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# Steam Blowing of Supercritical Thermal Power Plant 2x800 MW at YTPS Raichur

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**Abstract:** This thesis attempts to present the steam blowing activity of super critical boiler at different steam circuits and it show the state of the art of cleaning technology for life time extension of Supercritical Thermal Power Plant for both the units of 2x800MW, YTPS , Raichur, Karnataka, India.

Steam blowing dedicated to removal of all welding debris and particles, after installation and creation of propos conditions, for introduction of steam into the turbine without operation risk.

The purpose of each steam blowing is to protect the downstream steam turbine, this process requires that the pertinent CFR is obtained and mechanical steam purity is steam purity proved by means of target plate. Here by calculating it is found that actual value of CFR is 1.2 to 1.7 that show the steam blowing is effective and the target plate results are found to be satisfactory.

**Keywords**: Supercritical Thermal Power Plant, Steam Blowing, Clean Force Ratio (CFR) And Target Plate.

## I. INTRODUCTION

**1.1 General Introduction:** The world over energy resources are getting scarcer and increasingly exorbitant with time has resulted in enormous increase in power plant installation and in their size. So that thermal power plant is the main source of electrical energy generation in our country. Powers producers are looking for improve the efficiency of power plant and also grow concerns about the environmental impacts of power generation. This demonstrates technology up gradation of coal fired subcritical power plant in the market. Introduction of supercritical / ultra SC technologies on thermal power plants can change in improve the performance of power plant.In this project we have gone through the newly constructed supercritical thermal power plant 2x800 MW at YTPS Raichur being developed by Raichur Power Corporation Ltd (RPCL) a joint venture of Karnataka Power Corporation Limited (KPCL) and M/s BHEL. The plant is located at Yeramarus Village, Raichur district, Karnataka state, India.

The plant is consists of various interconnected intricate systems, consisting multi corers of rupees investment but when it comes to commissioning, a lukewarm approach is adopted which creates in perennial maintenance problems. It has been realized that many problems of operations are caused due to improper commissioning of the plant. To ensure plant commissioning in orderly, A systematic commissioning of boiler, turbine and its auxiliaries with proper understanding hold the key for getting standard result. Hence an integrated approach needs to be followed to minimize unscheduled losses. The various commissioning activities of newly constructed supercritical thermal power plant are HFO System, Regenerative Air Pre-Heater, ID Fan, FD Fan, Scanner Air Fan, Boiler Final Hydraulic Test, Boiler Alkali Boil Out (Chemical Cleaning), Steam Blowing, PA Fan, Seal Air Fan, Mills and Feeders.

In spite of maintaining higher standards of erection cleanliness and doing a preoperational chemical cleaning for the entire system a certain quantity of debris in the form of scales, loose materials, weld spatter, etc. will remain in the boiler and the pipe lines. Steam blowing completes the task of providing a cleaner system for passing steam into the turbine. In other words we attain steam of required quality standard by way of chemical cleaning and steam blowing. Failure to remove debris may result in increased turbine erosion, blade damage and rapid deterioration of turbine efficiency, the measures are provided and the blowing steps are discussed in detail to avoid the over high thermal stress among the temporary pipes and some issues during blowing are also analyzed, which could be helpful and referenced for the similar units.

**1.2 Scope of the project:** Keeping in view of the above mentioned scenario, the commissioning activity at YTPS is conducted; the present work is steam blowing of newly constructed plant. The following are included in the scope of the present work.

1) Discharge of loose particles such as rust, scale, sand, and to certain extent, also large
foreign matter to this end high steam velocities are required.

2) Thermal Shock induced exfoliation of adhesive deposits.

The steam blowing will only be effective if it is done at higher steam velocities than those prevailing during full load operation. The result of steam blowing or final criteria is checked by means of a target plate consist of a holding fixture to which a mirror finish stainless steel plate with a specified size of minimum indents. Steam blowing results can only be expected if the process and steam parameter involved with this relevant data such as,

1. CFR (clean force ratio)
2. Steam pressure and temperature
3. Steam mass flow rate
4. Specific Volume
5. Target plate dents result.

Pressure reduction and number of bursts per steam blow up operation. In this thesis a detailed study on steam blowing and its parameter is carried out.

**1.3 Plant details:**The steam generator is a once through super critical type (ALSTOM MAKE BOILER). The circuit which are subjected to steam blowing are super heater section of boiler, main steam line up to HP turbine, cold re-heater, hot re-heater line up to IP turbine, HP and LP by pass line. Predicted performance data of 800MW plant are as follows,

1. Steam flow (SH O/L BMCR) – 2592 TPH
2. Steam flow (RH O/L) – 2069 TPH
3. Feed water I/L temperature – 294°C
4. MCR Steam I/L pressure to SH – 250 bar
5. MCR Steam I/L pressure to RH – 60 bar.

**1.4 Statement of the project:** The statement of the project is steam blowing activity of supercritical thermal power plant 2x800 MW at YTPS Raichur. Steam blowing is one of the important commissioning activities at boiler and turbine side of thermal power plant, steam blowing allows boilers and pipelines to ensure that during normal operation no adhering material in the superheaters, re-heaters and steam pipelines will become dislodged to reach the turbine blades and damage them. The steam blowing operation cleans the system and provided the steam of requisite purity for the plant.

**1.5 Objective of the Project:** The objective of steam blowing project is to remove scales, loose material, iron cuttings, weld spatter etc, that might have been entrapped in super heaters, steam piping, re-heaters during manufacture, storage, erection at site. Failure to remove the debris may result in damage to turbine blades, valves etc.

**1.6 Limitation of the project:** The data collected for M/s BHEL and KPCL are from Secondary Sources and presentations given by the company at different places. But complete and up to date data was not available as most of them are related to trade secret of these companies and volatile in nature. The law of protection of confidential information effectively allows a perpetual monopoly in secret information. So that information can't be shared through the report.

## II. LITERATURE SURVEY

Martin Herberg, Dr. Eng. Zoran Micevic., (2014): This article shows the state of the art of cleaning technology for modernization and reconstruction of large Thermal Power. The chosen combination of chemical cleaning and steam blowing assured the best possible cleaning result and an optimal time schedule to the project. Chemical cleaning was dedicated to remove iron oxides and all mineral. Steam blowing was dedicated to removal of all remaining after installation and creation of proper conditions for introduction of steam into turbine without operational risk. The approach to project were as follows Orders integration avoids coordination problems, short rebuilding phases between chemical clean and steam blow, use of temporary steam blow pipes for execution of chemical cleaning, use of same equipment for chemical cleaning and steam blow, temporary steam blow pipes are already cleaned up to the target [1].

J.B. Pier and G. Goldman., (1990): Studied shown that compressed air blows may be the most effective and economical approach to cleaning main steam lines. Benefits are flexible scheduling because air-blows can be worked into the start-up schedule without affecting other major critical path activities, except for work on the boiler and steam-line pressure parts. Balance of plant equipment associated with the boiler and boiler auxiliary systems must be completed and checked before steam blowing is possible, reduce manpower, time, fuel and cost, extends boiler life by eliminating temperature cycles in the boiler associated with steam blows. In all cases the super-heater, re-heater, and main steam piping were cleaned with compressed air [2].

## III.SUPER CRITICAL THERMAL POWER STATION

**3.1. Super critical power generation:** The heat energy is produced by fuel combustion is used to transform the boiler feed water into superheated steam. The steam of high temperature and pressure is then fed through turbines to produce mechanical power which in turn drives an electric generator to produce electricity. The exhausted steam which can no longer drive the turbines is finally condensed into liquid through the condenser before it is re-circulated back to the boiler thereby completing the cycle this is known as Rankine cycle. SC is a thermodynamic expression describing state of substance where there is no clear distinction between the critical and gaseous phase. Water reaches this phase at a pressure above around 221 bar and temperature 374.15°C. In addition there is no surface tension in a SC fluid as there is no boundary between liquid and gas phase. By changing the pressure and temperature of the fluid, the properties can be “tuned” to be more liquid- or more gas like. Carbon dioxide and water are the most commonly used SC fluids, being used for decaffeination and power generation, respectively.

### 3.2. Supercritical technology

The SC technology in India is in its nascent stage as compared to the USA, which is one of the world’s leading electricity generator. If we compare the per capita energy or electricity availability in India which is 6419.30 KWh and the world’s average then it is found to be a very small fraction of that. The India has laid more emphasis on the efficiency improvement of the power plant through advanced technology like the SCl Technology. The meaning of SC is subject to interpretation. Depending on upper limit of pressure and temperature parameters, this system is generally categorized as SC, and there are further developed such as ultra-supercritical and advanced ultra-supercritical as indicated below SC is a thermal cycle with main steam temperature between 565 to 593°C operating at pressures between 221.18 and 275 bar.

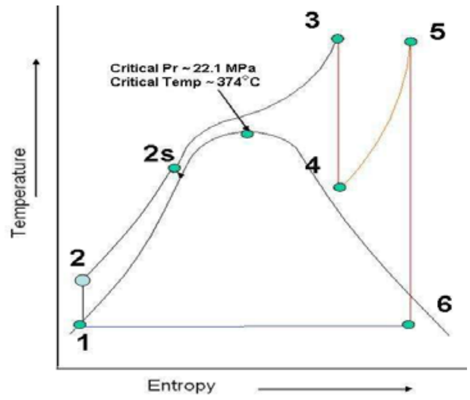


Fig 3.2: SC steam cycle temperature v/s entropy

Where,

1 - 2 > CEP work
2 – 2s > Regeneration
2s - 3 > Boiler superheating
3 – 4 > HPT expansion
4 – 5 > Reheating
5 – 6 > IPT &LPT expansion
6 – 1 > Condenser Heat rejection.

**3.9. Introduction to steam blowing:** In spite of maintaining higher standards of erection cleanliness and doing a pre-operational chemical cleaning for the entire system or part there off, a certain quantity of debris in the form of scales, loose materials, weld spatter, etc. Will remain in the boiler and the pipe lines. While chemical cleaning ensures cleanliness of the contours subjected to the cleaning resulting in surface cleaning and collection of loose materials, loose materials collected are to be removed effectively. Subsequent steam blowing completes the task of providing a cleaner system for passing steam into the turbine. In other words we attain steam into the turbine. In other words we attain steam of required quality standard by way of chemical cleaning and steam blowing. Failure to remove debris may result in increased turbine erosion, blade damage and rapid deterioration of turbine efficiency.

**3.10. Principle of steam blowing:** Steam blowing is carried out by adopting puffing method. It is performed by raising the boiler pressure 60 bar and releasing the steam through a quick opening valve. This technique gives a thermal shock to the contours being purged. This results in loosening of the adhered scale which is subsequently removed by expanding steam. The steam generator and turbine manufactures, piping systems suppliers, and the operator must reach joint decision on the type of cleaning method, the criteria for evaluation of cleanliness and the required degree of cleanliness.

**3.11. Steam blowing of power station pipelines**: Steam blowing allows power station boilers and pipelines to ensure that during normal operation no adhering material in the super-heaters, re-heaters, and steam pipelines will become dislodged, reach the turbine blades, and damage them. Puffing and continuous methods are mainly used for steam blowing.

**3.12 Definition of steam blowing**: The blowing of steam through piping to remove debris from the pipe, cleaning steam lines to a steam turbine, cleaning plant expansion lines, or new installs. As the definition says, to steam blow a pipe requires steam to blow through the pipe. This pipe can be attached to a boiler and the other end of the pipe can be attached to a steam turbine.

**3.13. Why steaming blowing is done:** The steam blowing operation cleans all the debris in the super-heater, re-heater and the steam pipe line connecting the turbine. During the maximum continuous rating load of the turbine the drag force in the pipe line can dislodge particles loosely adhering to the tubes internal surface, causing great damage to the turbine blades. Guidelines given by various boiler designers and agencies, etc., to effectively carry out this operation focus on creating a drag force created on the inside surface of tubes of pipes which is much higher than that occurring during the maximum continuous rating load of the turbine. Ratio of the drag created during steam blowing to the drag occurring during the maximum continuous rating load is called CFR.

**3.14. How steam bowling is done:** Steam blowing guidelines focus on creating a drag force on the surface of tubes or pipes much higher than that which occurs during the maximum continuous rating load of the turbine. The ratio of the drag created during steam blowing to the drag occurring during the maximum continuous rating load is called the clean force ratio CFR. Boiler designers and commissioning groups prefer to keep a CFR of about 1.2 to 1.7.

**3.15. Steam blowing equipments:** M/s BHEL has invested in the equipment and expertise for steam blowing. This equipment are as follows control valves, de-super-heater nozzles, flow elements, thermo wells pressure gauges, orifice plates, microsope, safety valves and instruments, temporary steam blow piping, target inserters and a reference list of previous steam blow projects can be acquired on request.

**3.17. Steam dumping:** Prior to admitting steam into the turbine, the quality of the steam should be ascertained and the steam can be admitted only when it confirms to the following standards for initial rolling. Silica less than 50 ppm. Main steam sample will be collected and tested for the above before steam admission into the turbine. The steam should be clear without any noticeable solid particles. During the initial stages the steam quality will be far form the above standard. Results can be achieved in a reasonable period of operation by dumping the steam to waste through HP/LP bypass system. The boiler drum pressure can be varied between 60 bar during the dumping period. Higher flow will help in achieving the target at a faster rate. Samples are taken at regular intervals and steam quality is closely monitored. Prescribed quality of steam once achieved to be ascertained in the subsequent 4 to 5 samples collected in a period of 2 hours. Values thus registered to be preferably in decreasing trend. Then the steam is admitted for rolling the machine.

**3.18. Requirement of temporary line for steam blowing:**

1) The temporary discharge piping may be of carbon steel.
2) The diameter of temporary discharge piping shall not be less than the diameter of respective line to be steam blown.
3) The through pieces should have an opening equal to the diameter of the respective temporary pipe line.
4) For cold reheat line blowing at boiler end, the temporary discharge piping normal bore should match the CRH line.
5)The temporary discharge piping and jumper shall withstand steam blowing parameters.
6)Temporary valves and lines are to be designed for 90 bar and capable to withstand steam blowing parameters.

## IV. METHODOLOGY

**4.1**. **Steam blow methods:** There are two types of steam blow methods such as follows:

1) Puffing or Shock blow Method
2) Continuous steam blow method

**4.1.1. Puffing method:** In this blow method, the steam pressure inside steam generator is raised to a certain maximum required pressure; a temporary sacrificial valve is opened quickly. During this pressure release the steam velocity is reached, but for a short period of time. Due to release of the pressure and temperature, the steam generator has to start again. The steam blowing operation carried within four to six hours, including start-up and shutdown of the steam generating plant. Normally not more than one steam blowing operation should be effected daily in order to ensure adequate cooling of the system, steam blowing at puffing method has

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preferably been performed especially in natural and assisted circulation boilers.

**4.1.2. Continuous steam blow method:** In this method There is no pressure build up, but after calculations, the CFR is reached continuously. During the continuous steam blow the target plates are inspected on impacts of particles. The steam generating plant shall be operated while by-passing the turbine and blowing the steam exhaust into the atmosphere. The average operational values range between 5 to 25 bar steam pressure and 380 to 510 °C steam temperature at 20 to 40 % load. The main steam stop valves shall be fully open during this operation.

**4.2. Scheme of steam blowing:**

In general BHEL offers the steam blowing in two stages. The electrically Operated temporary valve (EOTV) is to be located in the place as shown in the scheme. Loop pipes from HPSCV and IPSCV to turbine are to be taken care for cleanliness before erection and not to be steam blown. Systems covered in each stage are as follows,

Stage-1A: SH, MSL, MS strainer, ESV, temporary line from ESV to EOTV, EOTV to CRH NRV, CRH lines up to boiler end with temporary exhaust piping of size diameter 450.

Stage-1B: 1A plus HP bypass inter connection by opening hand operate valve mounted in place of HP bypass valve. 1A end point will be concluded by seeing target plate. 1A, 1B will be combination blowing and would result in effective blowing of CRHLS. However, 6 to 8 blows will be given only through HP bypass to ensure cleanliness of the limb.

Stage-2A: 1A+ 1B plus re-heater, HRHL, IV strainer, temporary pipe of size 450 m.

Stage-2B: 1A + 1B + 2A up to IV strainer + LP bypass up steam lines with temporary pipe exhaust of size diameter 450.

2nd stage blowing will be parallel blow in the path 2A, 2B but end point will be through target plate in IV exhaust on blanking LP bypass exhaust after 25 blows and concluded based on target plate condition. CRH NRV to be erected and blowing device is to be made with temporary pipe connection of size diameter 323. In stage 1 MSL & CRHL are combined and MSL blowing becomes very effective as the exhaust pipe is provided with higher size diameter. However, HP bypass line will not be included till the condition of the target plate provided in the temporary line connecting ESV and CRH stop valve is ascertained. Following fig: Steam Blowing Circuits - 1A, 1B, 2A and 2B shows the Steam Blowing Circuits at different stages of unit#1 and unit#2respectively.

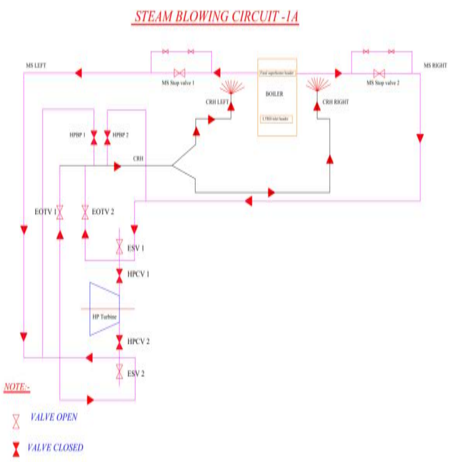


Fig 4.1: Steam blowing circuit – 1A

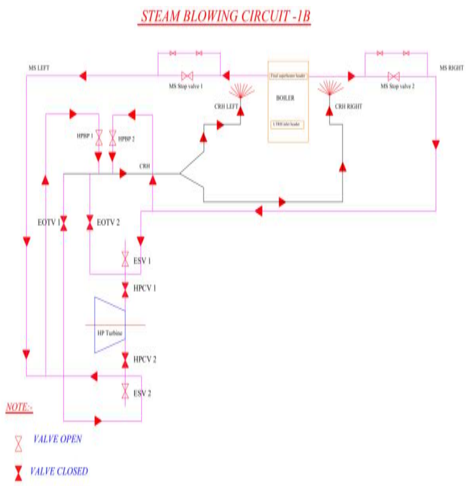


Fig 4.2: Steam blowing circuit – 1B

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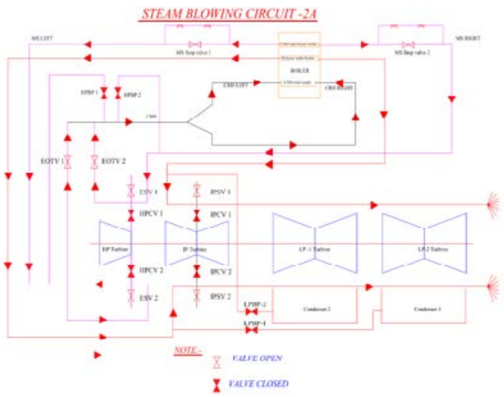


Fig 4.3: Steam blowing circuit – 2A

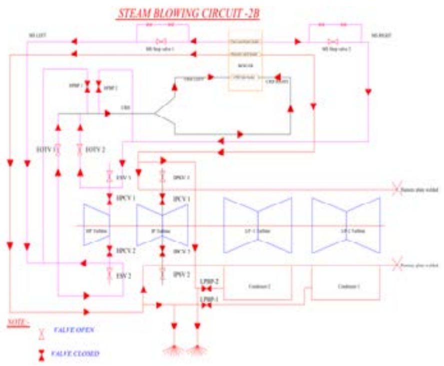


Fig 4.4: Steam blowing circuit – 2B

## V.EXPERIMENTATION& OBSERVATION

**5.1. Commissioning procedure:** The procedure of steam blowing for unit#1 and unit#2 was conducted for a period of 3rd November 2015 to 14th January 2016 and 28th April 2016 to 9th June 2016 respectively. There are two stages for a single unit and each stage are steam blown individually this is called as steam blowing stages. For an every single day minimum two blows has been done. As per agreement by M/s KPCL/RPCL efforts were made to conduct the steam blowing activity. Parameter such as day, date, steam blow stage, blow number, time of valve opening and closing, blow duration, separator outlet pressure start of blow, separator outlet pressure end of blow, main steam pressure start of blow, main steam pressure end of blow, main steam temperature start of blow, main steam temperature send of blow and target plate status. The readings were observed for every blow for each day and same are presented through. Both the unit readings were compared for conclusion of efficient steam blowing.

**5.2. Fuel consumption for steam blowing:**

Unit#1 1st stage: Light Diesel Oil is 1327.42 kiloliters; Heavy fuel oil is 1730.863 kiloliters.
Unit#1 2ndstage: Light Diesel Oil is 306.6 kiloliters; Heavy fuel oil is 1370.956 kiloliters.
Unit#2 1st stage: Light Diesel Oil is 1327.42 kiloliters; Heavy fuel oil is 1430.108 kiloliters.
Unit#2 2ndstage: Light Diesel Oil is 306.6 kiloliters; Heavy fuel oil is 1040.611 kiloliters.

**5.6. Services required:**

1. Availability of required quantity of DM water and fuel oil for the operation.
2. Availability of H.T/L.T/220 VDC/ 110 VAC power supply.
3. Availability of instrument / service air
4. Availability of lab facility for boiler water regime maintenance.
5. Availability of auxiliary steam.
6. Availability of manual feeding arrangement of Ammonia & Hydrazine.
7. Availability of portable fire extinguishers at selected locations.
8. Availability of required lighting / communication facility / manpower.
9. Availability of public addresses system or siren to communicate the commencement of steam blowing.
10.Availability of ambulance / fire tender in the power station premises.

**5.7. Safety precautions:**

1. Required quantities of safety gears such as helmets, Asbestos hand gloves, Ear Mufflers etc are available.
2. First aid kit box available in control room Service water shall be made available near the activity area.
3. Required stair cases or platform or approaches etc with hand rails to electrical operated quick opening temporary valves are made available.
4. Required barricades to be made to prevent personal from coming into contact with temporary piping.
5. Required number of sign boards to be put into position at selected locations to indicate the ongoing process of steam blowing.

**5.10. Procedure:**

1. The boiler is to be started in a normal manner following start up procedure. All normal recommendations and limitations with respect to fuel firing equipments, draft plant, drains and vents, instrumentation, interlocks, protections etc. should

be taken care of as if the unit is started to synchronies the generator with the grid.

2. The procedure is to raise the boiler pressure to 60 bar. shut off firing and the same time open temporary valve (EOTV). The steam lines which are being blown should be warmed up prior to blowing. The opening of temporary valve allows steam to escape to atmosphere at high velocity carrying with it loose and dislodged debris. To prevent thermal stresses in the thick walled shell like separator and headers the saturation temperature change in separator is limited to 40 °C maximum. Hence, for the purpose of steam blowing of all critical piping the temporary valve will be opened at 60 bar and closed at 40 bar separator pressure.

3. The water level in the separator swings beyond visible limits at the start, during and at the end of steam blowing. There are chances of water droplets to carry over to the saturated steam pipes and low temperature super-heater. This can possibly be minimized by keeping the water level in the separator at the lowest port (visible limit) before the start of each steam blow off.

4. All the steam lines are purged in parallel and it is a standard practices to limit number of blows per day to 8 with an interval of 1-1 ½ hours for cooling in addition to overnight cooling.

5. The furnace exit gas temperature should be limited to 540 °C to safeguard super-heaters and re-heaters.

6. Internal boiler water treatment to be carried out with liquid ammonia and hydrazine hydrate only to maintain pH value of 10.0 in boiler water and 5 to 25 ppm of $N_2H_4$ in feed water.

7. Hot tightening of flanges, studs or bolts is to be done wherever such connections have been made.

8. During steam blowing. MS, CRH and HRH line drains are kept open to atmosphere without any valve for achieving free and uninterrupted flow.

9. Target Plates will be used for stages, Stainless Steel target plates having mirror finish will be used in final stages. In the preceding stages target plates are not being used. During steam blowing, pressure and temperature readings at selected locations will be noted down for the purpose of determining CFR (Refer results and calculation chapter)

10. Completion criteria for all the stages of steam blowing are given at the end.

**5.11. Target plate Spesification**

**5.11.1.Dimensioning and surface quality:**

The result of steam blowing shall be checked by means of a target plate to consist of a holding fixture to which a mirror-finished impingement plate of stainless steel with a Brinell hardness between 200HB at room temperature, the length of target plate is 64mm width is 25mm thickness is 6mm, 1600mm$^2$ is the area considered, specific agreements shall be made regarding the assessment of steam purity (impact of debris). **5.11.2**

**Location of target plate installation**: When selecting the location of installation, the inlet conditions should be chosen such that an as uniform as possible impact velocity on the target plate is ensured. Here, the specific local conditions as being taken into account. The installation of target plates directly downstream of pipe bends shall be avoided. Not less than 5 times the nominal width of the line in which the target plate is installed is considered the guide value for a undisturbed inlet section upstream of target plate.

Principally two locations are possible,

1) Installation of target plate in the inlet section of temporary pipe work

2).Installation of target plate in the outlet section of the steam line.

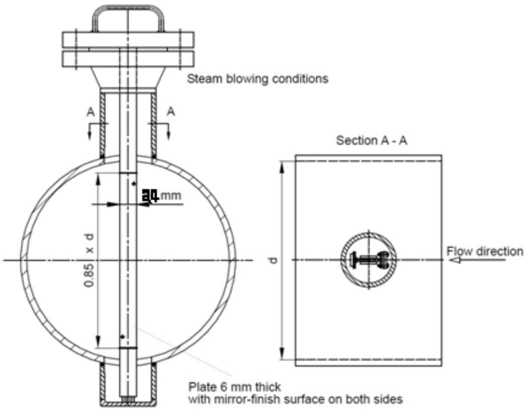


Fig 5.1: Target plate arrangement

**5.12. Cleanliness criteria:** The turbine vendor of the steam will generally specify the criteria to which the system should be cleaned if steam is used in a turbo generator the following criteria is generally used.

1) The successive target must result in mirror finished that meet the specified criteria.

2) After a cooling down period of at least 12 hours two more successive steam blows must result in mirror surfaces that meet the specified criteria.

**5.13. Results:** Indications for the result of each blowing are the number of pitting found on the target plate mounted in the temporary exhaust pipes nearer to the permanent line. The highest velocity of steam is in the centre of the pipe. Hence, judgement should be made for the end point of steam blowing in this area. The area for the above is 3 /4$^{th}$ the discharge pipe diameter at the centre. It is recommended to install the target plate after completing few blows in each stage.

1. For evaluating the cleanliness and termination point of the steam blowing, target plate of stainless steel are to be used.
2. The result of the blowing operations can be judged by the absolute number of pitting on the target plate in the central zone. The piping is considered clean if there are not more than 5 (five) pitting and shall not have any deformed edges. Besides there shall be no pitting in the rim zone.
3. Two or three blows may be given if required, after attaining the results before termination of steam blowing of respective stages.

## VI. RESULTS AND DISCUSSION

### 6.1.Performance parameters in steam blowing calculation .

**6.1.1. Cleaning force ratio (CFR):** Steam blowing will only be effective if it is done at higher steam velocities than those prevailing during full-load operation. In most cases, the condition of the steam generating plant will not permit, at the time of steam blowing, to establish the required design steam parameters. The steam velocities in the steam generator and associated pipe work can be calculated from the mass to volume flow ratio. The mass to volume flow ratio is called the Cleaning Force Ratio (CFR). Experience gained over many years has shown that the optimum measuring location for determining the CFR is at the steam generator outlet that is final super heater outlet or beginning of steam line. At this location, CFR should not exceed 1.2 to 1.7 for effective steam blowing. The location where the CFR in the steam range is to be determined should be agreed between all parties involved at planning stage.

The "CFR" is derived as follows: Caution must be taken to prevent piping configurations that require excessive inlet CFR's. Inlet CFR's, that significantly exceed 1.2 (i.e., 1.7 or greater), may cause system damage and should be avoided.

Critical Force Ratio (CFR) is calculated using where:

$$\mathrm{CFR} = \frac{\mathrm{Qb^2 \; x \; Vb}}{\mathrm{Q2\; MCR \; x \; VMCR}} \qquad \text{-----------Eq (1)}$$

Where,
Qb = Steam flow during blowing at (SH/CRH/HRH) in "T/Hr or kg/sec"
Qmcr = Steam flow at maximum continuous rating (SH/CRH/HRH) in "T/Hr or kg/sec"
Vb = Specific volume of steam during blowing in "$m^3$/kg"
Vmcr = Specific volume of steam at maximum continuous rating in "$m^3$/kg"
Since,

$$\mathrm{Qb} = \frac{\text{Sonic Velocity during blowing x Area x Length}}{Vb} \quad (2)$$

$$\text{Sonic Velocity} = \sqrt{k\ x\ P\ x\ Vb\ x\ g}\ \text{ m/sec} – (3)$$

Where,
k = 1.3 Constant
g = Acceleration due to gravity is 9.81 in "$m/sec^2$"
A = Area of main steam line in "$m^2$"
$A = \frac{\pi d^2}{4}$; Since d = Diameter of main steam line at (SH/CRH/HRH) in "m"
P = Main steam line exit pressure (SH/CRH/HRH) in "ksc or bar"
L = Standard length is 1 "m"
Substituting Equation 3 in 2 becomes

$$\mathrm{Qb} = \frac{\sqrt{k\ x\ P\ x\ Vb\ x\ g}\ \text{ x Area x 1}}{Vb} \quad (4)$$

Substituting equation 4 in equation 1 becomes

i.e :- $$\mathrm{CFR} = \frac{\mathrm{Qb^2 \; x \; Vb}}{\mathrm{Q2\; MCR \; x \; VMCR}}$$

$$\mathrm{CFR} = \frac{\left[\frac{\sqrt{k\ x\ P\ x\ Vb\ x\ g}\ \text{ x Area x 1}}{Vb}\right]^2 \text{ x Vb}}{\mathrm{Q2\; MCR \; x \; VMCR}}$$

$$\mathrm{CFR} = \frac{\frac{k\ x\ P\ x\ Vb\ x\ g\ \text{ x Area x Area}}{Vb\ x\ Vb} \text{ x Vb}}{\mathrm{Q2\; MCR \; x \; VMCR}}$$

$$\mathrm{CFR} = \frac{\mathrm{k\ x\ P\ x\ g\ x\ A^2}}{\mathrm{Q^2 MCR\ x\ VMCR}}$$

**6.1.2. Steam pressure and temperature:**

The relationship between steam pressure and steam temperature are critical in understanding the energy in the steam that a boiler produces. The higher the pressure of a boiler the more heat must be applied to make steam. With the increased pressure, you in turn get steam at higher temperatures. The relationship between steam pressure and steam temperature depending upon designed boiler application, in super critical thermal power plant steam pressure and steam temperature are raised at 221.18 to 275 bar and 565 to 593 °C respectively. While steam blowing the steam is blown at higher pressure and temperature than the normal operating range. This parameter increases the steam blowing effectiveness and quality of steam is achieved and also increase the overall efficiency of the plant. As compared to operational parameters the steam blowing pressure and temperature should be higher if not the steam blowing will not be effective. While calculating CFR we consider the average values of SH pressure at EOTV, CRH pressure at out let for 1A path of both the Unit and HRH pressure at out let for 2A path of both the unit. Pressure and temperature are recorded in the steam blowing log pertaining to every number of blow refer Annexure - 1, 2, 3 and 4.

**6.1.3. Steam mass flow rate:** Since the amount of steam delivered varies with temperature and pressure, a common expression of the boiler capacity is the heat transferred over time expressed as Tons/Hour. In our project we are using M/s ALSTOM super critical boiler 800X2MW Capacity were installed at YTPS Raichur. It is designed into three categories like boiler capacity of SH main steam EOTV is Qmcr = 2592.7 T/Hr or 720 kg/sec, CRH pressure at outlet is Qmcr = 2069.2 T/Hr Or 574 kg/sec and HRH pressure at outlet is Qmcr = 2069.2 T/Hr or 574 kg/sec, at maximum continuous rating for standard boiler design are taken for steam blowing CFR calculation. Steam mass flow rate can be calculated as Boiler Pressure, Condenser Pressure, Temperature of steam leaving the boiler, Pressure after High Pressure turbine, and Temperature before Low Pressure turbine. In the Puffing Blow method, the boiler is fired to gradually pressurize the system until a predetermined pressure is reached. Once achieved, a quick opening valve is opened and the contained steam is released directly into atmosphere through the temporary piping line; a transonic velocity is applied with a high mass flow rate. In order to employ the puffing blow method, temporary piping has to be properly engineered.

**6.1.4. Specific volume:** It is a property of substance, defined as the number of cubic meters occupied by one kilogram of a particular substance. The standard unit is the meter cubed per kilogram ($m^3$/kg). In puffing method we consider two specific volume the first one is the designed specific volume. Here it works due to the fact that high temperature steam at low pressure has a much higher specific volume than a corresponding temperature steam at high pressure. A reduction in steam pressure can also cause an increase in specific volume and, for a given mass flow, an increase in velocity. When the steam pressure is reduced during the steam blowing the velocity will increase for a given output.

**6.1.5. CFR calculation:**

**I. Unit # 1 (Stage 1A)**

1. Super heaters (SH)

$$\text{CFR} = \frac{\text{Qb}^2 \text{ x Vb}}{\text{Q2 MCR x VMCR}} = \frac{k\ x\ P\ x\ gx\ A^2}{Q^2\text{mcr x Vmcr}}$$

Where: k = 1.3 Constant
g = 9.81 in m/ $sec^2$
d = 0.378 m (Diameter of main steam line at SH)

$$A = \frac{\pi d^2}{4} = \frac{\pi\ x\ (0.378)^2}{4} = 0.112 \text{ m}^2$$

Qmcr = 2592.7 T/Hr or 720 kg/sec (SH)
Vmcr = 0.0132 m/sec; from, steam table, mollier diagram at P = 255 kg/$cm^2$ or 250 bar, T = 568 °C
P = Main steam line exit pressure at SH

$$\text{CFR} = \frac{1.3\ x\ P \text{ x } 9.81 \text{ x } 10000 \text{ x } (0.112)^2}{[\frac{2592.7\ x\ 1000}{3600}]^2 \text{ x } 0.0132}$$

$$= \frac{1599.736 \text{ x P}}{518679.39 \text{ x } 0.0132}$$

CFR = 0.233 x P

Since, Main Steam Line at HRH Exit Pressure is 6.12 ≈ 6.2 kg/$cm^2$

In SI unit, 6.12 kg/$cm^2$ = 6 bar = 0.233 x P
= 0.233 x 6
CFR = 1.40
Hence, CFR = 1.40 > 1.2 (Super Heat)

1.Cold Re-Heat (CRH)

$$\text{CFR} = \frac{\text{Qb}^2 \text{ x Vb}}{\text{Q2 MCR x VMCR}} = \frac{k\ x\ P\ x\ gx\ A^2}{Q^2\text{mcr x Vmcr}}$$

Where: k = 1.3 Constant
g = 9.81 in m/ $sec^2$
d = 0.748 m (Diameter of main steam cold Re-Heat)

$$A = \frac{\pi d^2}{4} = \frac{\pi\ x\ (0.748)^2}{4} = 0.439 \text{ m}^2$$

Qmcr = 2069.2 T/Hr or 574 kg/sec (CRH)

Vmcr = 0.0415 m/sec; from, steam tables or mollier diagram at P = 63.3 kg/$cm^2$ or 62.08 bar and T = 358.3 °C P = Main steam line exit pressure at CRH

$$\text{CFR} = \frac{1.3\ x\ P \text{ x } 9.81 \text{ x } 10000 \text{ x } (0.439)^2}{[\frac{2069.2\ x\ 1000}{3600}]^2 \text{ x } 0.0415}$$

$$= \frac{24577.709 \text{ x P}}{(574.77)^2 \text{ x } 0.0415}$$

CFR = 1.79 x P
Since, Main Steam Line at HRH Exit Pressure is 0.79 kg/$cm^2$ ≈ 0.8 kg/$cm^2$
In SI unit 0.79 kg/$cm^2$ = 0.77 bar
= 1.79 x P
= 1.79 x 0.7
CFR = 1.38
Hence, CFR = 1.38 > 1.2 (Cold Re-Heat)

**II.Unit # 1 (Stage 2A)**

1. Hot Re-Heat (HRH)

$$\text{CFR} = \frac{\text{Qb}^2 \text{ x Vb}}{\text{Q2 MCR x VMCR}} = \frac{k\ x\ P\ x\ gx\ A^2}{Q^2\text{mcr x Vmcr}}$$

Where: k = 1.3 Constant
g = 9.81 in m/ $sec^2$
d = 0.748 m (Diameter of main steam line at HRH)

$$A = \frac{\pi d^2}{4} = \frac{\pi\ x\ (0.748)^2}{4} = 0.439 \text{ m}$$

Qmcr = 2069.2 T/Hr or 574 kg/sec (HRH)

Vmcr = 0.0653 m/sec; from, Steam tables or Mollier diagram at P = 60.8 kg/cm$^2$ or 59.62 bar and T = 596 °C

P = Main steam line exit pressure at HRH

$$CFR = \frac{1.3 \ x \ P \ x \ 9.81 \ x \ 10000 \ x \ (0.439)^2}{[\frac{2069.2x \ 1000}{3600}]^2 \ x \ 0.0653}$$

$$= \frac{24577.709 \ x \ P}{(574.77)^2 \ x \ 0.0653}$$

CFR = 1.139 x P

Since, Main Steam Line exit Pressure at HRH is 1.49 kg/cm$^2$ ≈ 1.5 kg/cm$^2$

| Impact Diameter | Number of impact for Unit # 1 | | | |
|---|---|---|---|---|
| | 1A Left | 1A Right | 2A Left | 2A Right |
| Dia > 1mm | - | - | - | - |
| 1mm > Dia 5 mm | 2 | 3 | 3 | 1 |
| 0.5mm>Dia >0.2mm | 5 | 4 | 3 | 5 |

In SI unit 1.49 kg/cm$^2$ = 1.46 bar
= 1.139 x P
= 1.139 x 1.46

| Impact Diameter | Number of impact for Unit # 2 | | | |
|---|---|---|---|---|
| | 1A Left | 1A Right | 2A Left | 2A Right |
| Dia > 1mm | - | - | - | - |
| 1mm > Dia 5 mm | 3 | 3 | 2 | 3 |
| 0.5mm>Dia >0.2mm | 4 | 4 | 5 | 4 |

CFR = 1.66
Hence, CFR = 1.66 > 1.2 (Hot Re-Heat)

**Note:** The CFR is calculated for Superheated main steam line and cold reheat line these two lines are connected to 1A stage of both the unit #1 and unit # 2 respectively. Hot reheat line is connected to 2A stage of both the unit #1 and unit # 2 respectively. The CFR is not calculated for individual unit since both the unit design parameters and operational parameters are found to be same. Here we are not calculating CFR for 1B and 2B stages of both the units because limited number of blow is given due to very short pipe length is blown and which are not directly connected to the steam turbine. In experimental of steam blowing CFR value lays between 1.2 to 1.7 for both the units / stages, hence the steam blowing is effective.

**6.2.Guidelines for the target plate evaluation.**

**6.2.1. Target plate**: During the steam blows target plates made of stainless steel with brushed surface are to be used. The steam cleanliness is confirmed with the polished stainless steel (brinell hardness 110 -120) target plate installed to piping after temporary steam blow valve. The target area in the plate is determined to be 1600mm$^2$.

**6.2.2. Acceptance criteria**: The cleaning is successfully completed when the target plate examination fulfils the following criteria:
No impacts ≥ 1 mm dia in an area of 1600mm$^2$.
Less than, 4 impacts ≥ 0.5mm dia in an area of 1600mm$^2$
Less than, 10 impact ≥ 0.2mm dia in an area of 1600 mm$^2$.
Total number of Impacts ≤ 0.20mm dia at the end of steam blow can be accepted provided they are well dispersed and uniform in distribution without creating a rough surface. Maximum number of consecutive clean targets is 2.

**6.2.3. Agreement:** The evaluation method of the target plates and the steam purity criteria presented in this paper are hereby agreed to be indisputable and valid.

U#1: 1$^{ST}$ Stage steam blow 03-11-15 to 27-12-15; 2$^{nd}$ 03-01-16 to 15-01-16; U#2: 1$^{ST}$ Stage steam blow 28-04-16 to 10-05-16; 2$^{nd}$ 18-05-16 to 03-06-16. On behalf of the M/s ALSTOM boiler manufacturer. On behalf of steam M/s Siemens turbine manufacturer. On behalf of commissioning team of both M/s BHEL and RPCL Raichur. On behalf of YTPS Raichur (RPCL / KPCL).
Table 6.1: Unit#1 Impact size distribution

Table 6.2: Unit#1 Impact size distribution

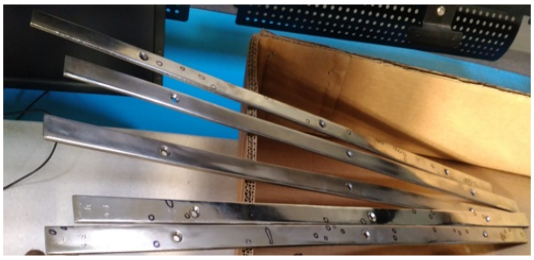

Fig 6.1: Dents on target plate of stage 1A unit-1

**6.2.4. Target Plate Results:**

The target plates have been in accordance with M/s BHEL Guidelines. At no point of the target plates 1A and 2A path of both the unit sites on an area of 25mm x 64 mm impact were found with the above mentioned extension, number and therefore steam blowing performed successfully.

**VII. CONCLUSIONS:**
The steam blowing activity for unit#1 and unit#2 completed with target plate achieved as per turbine manufactures requirement, unit#1 M/s ALSTOM boiler takes more numbers of blows which intern increase number of blowing days and consumes more LDO and HFO that is because of temporary

pipe regularly fails due to metallurgical defect and welding defects. Unit # 2 M/s BHEL boiler consumes less LDO and HFO hence takes lesser number of blows which intern reduces number of blowing days that is because we have taken care of temporary pipe welding and metallurgical aspects.
More obtainable cleaning results and consequence a minimum risk of damage is achieved more effective keeping to scheduled set of dates is possible. The puffing is the most preferred method of steam blowing hence at YTPS Raichur we adopted puffing method which as given more effectiveness on the boiler. CFR what we have achieved for 1st blow that we have achieved for entire blows. Steam pressure and temperature maintained 60 bar and 30°C more superheated so that we ensure all the blows what we blown is most effective. The effective steam blow process while helping to reduce the overall plant cost and schedule, without compromising safety.

The final results after steam blowing is steam dumping and we achieved steam quality within two days and admitted to the turbine and achieved synchronization of unit#1 on 09th of February 2016 and unit#2 on 21st of July 2016 and capacity addition test of unit#1 on 29th of march 2016. Balance of plant equipment associated with the boiler and boiler auxiliary systems must be completed and checked before steam-blowing is possible. Reduce manpower, time, fuel, condensate requirements, and cost. Extends boiler life by eliminating temperature cycles in the boiler associated with steam blows.

**7.1. Future scope :** Whether more than 60 bar pressure is effective for SC boilers that can be analyzed for future study and also by providing silencers night time also blowing could be possible which could be considered in future.

## VIII. REFERENCES

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