Implementation of Total Productive Maintenance in Thermal Power Station (Barauni Refinery)

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***Abstract*—** *This paper describes the course in TPM, Implementation in power plant for engineering students. Total productive maintenance (TPM) is a technique of maintaining and improving the integrity of production and quality systems through the machines, equipment, processes and employees that add business value to the organization. TPM has been keeping on all equipment in top working condition to avoid breakdowns and delays in the manufacturing process.The success of TPM is the support of top management. The areas of interest in this master's thesis are-TPM, the steps involved by the implementation of TPM in an organization, Objective of TPM, TPM – History, Pillars of TPM, Types of maintenance, TPM Targets, TPM in a organization, Fire & Safety department, TPS (Thermal Power Station), BXP (Barauni Expansion Project),Coker. Total productive maintenance is a concept which aims at zero down time. In this paper TPM focuses on Emphasizes Equipment Excellence as backbone of Manufacturing Excellence.*

I. TOTAL PRODUCTIVE MAINTENANCE (TPM)

It is a system of maintaining and improving the integrity of production and quality systems through the machines, equipment, processes and employees that add business value to the organization. TPM focuses on keeping all equipment in top working condition to avoid breakdowns and delays in the manufacturing process. One of the main objectives of TPM is to increase the productivity of plant and equipment with a modest investment in maintenance. Total quality management (TQM) and total productive maintenance (TPM) are considered as the key operational activities of the quality management system. In order for TPM to be effective, the full support of the total workforce is required. This should result in accomplishing the goal of TPM: "Enhance the volume of the production, employee morale and job satisfaction. TPM is an effective tool for the minimization of downtime of machines, production losses and material scraps [02].

A. Implementation of Total Productive Maintenance:-Following are the steps involved by the implementation of TPM in an organization:

- Initial evaluation of TPM level
- Introductory Education and Propaganda (IEP) for TPM,
- Formation of TPM committee,
- Development of master plan for TPM implementation,
- Stage by stage training to the employees and stakeholders on all eight pillars of TPM, Implementation preparation process,
- Establishing the TPM policies and goals and
- Development of a road map for TPM implementation.[03]

B. Objectives of Total productive maintenance:- TPM was introduced to achieve the following objectives. The important ones are listed below.

- Avoid wastage in a quickly changing economic environment.
- Producing goods without reducing product quality.
- Reduce cost.
- Produce a low batch quantity at the earliest possible time.
- Goods send to the customers must be non-defective.

The main objective of TPM is to increase the Overall Equipment Effectiveness of plant equipment. TPM addresses the causes for accelerated deterioration while creating the correct environment between operators and equipment to create ownership [03].

C. TPM - History:-TPM is an innovative Japanese concept. The origin of TPM can be traced back to 1951 when preventive maintenance was introduced in Japan. However the concept of preventive maintenance was taken from USA. Nippondenso was the first company to introduce plant wide preventive maintenance in 1960.The growth of TPM in Japan can be divided into the following four developmental stages:

Stage 1 : Breakdown Maintenance

Stage 2 : Preventive Maintenance

Stage 3 : Productive Maintenance

Stage 4 : TPM

D. Definition and Distinctive Features of TPM:-TPM is often defined as "productive maintenance involving total participation". Frequently, management misconstrues this to mean workers only and assumes that PM activities are to be carried out autonomously on the floor. To be effective, however, TPM must be implemented on a companywide basis. Unfortunately, some firms abandon TPM because they fail to support workers fully or involve management.

A complete definition of TPM includes the following five elements:

1. TPM aims to maximize equipment effectiveness (over all effectiveness).

2. TPM establishes a thorough system of PM for the equipment's entire life span.

3. TPM is implemented by various departments (engineering, operations, maintenance).

4. TPM involves every single employee, from top management to workers on the floor.

5. TPM is based on the promotion of PM through motivation management : autonomous small group activities.

The word "total" in "total productive maintenance" has three meanings that describe the principal features of TPM:

1. Total effectiveness (referred to in point 1 above) indicates TPM's pursuit of economic

efficiency or profitability.

2. Total maintenance system (point 2) includes maintenance prevention (MP) and maintainability improvement (MI) as well as preventive maintenance.

3. Total participation of all employees (points 3,4, and 5) includes autonomous maintenance by operators through small group activities.

The first principal feature of TPM, "total effectiveness" or "profitable PM", is also emphasized in predictive and productive maintenance.

The second feature, a "total maintenance system," is another concept first introduced during the productive maintenance era. It establishes a maintenance plan for the equipment's entire lifespan and includes maintenance prevention (MP: maintenance-free design), which is pursued during the equipment design stages. Once equipment is assembled, a total maintenance system requires preventive maintenance (PM: preventive medicine for equipment) and maintainability improvement (MI : repairing or modifying equipment to prevent breakdowns and facilitate ease of maintenance).

The last feature, "autonomous maintenance by operators" (small group activities), is unique to TPM.

In American-style PM (also in India), the maintenance department is generally responsible for carrying out PM. This reflects the concept of division of labour, an important feature of American labour unions, Japanese-style PM, or TPM, on the other hand, relies on everyone's participation, particularly autonomous maintenance by operators. If a company is already practicing productive maintenance, TPM can be adopted easily by adding autonomous maintenance by operators to the existing system. If a company has not yet implemented preventive or productive maintenance, however, a sudden shift from breakdown maintenance to TPM will be extremely difficult, although not impossible.[05]

Nine Essentials of TPM

1) Self maintained work place

2) Elimination of the 6 big losses

3) Zero Breakdowns

4) Zero Defects

5) Optimal life and availability of tools

6) Self-improvement

7) Short production-development time and low machine life cost

8) Productivity in indirect departments

9) Zero Accidents

Types of maintenance :-

1. Breakdown maintenance:-It means that people waits until equipment fails and repair it. Such a thing could be used when the equipment failure does not significantly affect the operation or production or generate any significant loss other than repair cost.

2. Preventive maintenance (1951):-It is a daily maintenance (cleaning, inspection, oiling and re-tightening), design to retain the healthy condition of equipment and prevent failure through the prevention of deterioration, periodic inspection or equipment condition diagnosis, to measure deterioration. It is further divided into periodic maintenance and predictive maintenance. Just like human life is extended by preventive medicine, the equipment service life can be prolonged by doing preventive maintenance.

2(a). Periodic maintenance (Time based maintenance - TBM):-Time based maintenance consists of periodically inspecting, servicing and cleaning equipment and replacing parts to prevent sudden failure and process problems.

2(b). Predictive maintenance:-This is a method in which the service life of important part is predicted based on inspection or diagnosis, in order to use the parts to the limit of their service life. Compared to periodic maintenance, predictive maintenance is condition based maintenance. It manages trend values, by measuring and analyzing data about deterioration and employs a surveillance system, designed to monitor conditions through an on-line system.

3. Corrective maintenance (1957):-It improves equipment and its components so that preventive maintenance can be carried out reliably. Equipment with design weakness must be redesigned to improve reliability or improving maintainability

4. Maintenance prevention (1960):-It indicates the design of new equipment. Weakness of current machines are sufficiently studied (on site information leading to failure prevention, easier maintenance and prevents of defects, safety and ease of manufacturing) and are incorporated before commissioning a new equipment.

II. METHODOLOGY

Steps in introduction of TPM in a organization

Step A - PREPARATORY STAGE :

STEP 1 - Announcement by Management to all about TPM introduction in the organization: Proper understanding, commitment and active involvement of the top management in needed for this step. Senior management should have awareness programmes, after which announcement is made to all. Publish it in the house magazine and put it in the notice board. Send a letter to all concerned individuals if required. [3].

STEP 2 - Initial education and propaganda for TPM: Training is to be done based on the need. Some need intensive training and some just an awareness. Take people who matters to places where TPM already successfully implemented. [3]

STEP 3 - Setting up TPM and departmental committees: TPM includes improvement, autonomous maintenance, quality maintenance etc., as part of it. When committees are set up it should take care of all those needs. [3]

STEP 4 - Establishing the TPM working system and target: Now each area is benchmarked and fix up a target for achievement [3].

STEP 5 - A master plan for institutionalizing: Next step is implementation leading to institutionalizing wherein TPM becomes an organizational culture. Achieving PM award is the proof of reaching a satisfactory level [3].

STEP B - INTRODUCTION STAGE: This is a ceremony and we should invite all. Suppliers as they should know that we want quality supply from them. Related companies and affiliated companies who can be our customers, sisters concerns etc. Some may learn from us and some can help us and customers will get the communication from us that we care for quality output. [3]

STAGE C – IMPLEMENTATION: In this stage eight activities are carried which are called eight pillars in the development of TPM activity. Of these four activities are for establishing the system for production efficiency, one for initial

control system of new products and equipment, one for improving the efficiency of administration and are for control of safety, sanitation as working environment [3].

STAGE D - INSTITUTIONALISING STAGE: By all there activities one would has reached maturity stage. Now is the time for applying for PM award. Also think of challenging level to which you can take this movement.

III. EIGHT PILLARS OF TPM

1. FIVE 'S' 5-S
2. AUTONOMOUS MAINTENANCE
3. KAIZEN
4. PLANNED MAINTENANCE
5. QUALITY MAINTENANCE
6. EDUCATION & TRAINING
7. OFFICE TPM
8. SAFETY, HYGIENE AND ENVIRONMENT CONTROL.

1. **PILLAR 1 - 5S :** TPM starts with 5S. Problems cannot be clearly seen when the work place is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement.

JAPANESE TERM	ENGLISH TRANSLATION	EQUIVALENT 'S' TERM
Seiri	Organisation	Sort
Seiton	Tidiness	Systematise
Seiso	Cleaning	Sweep
Seiketsu	Standardisation	Standardise
Shitsuke	Discipline	Self – Discipline

2. **PILLAR 2 - JISHU HOZEN (AUTONOMOUS MAINTENANCE) :** This pillar is geared towards developing operators to be able to take care of small maintenance tasks, thus freeing up the skilled maintenance people to spend time on more value added activity and technical repairs. The operators are responsible for upkeep of their equipment to prevent it from deteriorating.

   POLICY :

   - Uninterrupted operation of equipments.
   - Flexible operators to operate and maintain other equipments.
   - Eliminating the defects at source through active employee participation.
   - Stepwise implementation of JH activities.

3. **PILLAR 3 - KAIZEN:** "Kai" means change, and "Zen" means good (for the better). Basically kaizen is for small improvements, but carried out on a continual basis and involve all people in the organization. Kaizen is opposite to big spectacular innovations. Kaizen requires no or little investment. The principle behind is that "a very large number of small improvements are move effective in an organizational environment than a few improvements of large value. This pillar is aimed at reducing losses in the workplace that affect our efficiencies. By using a detailed and thorough

procedure we eliminate losses in a systematic method using various Kaizen tools. These activities are not limited to production areas and can be implemented in administrative areas as well.

KAIZEN POLICY:

- Practice concepts of zero losses in every sphere of activity.
- relentless pursuit to achieve cost reduction targets in all resources
- Relentless pursuit to improve over all plant equipment effectiveness.
- Extensive use of PM analysis as a tool for eliminating losses.
- Focus of easy handling of operators.

4. **PILLAR 4 - PLANNED MAINTENANCE:** It is aimed to have trouble free machines and equipments producing defect free products for total customer satisfaction. This breaks maintenance down into 4 "families" or groups which was defined earlier.
   - Preventive Maintenance
   - Breakdown Maintenance
   - Corrective Maintenance
   - Maintenance Prevention

   With Planned Maintenance we evolve our efforts from a reactive to a proactive method and use trained maintenance staff to help train the operators to better maintain their equipment.

   POLICY:

   - Achieve and sustain availability of machines
   - Optimum maintenance cost.
   - Reduces spares inventory.
   - Improve reliability and maintainability of machines.

5. **PILLAR 5 - QUALITY MAINTENANCE** : It is aimed towards customer delight through highest quality through defect free manufacturing. Focus is on eliminating non-conformances in a systematic manner, much like Focused Improvement. We gain understanding of what parts of the equipment affect product quality and begin to eliminate current quality concerns, then move to potential quality concerns. Transition is from reactive to proactive (Quality Control to Quality Assurance).

   QM activities is to set equipment conditions that preclude quality defects, based on the basic concept of maintaining perfect equipment to maintain perfect quality of products. The condition are checked and measure in time series to very that measure values are within standard values to prevent defects. The transition of measured values is watched to predict possibilities of defects occurring and to take counter measures before hand.

   POLICY:

   - Defect free conditions and control of equipments.
   - QM activities to support quality assurance.
   - Focus of prevention of defects at source
   - Focus on poka-yoke. (fool proof system)
   - In-line detection and segregation of defects.
   - Effective implementation of operator quality assurance.

6. **PILLAR 6 - TRAINING :** It is aimed to have multi-skilled revitalized employees whose morale is high and who has eager to come to work and perform all required functions effectively and independently. Education is given to operators to upgrade their skill. It is not sufficient know only "Know-How" by they should also learn "Know-why". By experience they gain, "Know-How" to overcome a problem what to be done. This they do without knowing the root cause of the problem and why they are doing so. Hence it become necessary to train them on knowing "Know-why". The employees should be trained to achieve the four phases of skill. The goal is to create a factory full of experts. The different phase of skills are
   - Phase 1 : Do not know.
   - Phase 2 : Know the theory but cannot do.
   - Phase 3 : Can do but cannot teach
   - Phase 4 : Can do and also teach.

   POLICY :
   - Focus on improvement of knowledge, skills and techniques.
   - Creating a training environment for self learning based on felt needs.
   - Training curriculum / tools /assessment etc conductive to employee revitalization
   - Training to remove employee fatigue and make work enjoyable.

TARGET :

- Achieve and sustain downtime due to want men at zero on critical machines.
- Achieve and sustain zero losses due to lack of knowledge / skills / techniques
- Aim for 100 % participation in suggestion scheme.

7. **PILLAR 7 - OFFICE TPM :** Office TPM should be started after activating four other pillars of TPM (JH, KK, QM, PM). Office TPM must be followed to improve productivity, efficiency in the administrative functions and identify and eliminate losses. This includes analyzing processes and procedures towards increased office automation. Office TPM addresses twelve major losses. They are
   - Processing loss
   - Cost loss including in areas such as procurement, accounts, marketing, sales leading to high inventories
   - Communication loss
   - Idle loss
   - Set-up loss
   - Accuracy loss
   - Office equipment breakdown
   - Communication channel breakdown, telephone and fax lines
   - Time spent on retrieval of information
   - Non availability of correct on line stock status
   - Customer complaints due to logistics
   - Expenses on emergency dispatches/purchases

8. **PILLAR 8 - SAFETY, HEALTH AND ENVIRONMENT:**

TARGET:

- Zero accident,
- Zero health damage
- Zero fires.

In this area focus is on to create a safe workplace and a surrounding area that is not damaged by our process or procedures. This pillar will play an active role in each of the other pillars on a regular basis.A committee is constituted for this pillar which comprises representative of officers as well as workers. The committee is headed by Senior vice President (Technical). Utmost importance to Safety is given in the plant. Manager (Safety) is looking after functions related to safety. To create awareness among employees various competitions like safety slogans, Quiz, Drama, Posters, etc. related to safety can be organized at regular intervals [05].

The function of Fire & Safety department is to reduce losses in terms of Machine, Men, Material and Environment because of fire, accident, near miss incident, dangerous occurrence and disaster by assisting in development of safe/ suitable working environment, adopting established procedure for critical and emergency operation, giving necessary guidance to PLANT and contractor employees and tackling the emergency situations in shortest possible time.Two wings carry out above activities : (1).Fire Protection Wing, and (2).Safety Wing.

GENERAL SAFETY RULES OF BARAUNI REFINERY:-

- No match box/lighter/mobile phone/two wheeler is allowed in the Refinery.
- Smoking is not allowed in the Refinery except at designated places.
- No one is allowed in battery areas of the Refinery with loose clothing and without shoes.
- No one is allowed in battery areas of the Refinery without helmet with chinstrap in place.
- No vehicle is allowed in the Refinery without approved spark arrestor fitted in the exhaust pipe.
- Vehicle should follow the speed limit of 25 Km/Hr inside the Refinery.
- No visitor is allowed inside any operational plant/unit area without the permission of the Area-in charge.
- No photography/videography is allowed without permission.
- No maintenance work should be started without proper work permit & clearance
- Separate permission should be taken for working inside confined place and working at height. Separate permit also
- to be taken for excavation work, radiography and the area must be barricaded.
- Use safety belt if you are working above 2 Meters from ground level.
- Do not walk on pipelines or false ceilings.
- Do not stand below suspended load or under the boom of a crane while it is in use
- Do not tamper with fire fighting equipment and do not use fire hydrant water other than fire fighting.
- Report all sub-standard conditions/acts, incident/accidents to the Area in charge/Shift in charge and fire & Safety
- Department (Tel no.:333/7777, 301, 5998). Report the same to Fire & Safety section through prescribed format.

- In case of toxic gas release, assemble at designated locations i.e. assembly points.[20]

IV. THERMAL POWER STATION(TPS)

- Introduction
- Boiler
- Turbine
- De-Mineralised Water Plant
- Steam Generation Plant
- Turbo-Generator Unit
- Cooling Tower

Barauni refinery has its own thermal power station for production of steam and electricity. TPS is very important unit of Barauni refinery. The generated electricity is consumed by refinery, township and site colony. It also takes power from BTPS for emergency need. Thermal energy is converted into electrical energy. Fuel for steam generators comes from AVU units. Steam generated in boilers at high pressure is dropped on turbine blades, which is coupled to the rotor of the generator. The magnetic field in the generator is produced by the Exciter. As per the right hand rule, electricity is produced is produced. Some salient features of TPS (CPP), Barauni refinery are following :

- There are four Russian boilers and a new boiler of IJT Company Ltd. being installed. All are water tube boilers.
- It has two Russian turbo generators TG-1 & TG-2 each of capacity 12 MW and one Indian turbo generator made by BHEL, Hyderabad of capacity 12.5 MW.
- Water is treated in DM plant after artesian well storage for steam generation in boilers.
- Circulation water is cooled in Cooling Tower system.
- Circulating water is used to cool the turbine.
- It has two Gas Turbines of capacity 20 MW each.
- Steam is delivered to various units like Turbine, Processing on their demand pressure and quality.

BOILER:-Boiler is a stem generating unit used for producing, furnishing and recovering heat together with the apparatus for transferring the heat, so made available to the fuel being heated and vaporized. There are five boilers in the refinery out of which four are Russian made while the fifth one is Isaac John Thompson (IJT): IWT 6001. The four Russian boilers have combined chimney and a common header. Fuel is furnace oil and refinery gas.[1]

Types of boilers:-Boilers are mainly classified into two classes :

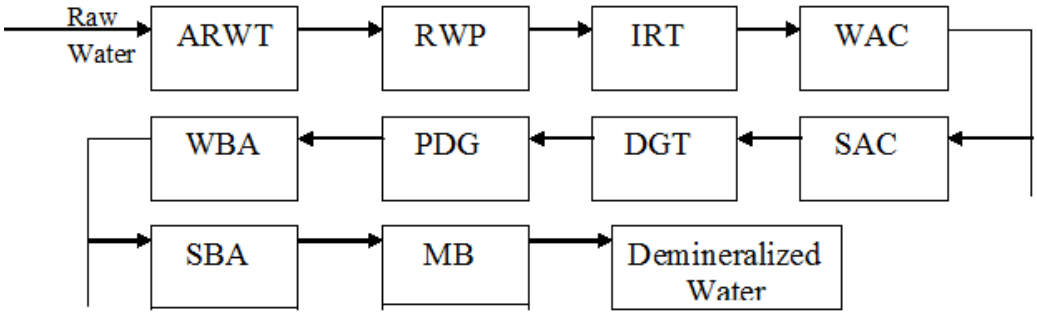
1. Smoke tube boiler
2. Water tube boiler

TURBINE

There are total five turbines in the Thermal Power Station. Three steam turbines and two gas turbines are there. Two steam turbines are Russian made while one TG-3 is made by BHEL, Hyderabad. The two Gas turbines are made by GE (General Electric).[1]

DIMNERALISED WATER PLANT

DM plant takes raw water from artesian well and removes mineral present in it to supply pure distilled water.
A block diagram showing different water treatment processes is shown as :



Where :
ARWT = Aerated Water Tank
RWP = Raw Water Pump
IRT = Iron Removal Tank
WAC = Weak Acid Cation Exchanger
SAC = Strong Acid Cation Exchanger
DGT = Degassed Tank
DGP = Degassed Pump
WBA = Weak Base Anion Exchanger
SBA = Strong Base Anion Exchanger
MB = Mixed Bed

COKER UNIT:- From the operational point of view the Delayed Coker unit is divided into following sections

- Feed Handling and Preheat
- Furnace
- Coke chamber
- Quench column
- Fractionator and Strippers
- Quench, Flushing & Instrument Purge Oil System[20].

Barauni Expansion Project(Bxp):- The main section of BXP are given as

- RFCCU
- CRU
- DHDT
- HGU
- SRU[20]

Residue Fluidised Catalytic Cracking Unit(Rfccu):-The main product of cracking reaction in a fluid catalytic cracking (FCC) reactor are-

- Absorber Gas
- Liquified Petroleum Gas (LPG)
- Heavy Naptha
- Light cycle Oil (LCO)
- Heavy cycle oil (HCO)
- Slurry oil[20]

Catalytic Cracking Unit(Cru):-To get motor spirit of low lead and high octane number, the Catalytic Reformer Unit is setup at Barauni Refinery in 1990. The plant is having following facilities:

- Naphtha Splitter Unit
- Naphtha Hydro – Treater Unit
- Catalytic Reformer Unit
- Feed and Hydro-Treated Naphtha Storage Facility
- Circulating Water Facility.
- Compressed Air & PSA system
- Hydrogen Storage & Un-loading Facility.
- Flare System[20]

Diesel Hydrotreatment Unit(Dhdt):-Petroleum fraction contains various amount of naturally occurring contaminants including organic sulfur, nitrogen, and metals compounds.The hydrotreater unit is designed to improve the Diesel cetane number to 48.5(min) while meeting the diesel stability specification of 1.6 mg/100ml(max) and reducing sulfur content to 0.2wt%. Future provisions are considered in this unit to produce HSD of cetane no.51 and further reduction of sulfur content to 0.05wt%. The two features of Hydro treating Process and refining reactions.The desired degree of hydro treating is obtained by processing the feedstock over a fixed bed of catalyst in the presence of large amounts of hydrogen at temperatures and pressures dependent on the nature of the feed and the amount of contaminant removal required [20,21].

Hydrogen Generation Unit (Hgu):-A Hydrogen Unit with a nominal capacity of 34,000 metric tones per annum of hydrogen is included in the processing scheme of Barauni Refinery. The primary objective of the Hydrogen Unit is to

produce hydrogen of 99.9-vol % purity to meet the hydrogen requirement of the Hydro treating Unit. The main sections of HGU are: -

- Hds Section
- Reformer
- Mt Shift Section
- PSA Section[20,23]

Sulphur Recovery Unit(Sru):-The purpose of this unit is to receive H2S from ARU and SWS and convert it to elemental Sulphur using clause reaction, followed by super clause reaction. This liquid Sulphur is converted to solid form in the Sulphur yard. The Sulphur Recovery Unit (Unit 706) in Barauni Refinery consists of two trains 706-1 (Train 1) & 706-2 (Train 2) of 40 MT/day capacities each with 10 % design margin. The guaranteed turndown for SRU is 30 % (or 13.3 MT/day) based on the design base case feed gas rate (110 %) and12 composition as given below. The feed gas to SRU is a mixture of the "Acid Gas ex ARU" and the "Sour Gas ex SWSU". Each train in designed for 2738 kg/hr of feed [20,21,23].

V. RESULT & CONCLUSION

TPM has keeping on all equipment in top working condition to avoid breakdowns and delays in the manufacturing process and power plant. Today, with competition in industry at an all time is high; TPM may be the only thing that stands between success and total failure for some companies. It has been proven to be a program that works. It can be adapted to work not only in industrial plants, but in construction, building maintenance, transportation, and in a variety of other situations. Employees must be educated and convinced that TPM is not just another "program of the month" and that management is totally committed to the program and the extended time frame necessary for full implementation. If everyone involved in a TPM program does his or her part, an unusually high rate of return compared to resources invested may be expected. Total quality management (TQM) and total productive maintenance (TPM) are considered as the key operational activities of the quality management system. In order for TPM to be effective, the full support of the total workforce is required. This should result in accomplishing the goal of TPM: "Enhance the volume of the production, employee morale and job satisfaction. I have done the work on TPM in Power Inframech Pvt. Ltd. Jamshedpur as well as other industries like IOCL Barauni Refinery Begusarai and ITC Munger.

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