COASTAL GUJARAT POWER LIMITED
(A TATA POWER COMPANY)

TITLE:-
"A Journey to Raise the Bar of Operational Excellence at UMPP Mundra"
"A Journey to Raise the Bar of Operational Excellence at CGPL Mundra"

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1.0 Abstract:

UMPP Mundra being the 1st UMPP of India, is 100% imported coal base power plant erected and commissioned all five units of 800 MW in a record time. There are a lot of project management to O&M phase UMPP Mundra proved its operational excellence and is continuous strive to raise the bar of operational excellence. In this paper some of the unique problems faced at CGPL Mundra and how overcome it is shared.

2.0 Introduction and Overview of Supercritical Units:

The drivers may be different, but the destination—higher efficiency—is the same worldwide. As a primary Component of current efforts to reduce the environmental impact of burning coal, new and more-efficient steam plant designs are being considered by the generation industry.

The efficiency of a steam cycle is influenced by, among other factors, the pressure, superheat and reheat temperature of the steam. Supercritical is a thermodynamic expression where there is no distinction between the liquid and gaseous phase. Water/steam reaches this state at about 22.1 MPa (221 bar) pressure. Above this operating pressure of the steam, the cycle is supercritical and its cycle medium is a single-phase fluid; as a result there is no need to separate water from steam as in the boiler of a sub-critical cycle. Once-through boilers are therefore used in a supercritical cycle.

Below Trend Showing Share of Supercritical Generating Units at Various countries worldwide.
The first supercritical unit, Eddy stone 1, was built in the United States in 1959. Originally designed to run at 345 bar and 650/650/650 °C in a double reheat cycle, the unit faced problems of low availability resulting from material issues and problems that are typical of ‘first-of-its-kind’ developments.

Considerable progress in the development of highly efficient supercritical technology is there worldwide in last few couple of years. The development of supercritical steam cycles with progressively higher steam temperatures, Combined with modern plant design and automation, provides significant potential for efficiency improvement.

3.0 CGPL Mundra 1st UMPP of India:

Supercritical technology is already used in a number of countries and has become the norm for new plants in industrialized countries. Supercritical plants are currently located in eighteen Countries, where their share in coal-fired power generation in those countries varies globally between 2004 and mid-2007, the share of Supercritical plants increased from approximately 18% to 20% (~ 265 GW) of coal-fired capacity. This rose to over 25% in 2009 and increased further as new Supercritical units were built in China, India, South Africa and Russia.

The Ministry of Power (MoP), Government of India (GoI) has launched an initiative for facilitating the development of COAL BASED ULTRA MEGA POWER PROJECTS (UMPPs) in India.
The project has been developed on build-own-operate (BOO) basis. Bids for the selection of a developer for Mundra UMPP were opened on December 18, 2006. The Tata Power Company Limited (“Tata Power” or “the Sponsor”) was short listed bidder for the Mundra UMPP amongst six bids and the Letter of Intent dated December 28, 2006 was issued in favor of Tata Power.

**CGPL-Mundra Milestone Dates at a Glance**

<table>
<thead>
<tr>
<th>UNIT</th>
<th>SYNCHRONISATION DATE</th>
<th>COD COMPLETION DATE</th>
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<tr>
<td>10</td>
<td>08.01.2012</td>
<td>07.03.2012</td>
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<td>30</td>
<td>06.10.2012</td>
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</tr>
<tr>
<td>50</td>
<td>04.03.2013</td>
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</tr>
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Average gap between two Units synchronization has been 3.5 months, better than the baseline schedule of 4 months and much better than the 5 months provided in original PPA for CGPL-Mundra.

**Gap (days) Between Consecutive Units Synchronization**

4.0 Unit Configuration:

4.1 Steam Generator:
Type: Once-thru super-critical, two-pass design, balanced draft. The water wall consists of spiral wound plain tubes with vertical tubes over the spiral water walls.
Make: M/s. Doosan, Korea
Super heater outlet pressure: 250.1 bar (g), at TMCR
SH outlet Temp: 568.5°C
HRH outlet Temp: 595.6°C

4.2 Steam Turbine:
Type: Tandem compound
Make: M/s. Toshiba, Japan
Maximum Continuous Rating: 830 MW
Throttle Steam Pressure: 242.2 Bar (a)
Main Steam Temp: 565°C
HRH Steam Temp: 593°C
Design Back Pressure: 0.08 Bar (a)
Pressure at IP turbine inlet: 57.4 Bar (a)

4.3 Main Generator:
Type/Form: TAKS-LCH 3 Rating (MCR) MVA-960; MW-864
Make: Toshiba, Japan
Power Factor: 0.9 (lag) to 0.95 (lead)
Rated terminal voltage: 26 KV
Rated armature current: 21318 amps
Rotor current at MCR: 5250 amps
Rotor voltage at MCR: 570 volts
Type of cooling:
   Stator core - H2 direct
   Stator winding - Water direct
   Rotor - H2 direct
Rated Hydrogen pressure: 5.2 Kg/Cm². Excitation System: Static

5.0 Learnings & Raising the Bar of Excellence at CGPL Mundra:-
As the opportunity grows for unlimited growth and progress, the chances of failure will also be there. There is no such thing as a program that will provide security and growth and progress with no risk . . . even within the church. Along the journey of Commissioning, Start-up and operation, Team Mundra has encountered few successes as well as some unwanted huddles. These learnings have been listed below for future upcoming challenges.

5.1 **HP Turbine Control Valve after Seat Drain Pipe Failure**

Main Turbine has 4 Main Steam Stop and Control Valves which admit steam to the turbine. Stop and Control Valves are located in a common body. 2 valves are located at 17m elevation (A & C) and 2 valves are located at 10.5m elevation (B & D)

There are 3 drain lines connected to the Main Steam Stop and Control Valves viz.
• Stop Valve Before Seat Drain
• Stop Valve After Seat Drain
• Control Valve After Seat Drain

These are provided for draining the condensate during start up. There are 2 valves provided on the line one Manual Isolating Valve and one Motorized Isolating Valve. The motorized valve is closed after 15% load.

There were five incidents of control valve after seat drain pipe (material P91) failure in lines A and C (from Dec’12 to April’13).

After analyzing the reasons, M/s. Toshiba came out with the following RCA:

• Substantial deformation as well as dimple rupture reveal bursting was due to extreme low strength of materials own properties by abnormal heating. The microstructure examination revealed heating to a temperature of about 800 – 850 deg C, though no excursion in steam temp was reported.
• Continuous Low load Operation was observed for one hour prior to the incident.
• In the upper valve (A & C) steam flow is unstable, especially at the lower side of the flow area due to flow separation from piping wall near to drain pipe hole. The reverse flow caused by the interference of down stream elbow is observed. In the upper valve (B&D),
steam flow is stable and flow velocity decreases as flow goes to downstream from valve seat area.

CFD Analysis

- Investigations carried out by Toshiba reveal that only mechanical vibration in piping system cannot produce enough energy to heat up the entire piping system over 800 deg C. Fluid vibration in piping system i.e, acoustic resonance and/or shock wave could be the root cause of the incidence. Toshiba shared about similar incidence reported in Combined Cycle Journal posted on 14th August 2012. It tells that extreme overheating on the isolation valve of steam drain line was observed on several steam turbines.

- Toshiba also reported a similar failure in a U S plant. Toshiba focused on “Thermo Acoustic” effect caused by supersonic or subsonic steam flow from control valve passing on the CV after seat drain port. In case the shock wave is generated under the supersonic flow at the throat of the control valve disc and seat and then propagating to the downstream, it may be possible that shock wave reaches to the inside of the drain pipe and reflect at the closed end, then this high frequency cycle causes intense friction on the wall. The local high turbulence at the root of the CV after seat drain valve may lead to such a phenomenon of compression pressure wave.
The Following corrective actions were suggested by Toshiba and implemented:

- Restriction of turbine operation below Pressure ratio 0.6.
- Elimination of downstream elbow
- Elimination of closed terminal end of drain piping.
- MIV & MOV relocated to near Control Valve
- Installation of thermocouple to monitor drain pipe temperature during operation.

5.2 Slagging and Fouling

- Slag is defined as the fused deposits or resolidified molten material that forms primarily on furnace walls and other surfaces exposed predominantly to radiant heat or excessively high gas temperatures. The study of slagging in boiler provides boiler designers with the tools to evaluate furnace absorption and determine gas temperatures. A key consideration in the design of any furnace is the volumetric and plan area sizing in order to achieve desired limits set for furnace exit gas temperatures (FEGT). FEGT plays a predominant role in PC fired boiler to overcome slagging problem.
- Slag primarily occurs in furnace area or first pass of the boiler i.e in the hottest parts of boiler. Two type slag formation namely appeared in the PC fired boiler, wall slag and super heater slag.

5.2.1 Slag Location :
5.2.2 Challenges at CGPL

1. High Slagging and fouling
2. High metal temperatures (Restricted RH steam temperature thus high RH spray and higher heat rate)
3. High FEGT, Lower boiler efficiency due to high FGET
4. Clinker Grinder part wear out
5. Ash line choking due to density difference
6. High ash evacuation time (Aux power)
7. Soot blower frequency high (high steam consumption)
8. Firing of High VM and High Moisture Coal

5.2.3 Action Taken to Achieve Plant Performance on sustainable level.

- Combustion Tuning – CCOFA, FAD adjustment
- Soot Blower Operational Philosophy - ISB
- Chemical Additives- Solid and Liquid injection
- Water Cannon

5.3 Briefing about Water Cannon

- There are total four no. of water cannons mounted in the middle of each wall at 41 Mtr. These water cannons blow water into the boiler at 18 KG/cm². Water impacts on soot surface and penetrates into the pores of deposit. Due to high temperature, water flashes into steam causing deposit layer to expand and then explode from the wall.
- Total 40 heat flux sensors are there for mapping heat transfer from flue gases to steam in the tubes of boiler. If there is soot deposit in any area, heat flux for that area would decrease. Based on these 40 sensors, whole boiler is divided into 40 zones.

5.3.1 WATER CANNON – Post Result at CGPL

- Water cannon operation started at U-10 from 23rd September 2014. Per day 60 to 90 blows are performed by Water Cannon. Blowing duration varies from 42 sec to 304 seconds depend on Zone.
Water Cannon Flow 15 Ltr / Sec (54 M3 / Hr – DM water). Water Cannon operates 1.5 hrs per day and consumes 80 M3 / day. Maximum idle time for each zone is 24 hrs.

- FEGT dropped by almost 50 deg C to 80 deg C. FGET dropped by 2 ~3 deg C
- RH spray reduced considerably. Burner tilt upward movement possible after water cannon
- BA evacuation time reduced by 30 minutes. No Chemical injection in Unit-10

- No wall soot blower operation

6.0 Exfoliation and mitigation measure

6.1 Reason for Exfoliation

- Exfoliation is the expected result of continued oxide growth
- The rate of oxide growth increases exponentially with temperature, and also with the steam pressure raise.
- The major factors associated with scale exfoliation include:
  - thick scales;
  - rate of temperature change;
  - Alloy type (ferritic versus austenitic).
- Schematic Representation of the Usual Sequence of Events in the Exfoliation of Scale

![Diagram of exfoliation process]

- Other potential sources of stress external to the oxidation characteristics of the tube alloys that have not been examined in depth include:
  - Externally-applied mechanical stresses such as those imposed by movement of the tubes under thermal loading (for example, front-to-back temperature differentials across tubes in a platen)
  - Differential thermal expansion due to large thermal gradients across tube walls (due to large heat fluxes, or application and removal of heat fluxes)
  - Differential thermal expansion between tubes and supporting structures.

- Trigger For Exfoliation
  - stress differential between the oxide and underlying metal
  - large temperature reductions (or increases)
- The post-formed scale is effective on reducing the growth rate of oxide scale by preventing Fe from contact to O2 in steam.
- Scale growth will be decreased after scale exfoliation.

✓ Exfoliation is the expected result of continued oxide growth. The rate of oxide growth increases exponentially with temperature, and as the steam pressure raised to the power of, for instance, one fifth.
Events that can increase the strain differential between the oxide and underlying metal can trigger an exfoliation event; large temperature reductions (or increases) are the most typical triggers.

The magnitude of the effect of exfoliation on plant operation depends on the amount of oxide debris released at any given time, the size and shape of the individual oxide flakes, and the part of the operating cycle in which the event occurs.

The circumstances that lead to blocking of tubes by exfoliation debris are well understood in principle, and point the way to operating procedures that could be used to “manage” exfoliation; verification is needed through testing.

The rate of oxide thickening, the type of oxide formed, the conditions under which exfoliation can occur, and the mode of exfoliation (in terms of the size and shape of the oxide flakes) are to a large degree determined by the alloy composition.

From the state of knowledge of the oxidation behavior of the alloy classes of interest, it is clear that capabilities are available currently for making a very reasonable assessment of the scale exfoliation behavior of standard ferritic steels with Cr levels up to 9%, and for austenitic steels that belong to the same category as TP304/347 in terms of steam oxidation behavior. Updating of the information for these alloys is needed to improve this predictive capability.

Alloy T-91 appears to be a special case, since (a) the oxides formed typically do not transition to the multi-laminated structures usually found on the standard ferritic steels; (b) when exfoliation occurs, separation typically follows the alloy-oxide interface, and the full scale thickness detaches; and (c) the size of the exfoliated flakes formed is significantly larger than that from the standard ferritic steels. This mode of cracking is associated with the presence of increasing amounts of Fe2O3 in the outer scale, which introduces a compressive component of stress that promotes a transition in the failure mode from tensile through-scale cracking to delamination.

6.3 Measures to preventing Exfoliation

- Detection of blockages by X-ray/radiographic or LFET techniques and removal by mechanical & Initial blowing during start up
• Better operating practices:
  - Temperature difference above 600°C condition can be a big effect to increase oxide scale.
  - Allowing Boiler to cool down naturally

![Effect of temperature on steam oxidation](image)

- Steam flow velocity in tubes

  Early Japanese experience was that super heater tubes operated with a steam velocity of 6 m/s were prone to blockage, whereas super heaters with a steam velocity of 12 m/s did not experience blockages.

- In all-ferrous feed water systems, extensive research by EPRI and others have clearly indicated that reducing agents are not needed, and that a minimum in corrosion and corrosion product transport occurs under oxidizing feed water conditions. This can be achieved via two approaches:
  1. Simply by eliminating the reducing agent and maintaining low level of oxygen (<10 ppb) that enters as air in-leakage.
  2. By adding oxygen to the feed water.

**Note:** During Clean up cycle, monitoring of Dissolved Oxygen at Deaerator is of higher priority. With this clean up will be faster.
✓ Avoidance of rapid or extreme boiler transients, and careful control of temperature, especially during start ups.
✓ Limit the introduction of foreign material into the steam path during tube repairs.
✓ Steam blowing with HP/LP bypass to be done during boiler pressurization itself, before unit synchronization. Turbidity and Metal temperature profile will decide the termination criteria.

7.0 Circulation System NRV failure

Station Black out at 02:37hrs of 13thJuly’16 was there at CGPL Mundra. During, Unit-30 Restoration, after finishing boiler water filling, BRP started at 03:47. Boiler Light up at 06:19hrs and Unit was Synchronized at 19:08hrs. Around 200MW, Knocking sound coming from feed water line intermittently at 23:44, after BRP stop (Wet to dry Change) at 280MW, Boiler MFT happened due to Eco inlet flow low low.

Note:-
- NRV Knocking Noise : NRV Disk Open/Close Repeating (1time/1~2 sec)
7.1 Unit #30 Eco Inlet Flow Low Trip & Mixing piece Suction NRV Issue Overview

7.2 Unit-30 Observations

- 17 mm gap between seat & disc of mixing piece suction NRV. So water passing occurred in NRV due to this gap. This twin directional flow made Circulation line vibration & Knocking noise during wet mode.
- Above trend show, After BRP stop, SST Level increased 5m to 14m and Eco inlet flow collapsed from 890 to 0TPH. This is indicating that, water reverse flow occurred.
- This NRV water reverse flow cause Eco inlet flow low low Trip during wet to dry mode change on 16th July.
- NRV Repair and Bending of arm with Hydraulic press machine by 17mm & gap between the Disc & seat has been resolved & closed fully.
- On 22nd July 2016 at 21:12hrs, U30 Synchronised. AT 03:10hrs of 23rd Wet to Dry mode Change over done at 325MW, Eco inlet flow low Trip NOT Happened. No Line Vibration, Everything was found OK.
8.0 Way Forward.

Establishment of best practices, enhancement of Knowledge, Proactive initiatives are the indispensable and Key attributes for overall improvement to gain expertise in Standardized O&M systems. To accomplish sustainable high level of performance and to set up bench mark in the world market CGPL-Mundra has set high level of target for sustainable improvements for maintaining high level of standards in O&M practices. Along with it CGPL-Mundra is also in the line to run the plant with eminent level of safety and quality standards.

Bibliography

- Doosan & Toshiba O&M manuals
- EPRI & JICA super critical units best practices
- RCA of OEM
- Technical literatures on exfoliations of boiler tubes in super critical units