

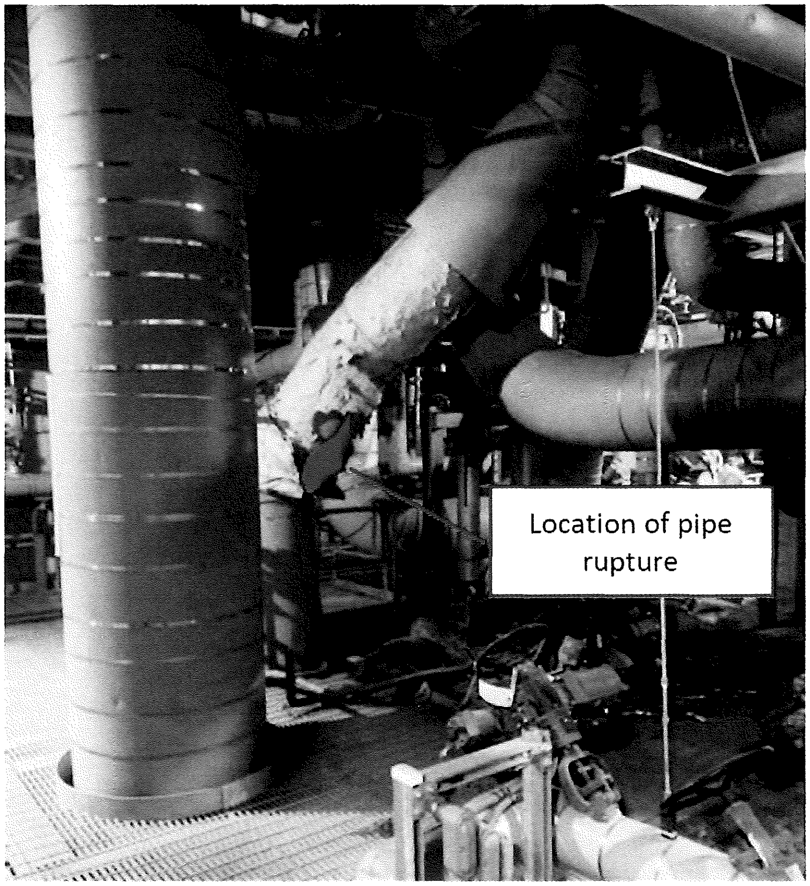
Latent Root Causes Addressed:

- Lack of operator knowledge of by-pass steam process and related controls logic
- Lack of understanding on emissions Air Permit requirements and operation to meet them.

Details:

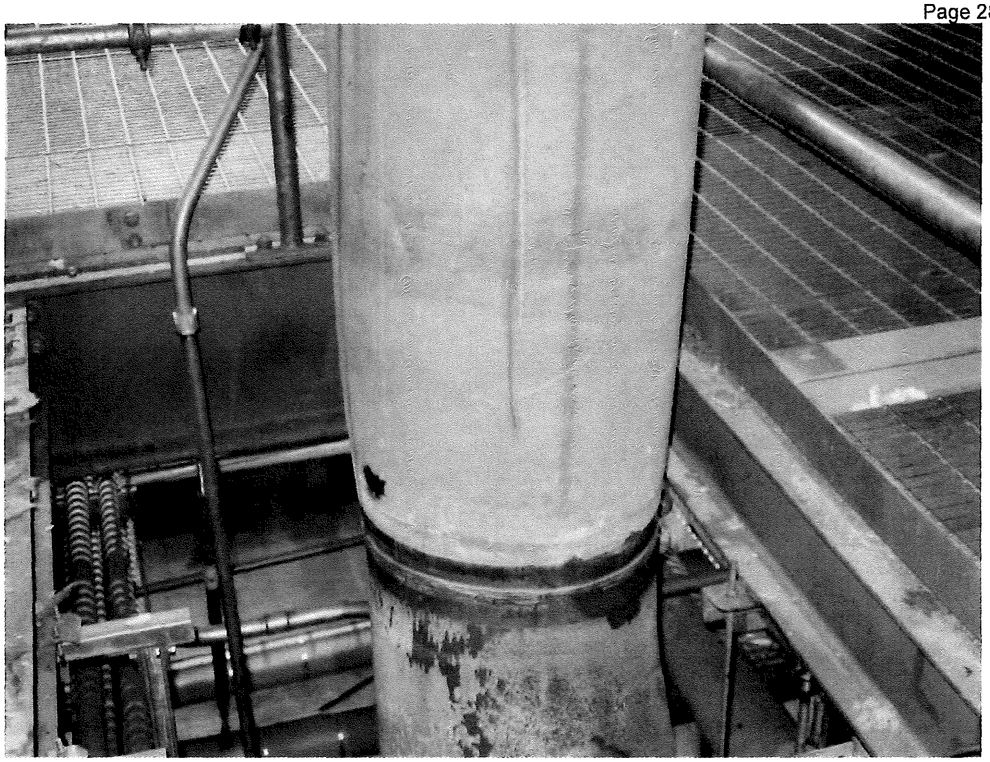
After a skills and knowledge assessment of pant personnel, it is recommended AES develop training to meet the identified teams' weaknesses. The focus of the training needs to be on understanding how the various plant systems work and then how the operators control them in the DCS. The next part of training will be solely on the startup process. From **Recommendation VIII**, training will also be conducted on the new procedures. The training needs to include the roles and responsibilities of the leaders, operators, and technicians. There needs to be training on the Management of Change process to ensure all personnel understand the requirements when a Management of Change review is required.

Supporting Photographs

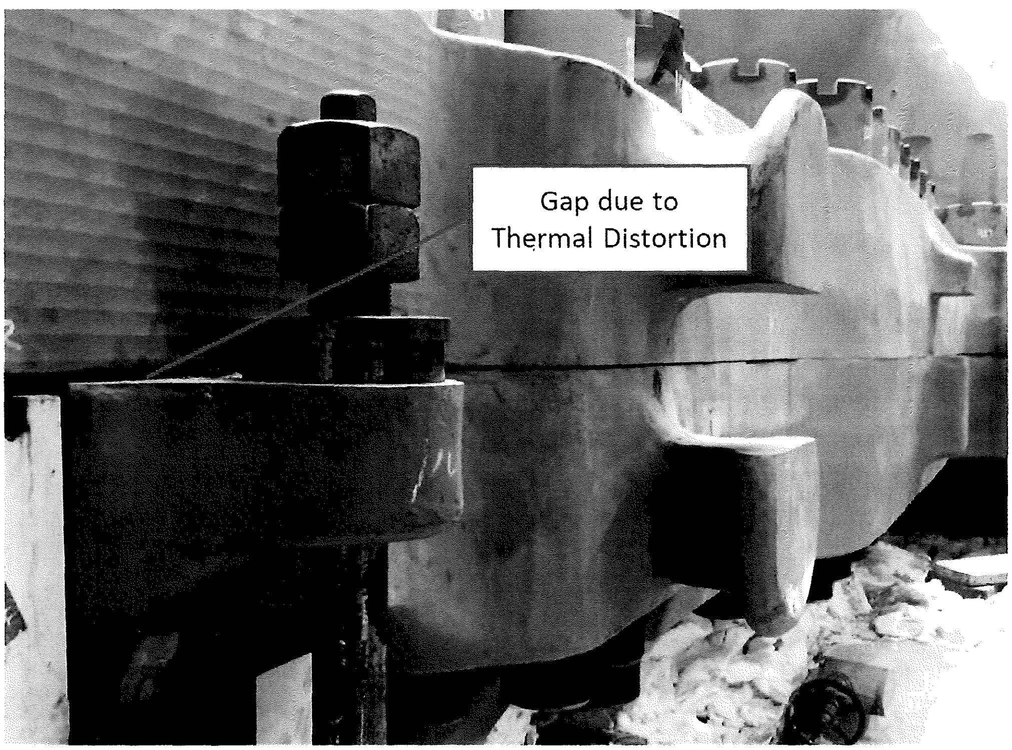


Photograph 1, HP Turbine Exhaust pipe (8 minutes after rupture)

Photograph 2, Ruptured HP Turbine Exhaust pipe (South Leg)



Photograph 3, Bulging HP Exhaust Pipe (North Leg with insulation removed)



Photograph 4, STG Upper and Lower Casing