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Optimization of Time for Cold Start-up of Boiler and TG by Using ECRS Principle: A Case Study at Power Plant of JSP-Raigarh

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ABSTRACT: Overall Equipment Effectiveness (OEE) has become an accepted management tool to monitor and improve the efficiency in any manufacturing process. OEE is broken down into three measuring metrics i.e., Equipment Availability, Performance and Quality. These metrics help gauge to the plant's efficiency and effectiveness and categorize these key productivity losses that occur within the manufacturing process. Availability of equipment has become an important goal for today's manufacturing or service industries as it directly impacts productivity of plant. Apart of a good maintenance management, availability of equipment can be increased by eliminating the wastes also.

Waste is an activity that wastes resources such as expenditure or extra time but does not add any value to the activity. There are seven types of waste that often occur in the manufacturing industry, including: waste of overproduction, waste of inventory, waste of defects, waste of transportation, waste of motion, waste of waiting, and waste of overprocessing. Eliminating waste is a basic principle in TPM (Total Productive Maintenance) / lean manufacturing. The elimination of waste must be taught to each member of the organization so that the effectiveness and efficiency of work can be improved. The critical waste found in the power plant process named "cold start-up of a boiler & turbo generator (TG) after shutdown". Improvements are made using ECRS (Elimination, Combine, Rearrange and Simplify) approach, one of the TPM / lean manufacturing tools which helps to implement an immediate and rapid improvement action to improve a system's efficiency. The workload of operator was also considered to avoid bottlenecks and decrease the lead time. The result was quietly remarkable as the lead time decreased significantly by around 18.18% and able to balance the workload received by the operator.

KEYWORDS: TPM, ECRS, Power plant, Cold start-up, Equipment Availability, OEE, Lean Manufacturing

I. INTRODUCTION

Global performance evaluation is the most critical aspect in the field of continuous improving of the production process. Overall Equipment Effectiveness (OEE) is one of the performance evaluation methods that is most common and popular in the production industries. OEE plays a vital role where performance and quality of the product are of importance to the organization. The OEE is intended at minimizing the breakdowns, increasing performance and quality rate and thus improving the effectiveness of the machine/system. The availability rate of the machine, performance rate of the machine and quality rate of the products are three measuring metrics and considered as main parameters for maximizing the OEE of a manufacturing system. These metrics help gauge plant's efficiency and effectiveness and categorize these key productivity losses that occur within the manufacturing process. It is found that poor availability (higher downtime losses) contributes more than performance rate and quality rate.

The downtime losses include setup time and adjustment time can be reduced using the TPM (Total Productive Maintenance) / lean manufacturing tools and techniques. There are a number of TPM / lean manufacturing tools and

techniques which can perform the systematic examination of the methods of carrying out activities so as to improve the effective use of resources and to set-up standards of performance for the activities being carried out. ECRS is one of such techniques used to analyse processes in a production line. It is one of the most powerful tools that management can use to improve productivity by minimising the setup and adjustment time to improve OEE.

II. LITERATURE REVIEW

Considering the previous research from literature reviews it can be stated that ECRS is a simple and effective method used in manufacturing for improving efficiency of production lines. Awapak et al. used ECRS technique and Single Minute Exchange of Die (SMED) method to reduce idle time during the ice-cream making process. Miranda proposed to adopt ECRS in increasing man efficiency of the clean room assembly process that influenced the reduction of manpower costs of one electronics manufacturer in Philippines. Makprang applied ECRS to reduce the total internal transportation distance and number of operators of the canned fruits production line. Kasemset et al. adopted ECRS to reduce negative product cost from defects of one plastics packaging factory in Thailand. Thus, ECRS used as an improvement tool can be used also in administrative processes given the fact that the main aim of this method is to reduce the non-value adding activities. In some literature, the “R” in ECRS is in some cases replaced with an “I” (for Improve) and the method is used in forms that analyses the process flow for a part.

ECRS is a unique approach towards process activity optimization by analysing processes and activities using the following core principles :

- E = Eliminate unnecessary work
- C = Combine operations
- R = Rearrange sequence of operations
- S = Simplify the necessary operations

ECRS is a widely used method for analysing whether the process is inefficient. If we keep the 7 types of waste in mind and use the ECRS tool in combination with other efforts such SMED, 5W1H, 5WHY's or 5S it will be powerful indeed (Fig. 1).

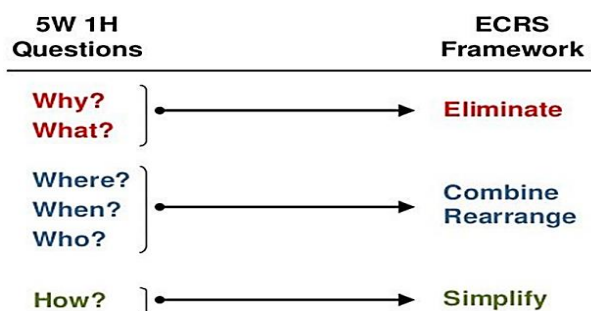


Fig. 1 Correlation between 5W1H and ECRS

This technique is primarily used to reduce or remove wasteful steps entirely from manufacturing processes or even office procedures. When implementing ECRS, complex and time-consuming tasks are reviewed successfully, with suitable and appropriate questions (Fig. 2), by applying any one or all of the strategies in the ECRS acronym. The end result aims to streamline any process, by eliminating the wastes, and create a more efficient business as a whole.



Fig. 2 Questions for ECRS

In order to eliminate waste, it is essential to identify the value adding and non-value adding activities in a process.

At JSP-Raigarh, we considered a task “Cold start-up of boiler & TG (turbo generator) after shutdown” which is one of the major and critical processes of a thermal power plant. ECRS was chosen to help the team to focus on breaking down each step into possible future improvements and extracting the value from the process. As stated above, every action that did not require elimination, combination, rearrangement or simplification and which visibly contributed to the final objective (eliminating the waste i.e., setup time and adjustment time) was considered for value addition. For this, a Gantt Chart was used. The Gantt charts show the dependency relationships between activities and the current schedule status.

The main purposes of this paper are to find out the cyclic and non-cyclic activities, identify the parallel activities and to effectively utilize the resources by the effective implementation of ECRS tool which leads to increase in productivity and reduce in lead time by reducing nonvalue-added activities.

III.METHODOLOGY

About JSP-Raigarh : Jindal Steel & Power Limited (JSPL) is an industrial powerhouse and one of the leading companies in the Indian steel industry with a significant global presence. It operates the largest coal-based sponge iron plant in the world and has a substantial presence in domestic power, mining and infrastructure sectors.

JSP-Raigarh plant is the one of the world’s largest coal-based sponge iron manufacturing facility, with up to 3.6 million tonnes per annum (MTPA) steel production capacity. It has an installed 299 MW thermal based captive power plant (CPP) at JSP-Raigarh and a 540 MW thermal based CPP at Dongamauha, Raigarh, Chhattisgarh.

At, JSP-Raigarh, thermal CPP is divided into 3 units as per the details given below :

- Unit-1 : 40 MW
- Unit-2(Ph-1) : 55 MW
- Unit-2(Ph-2) : 55 MW
- Unit-2(Ph-3) : 50 MW
- Unit-3 : 75 MW

where MW is unit of measure of power [1 MW= 1000 kWh (kilo Watt Hour)]

Thermal Power Plant : A thermal power plant is power plant in which prime mover is steam. Water is heated, turns into steam and spins turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated, this is known as Rankine cycle (Fig. 3). The flow diagram of a thermal power plant has depicted in Fig. 4.

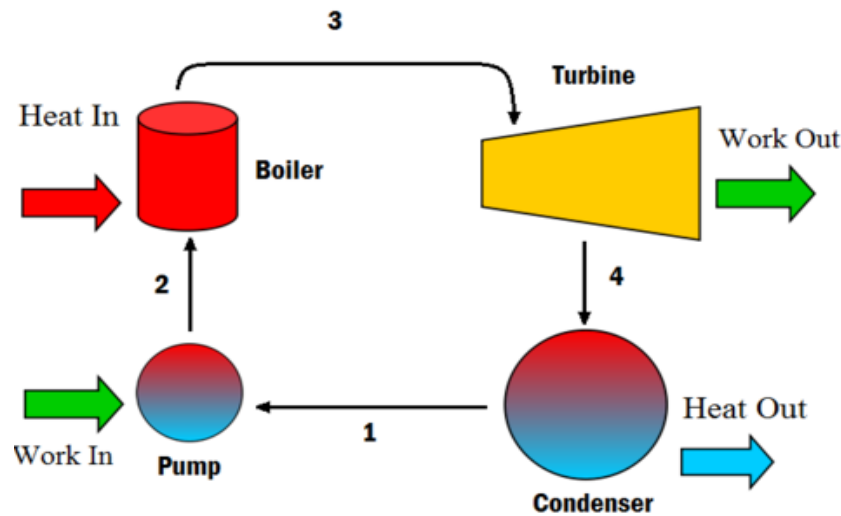


Fig. 3 Rankine cycle

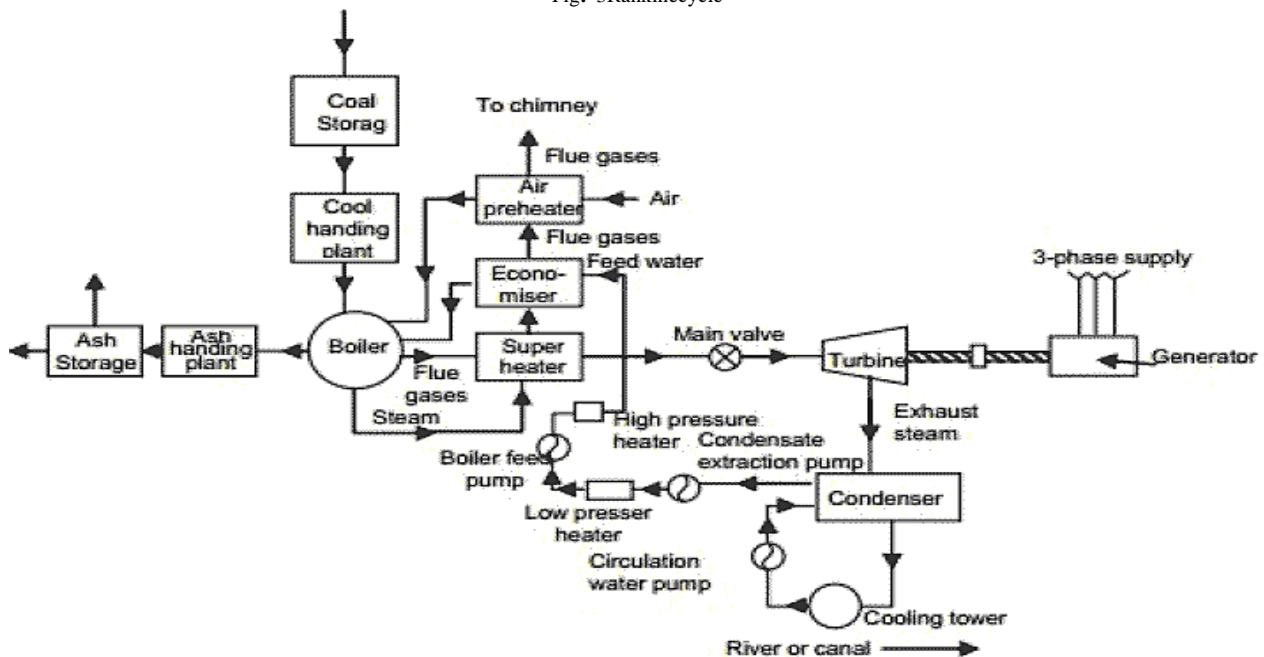


Fig. 4 Flow diagram of thermal power plant

The basic machinery of a thermal power plant is as follows :

- Coal handling system
- D M Plant
- Boiler
- Turbine
- Condenser
- Cooling tower
- Generators
- Excitation system
- Transformer
- Ash handling system
- Ash Dyke

As per Indian Boiler Act 1923, a boiler [Fig. 5 (a)] is defined as any closed vessel exceeding 22.75 liters in capacity which is used exclusively for generating steam under pressure and includes any mounting or accessories attached to such vessel, which is wholly or partially under pressure, when steam is shut off. Boiler is enclosed vessel in which water is heated and circulated until the water is turned into steam at the required pressure. Coal is burned inside the combustion chamber of boiler whereas Turbine is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft [(Fig. 5 (b))]. A turbo generator (TG) is an electric generator connected to the shaft of a steam turbine or gas turbine for the generation of electric power.

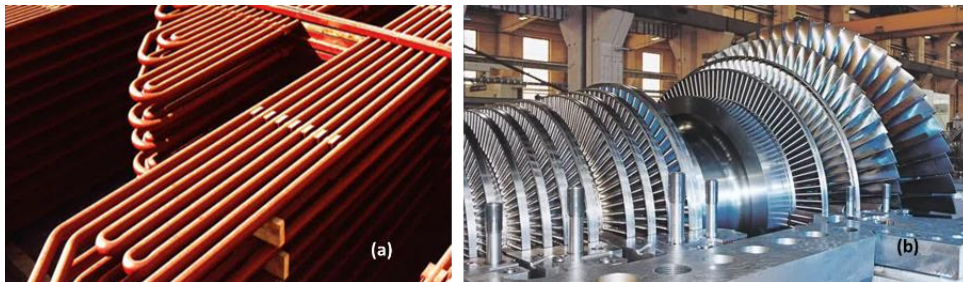


Fig. 5(a) Boiler (b) Turbine

Usually, the boiler is isolated and taken for shut down for repair & maintenance, inspection, etc. After completion of the aimed jobs, the boiler must be carefully and properly prepared for start-up. This is a step-by-step process, and all plants will have their own procedure based on the role that the steam system plays in that plant. The start-up of boiler and turbine after a scheduled / planned shutdown is known as the “Cold Start-up of boiler and TG”.

Data collection: Data are collected for one major job of power plant i.e., “Cold start-up of boiler & TG after shutdown” using a stopwatch. The time actually consumed in each activity was recorded. It helped to find out the major time-consuming activities, cyclic and non-cyclic activities. It also helped to visualize the root causes and possible solutions for the problems.

Data are collected for a process named “Cold start-up of boiler & TG after shutdown”. The steps involved in this process is represented in Fig. 6 whereas the no. of activities involved in each step and typical time being consumed by each step, before ECRS implementation are tabulated as Table 1.



Fig. 6 Steps involved in the cold start power plant after shutdown task of power plant

S. No.	Step	No. of activity	Time (in Min.)
1	Post light-up of boiler	10	260
2	Pre-mixing of boiler	08	150
3	Cold start-up of TG	16	305
Total Time		34	715

Table 1 Steps, no. of activities involved in each step and time being consumed in the process named “cold start-up of boiler & TG after shutdown”(before ECRS implementation)

All the activities, with time being consumed to perform it, involved in the above mentioned 3 steps (Post light-up of boiler, Pre-mixing of boiler and Cold start-up of TG are depicted below in Figs. 7 and 8 respectively.

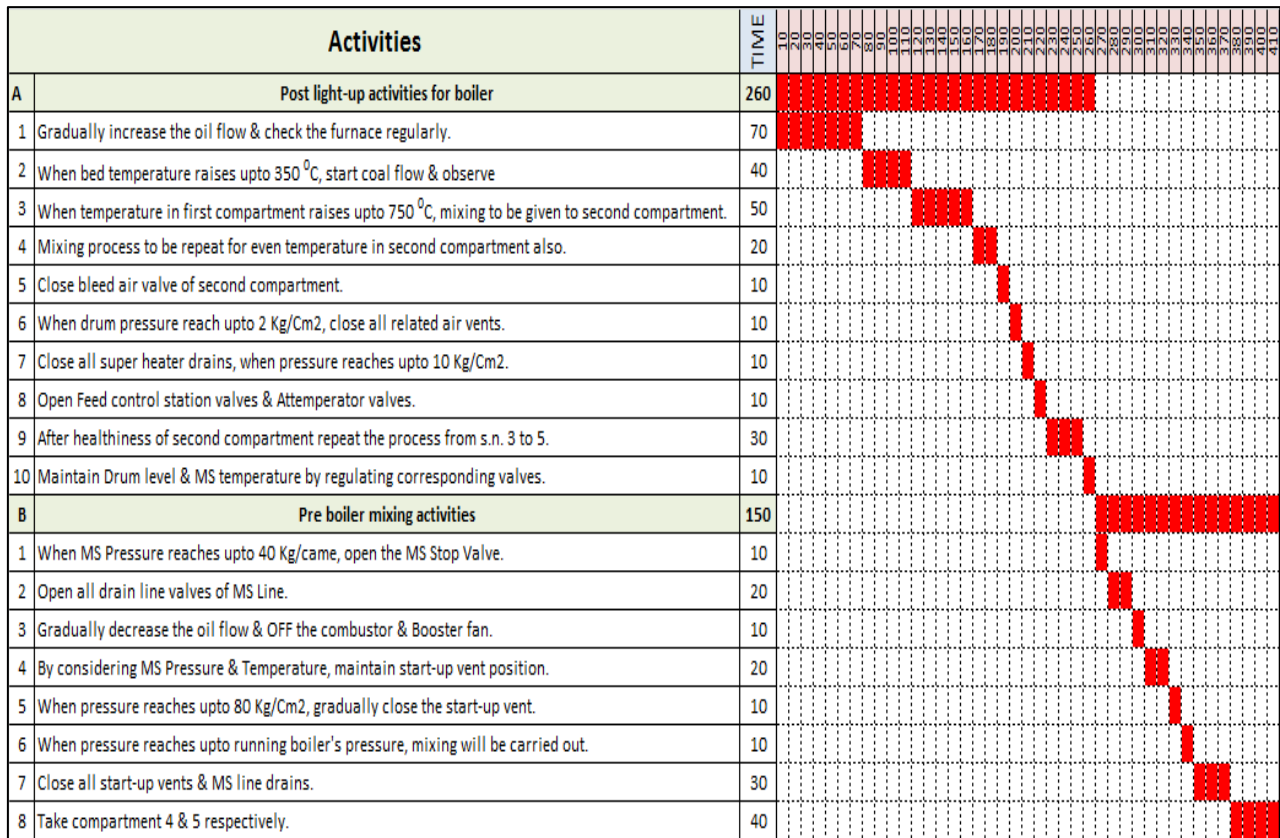


Fig. 7 Activities and time being consumed in boiler light up step and pre boiler mixingstep (before ECRS implementation)

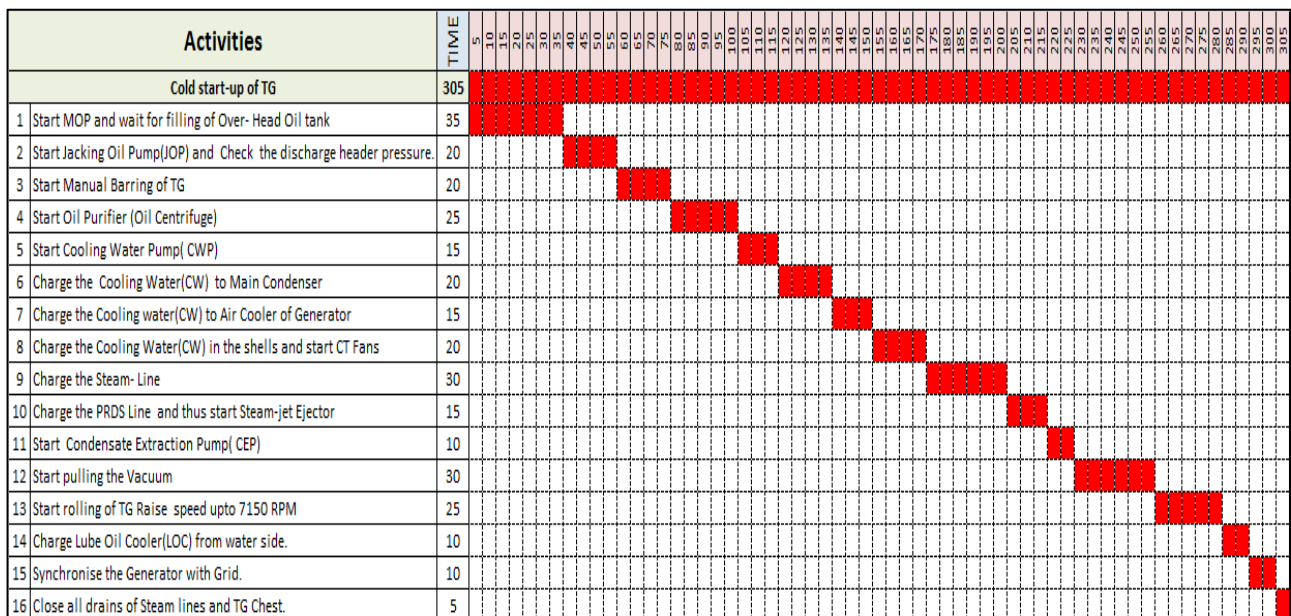


Fig. 8 Activities and time being consumed in cold start-up of TG step (before ECRS implementation)

From the above Gantt chart, it is evident that the total time consumed to perform the process, considered for redesign using ECRS (the cold start-up of boiler & TG after shutdown) is 715 minutes.



IV. EXPERIMENTAL RESULTS

All the three steps, involved in the process named “Cold start-up of boiler & TG after shutdown”, i.e., Post light-up activities, Pre boiler mixing activities and Cold start-up of TG, were considered for the study. This study used the ECRS technique to redesign the entire process as follows :

- **Eliminate** : Under this step, each and every activities were evaluated whether this was necessary. If it was not necessary and could be eliminated, the work, process and operation studied were eliminated without affecting the process. If it could not be eliminated, partial elimination (elimination of some of its nonvalue added sub-activities) was also considered. The following 4 activities were partially eliminated :
 1. Gradually increase the oil flow & check the furnace in regular interval (e.g., 05 minute).
 2. Whenever the bed temperature raises up to 350°C, start coal feeding and observe the furnace.
 3. Open all drain valves of main steam (MS) Line.
 4. Start MOP and wait for filling of the Over- head Oil tank.
- **Combine** : Under this step, merging was to turn two or more activities into one. The purpose of the merger was to effectively eliminate duplication. It is implemented on following 08 activities :
 1. Close all super heater drains, when pressure reaches up to 10 kg/cm².
 2. Open feed control station (FCS) valves & attemperator valves.
 3. Take compartment 4 & 5 respectively
 4. Start MOP and wait for filling of over- head oil tank.
 5. Start cooling water pump (CWP).
 6. Charge the cooling water (CW) to main condenser.
 7. Charge the cooling water (CW) to air cooler of generator.
 8. Charge the cooling water (CW) in the shells and start CT fans of cooling tower.
- **Rearrange** : Rearrangement is also known as replacement. Under this step, the order of work was recognised to achieve the purpose of changing work procedures and improving work. The following 8 activities were rearranged :
 1. Close all super heater drains, when pressure reaches up to 10 kg/cm².
 2. Open feed control station valves & attemperator valves.
 3. Start MOP and wait for filling of over- head oil tank.
 4. Start cooling water pump (CWP).
 5. Charge the cooling water (CW) to main condenser.
 6. Charge the cooling water (CW) to air cooler of generator.
 7. Charge the cooling water (CW) in the shells and start CT fans.
- **Simplify** : Simplify the work content and links in the original work. This is not a cancellation, merger, or rearrangement. It is a re-examination of the original procedure and a streamlining of the content of the link. It is only a partial scope omission. After cancellation, consolidation, and rearrangement, the work is further deepened. Analytical research is to minimize work time and improve work efficiency. Simplification was done for 7 activities which are given below :
 1. Gradually increase the oil flow & check the furnace regularly.
 2. When bed temperature raises upto 350° C, start the coal feeding and observe the furnace.
 3. Open all drain line valves of main steam (MS) line.
 4. Start cooling water pump (CWP)
 5. Charge the cooling water (CW) to main condenser.
 6. Charge the cooling water (CW) to air cooler of generator.
 7. Charge the cooling water (CW) in the shells and start CT Fans of cooling tower.

In Fig. 9, the ECRS which applied for various process was tabulated for better understanding. Various symbols (✓ and ✓★) indicate that the corresponding tool used for that corresponding process. Example: in Start cooling, three tools are used (E, C, R). Symbol “✓” indicates that the corresponding tool used for that corresponding process, where as “✓★”

indicates that in place fully elimination of the corresponding activity, partial elimination (elimination of some of its nonvalue-added sub activities) of that activity were done.

Activities		E	C	R	S
A Post light-up activities for boiler					
1	Gradually increase the oil flow & check the furnace regularly.	✓*	—	—	✓
2	When bed temperature raises upto 350 °C, start coal flow & observe	✓*	—	—	✓
3	When temperature in first compartment raises upto 750 °C, mixing to be given to 2nd compartment.	—	—	—	—
4	Mixing process to be repeat for even temperature in second compartment also.	—	—	—	—
5	Close bleed air valve of second compartment.	—	—	—	—
6	When drum pressure reach upto 2 Kg/Cm2, close all related air vents.	—	—	—	—
7	Close all super heater drains, when pressure reaches upto 10 Kg/Cm2.	—	✓	✓	—
8	Open Feed control station valves & Attemperator valves.	—	✓	✓	—
9	After helathiness of second compartment repeat the procoess from s.n. 3 to 5.	—	—	—	—
10	Maintain Drum level & MS temperature by regulating corresponding valves.	—	—	—	—
B Pre boiler mixing activities					
1	When MS Pressure reaches upto 40 Kg/come, open the MS Stop Valve.	—	—	—	—
2	Open all drain line valves of MS Line.	✓*	—	—	✓
3	Gradually decrease the oil flow & OFF the combustor & Booster fan.	—	—	—	—
4	By considering MS Pressure & Temperature, maintain start-up vent position.	—	—	—	—
5	When pressure reaches upto 80 Kg/Cm2, gradually close the start-up vent.	—	—	—	—
6	When pressure reaches upto running boiler's pressure, mixing will be carried out.	—	—	—	—
7	Close all start-up vents & MS line drains.	—	—	—	—
8	Take compartment 4 & 5 respectively.	—	✓	—	—
C Cold start-up of TG					
1	Start MOP and wait for filling of Over- Head Oil tank	✓*	✓	✓	—
2	Start Jacking Oil Pump(JOP) and Check the discharge header pressure.	—	—	✓	—
3	Start Manual Barring of TG	—	—	—	—
4	Start Oil Purifier (Oil Centrifuge)	—	—	—	—
5	Start Cooling Water Pump(CWP)	—	✓	✓	✓
6	Charge the Cooling Water(CW) to Main Condenser	—	✓	✓	✓
7	Charge the Cooling water(CW) to Air Cooler of Generator	—	✓	✓	✓
8	Charge the Cooling Water(CW) in the shells and start CT Fans	—	✓	✓	✓
9	Charge the Steam- Line	—	—	—	—
10	Charge the PRDS Line and thus start Steam-jet Ejector	—	—	—	—
11	Start Condensate Extraction Pump(CEP)	—	—	—	—
12	Start pulling the Vacuum	—	—	—	—
13	Start rolling of TG Raise speed upto 7150 RPM	—	—	—	—
14	Charge Lube Oil Cooler(LOC) from water side.	—	—	—	—
15	Synchronise the Generator with Grid.	—	—	—	—
16	Close all drains of Steam lines and TG Chest.	—	—	—	—

Fig. 9 Use of ECRS technique on the power plant process called “cold start of boiler & TG plant after shutdown”

After Implementation of ECRS technique, the time consumed against each step of the process (cold start-up of turbine after shutdown) and % improvement istabulated in Table 2. The time consumed by each activity of all the steps are shown in Fig. 10 and Fig. 11.

S. No.	Process	Time(in Minutes)		% Improvement
		Before ECRS implementation	After ECRS implementation	
1	Post light-up of boiler	260	220	15.38
2	Pre-mixing of boiler	150	130	13.33
3	Cold start-up of TG	305	235	22.95
Total		715	585	18.18

Table 2 Steps with time being consumed (before and after ECRS implementation) in the process named cold start-up of boiler & TG after shutdown and % improvement achieved after implementation of ECRS.

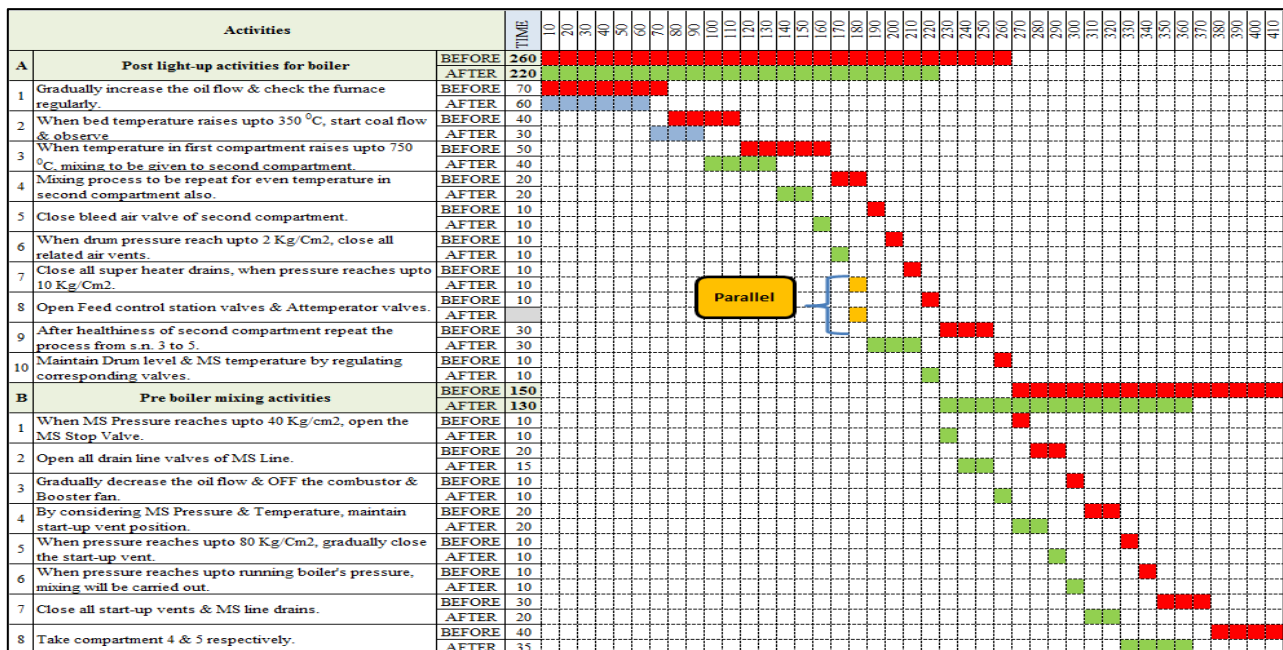


Fig. 10Boiler light up and pre-mixing activities (after ECRS)

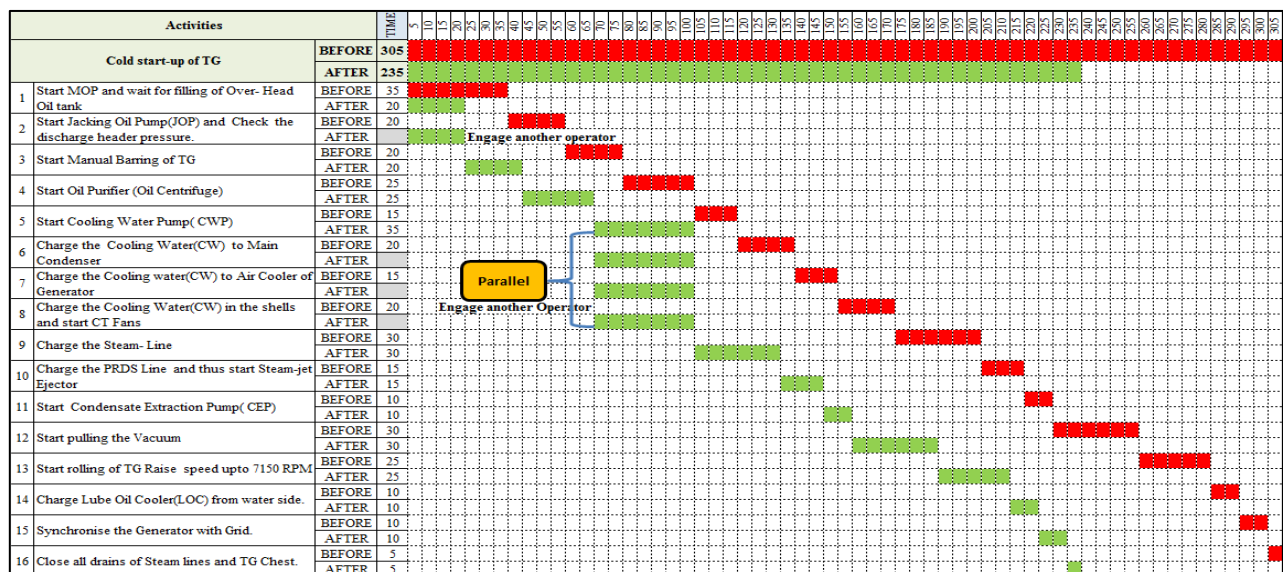


Fig. 11 Cold Start-up of boiler & TG activities (after ECRS)

V. CONCLUSION

ECRS stands for Eliminate, Combine, Rearrange and Simplify. This TPM / lean manufacturing technique is primarily used to reduce or remove wasteful steps entirely from anything regarding manufacturing processes. The ECRS technique emphasizes fast application of new ideas after brainstorming potential improvement opportunities with those who perform the task. With that being said, most newly framed processes don't require money to be spent, it should just be about restructuring and making improvements upon old procedures. The beauty of ECRS is its flexibility, if something doesn't work it can be changed without overspending on an unproven solution. The ECRS method is significant tools that aids improve productivity in organizations, but for continuous improvement and to build a strong organization ECRS to be frequently used in each and every process. The good performance indices of ECRS technique are yield improved productivity, improved quality, improved efficiency, improved safety, reduced downtime and improved employee morale.



Of the above, it can be concluded that there is a way to reduce work time by dint of ECRS technique. The results illustrate that approx. 18% setup time reduction can be achieved with above methodology.

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