POLYDADMAC – AN EMERGING SOLUTION TO CONTROL IMPACTS OF COLLOIDAL SILICA IN BOILER CYCLE OF POWER PLANTS

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1.0 FOREWARD:

NTPC Ltd has been a pioneer in the power sector and has led from the front in boosting the power growth of our country. With its pace in capacity addition and assured uninterrupted & reliable power generation from its older units, NTPC Ltd, a Maharatna PSU has set benchmark for its private players / competitors not only in India but globally also. In present scenario of competitive market, generation cost is to be competitive enough to get schedule for generation for which generator has to make its processes not only efficient but reliable too. It is now vital for stations to improve its processes by adopting latest technologies in design phase itself so as to reduce the operating cost of generation.

Water being an essential resource for life, sustainable growth and healthy ecosystems, water has been high on the industrial requirement. The water requirement for industries especially power sector is substantial high and in many cases the power plants are not able to get the desired quantum of fresh water due to limitation of fresh water availability in the water courses. ***Further the practices of dumping the municipal sewage and industrial waste into the river bodies has worsen the water quality by polluting the fresh water resources. This pollution load is forcing industries to continuously revamp its processes & technology upgradation is becoming the need of the hour.*** Presently continuous R&D in industrial market is bringing variety of water treatment technologies but the cost implications is lagging it to materialize, as the technology cost is increasing the ECR merit order rating of industry thereby making it unviable.

This degradation of fresh water quality is cascading water related problems in critical processes of power plants thereby having significant impact on the availability & efficiency of power plant. De mineralized water is one of the key input resource required in boilers and its quality directly impacts the boiler cycle efficiency. Any unwanted impurity [like silica, chloride] in boiler cycle beyond desired limits has significant potential to damage the boiler tubes and turbine components. Hence effective treatment of raw water in Pre Treatment plant or at Demineralization plant is the essence of good power plant chemistry. Colloidal silica is one of key impurity which if not controlled in pre treatment plant can severely affect the boiler cycle chemistry.

Water chemistry is one of the key operational criteria's in any power plant. With the aging of the power plants, to maintain good & effective water chemistry is always a challenge. ***Any compromise in water chemistry parameters in any of process parameters can lead to severe damage to the system resulting in unavailability of the plant and lowering of declared capability of power plant***. This ultimately affects the plant merit order rating and yearly targets & performance.

This paper provides an insight into impact of Colloidal Silica in boiler cycle chemistry, methodology to control colloidal silica using polyDADMAC in pre treatment plant. A case study on "Controlling the issue of Colloidal silica using polyDADMAC and improving the Boiler Cycle chemistry parameters at Mouda Stage – I" is a part of paper to understand the emergence of polyDADMAC to control Colloidal Silica problems in power plants.

2.0 WATER CHEMISTRY & ITS IMPORTANCE IN POWER PLANTS:

Water chemistry is one of the key operational criteria's in any power plant which directly impacts the efficiency of the power plants. The water chemistry in power plants needs to be maintained as per design control limits so as to ensure efficient operation of machine. ***Any compromise in water chemistry parameters in any of process parameters can lead to severe damage to the system resulting in unavailability of the plant and lowering of declared capability of power plant.*** This ultimately affects the plant operational yearly targets & performance. With the present scenario of machines with supercritical operating regime, importance of chemistry parameters has emerged as guiding factor right from permitting good quality steam entering into turbine to optimized water chemistry in oxygenated treatment mode.

As all supercritical & ultra supercritical units are drum less units, hence the feed water quality entering to boiler plays a critical role in achieving the boiler operating regime in optimum time period. Any impurity seepage into the boiler will be carried over directly to turbine in once through mode. Being drum less units, there is no option to give blow down to control the main steam parameters. Hence, the pre treatment and DM Plant operational performance has to be closely monitored to ensure impurities like colloidal silica, TOC are effectively controlled and are not carried over to the boiler cycle.

Colloidal silica is one of such impurities which are curse to the high pressure boiler cycle chemistry. Colloidal silica is a non-ionic and is typically found in surface waters. It creates problem in water treatment because of its stability as anunionised compound, which makes it difficult to remove using conventional ion exchange processes. It can even cause some resin fouling where colloidal silica levels are exceedingly high. It is essential to remove colloidal silica from water to be used in high pressure boiler operations. Colloidal silica slips through DM plant to get converted into reactive silica at high temperature and pressure leads to heavy blow down and low load operations which ultimately causes energy losses.

The problems with colloidal silica becomes acute during rainy season. In 660 & 800 MW units, colloidal silica carry over through make up to boiler will be a troublesome as there are chances of its carry over along with steam to turbine. ***Data collected from power stations shows that about 55 % of the stations faced the problems of colloidal silica out of which 30% of the stations are facing the problem almost every year while 25% have faced the problem once or twice.***

Hence proper treatment to control colloidal silica has become the need of the hour for stations which are facing high colloidal silica in raw water. The selection of suitable technology to control the colloidal silica is very crucial in present scenario as it should be cost effective on one hand and environment friendly as well.

3.0 IMPACTS OF COLLOIDAL SILICA IN BOILER CYCLE

Presence of colloidal silica in raw water impacts the power plant processes either by existing in same form or converting into different form under the impact of process temperature or pressure. Let us try to understand the properties of colloidal silica and its effect on process parameters.

3.1 COLLOIDAL SILICA

Before exploring the colloidal silica, we must understand colloids. Colloids or colloidal solution is a substance in which one substance of microscopically dispersed insoluble particles is suspended throughout another substance. The dispersed substance is known as colloid which have diameter of between 1 and 1000 nanometre. Colloidal silica is a suspension of fine amorphous, non-porous, non-ionic and typically spherical silica particles in a liquid phase.

Mostly colloidal silica particles are with size raging between 2 and 100 nm in diameter. Colloidal silica has the same chemical formula as quartz sand i.e SiO_2. Colloidal silica being non-ionic is also termed as non-reactive silica as it has less affinity to reacts with other chemicals. This is the reason why measurement of colloidal silica itself is a challenging job. The colloidal silica needs to be converted to reactive silica for its measurement.

3.1.1 IMPACT OF COLLOIDAL SILICA

Colloidal silica if not trapped & removed in pre-treatment plant, gets carried over to DM water as it is not exchanged in ion exchanger units of DM Plant. Colloidal silica as such does not affect the ion exchange process but as it forms a complex with organic matter, it can sometimes foul the anionic resin and some part of it then passes through the resin and reaches downstream equipment to the DM water storage tanks. This DM water carrying colloidal silica further reaches the boilers as cycle make up. In 500 MW units, in the boiler drum, colloidal silica is converted into reactive silica due to the high temperature and pressure conditions present in the boiler drum. Thus the colloidal silica converted reactive silicagets added to the inherent reactive silica present in the DM water and boosts the silica level in the boiler drum. Hence, boiler blow downs need to be opened to control the drum silica levels as per boiler drum pressure restrictions. A typical drum water silica v/s drum pressure curve is shown at Exhibit – 1.

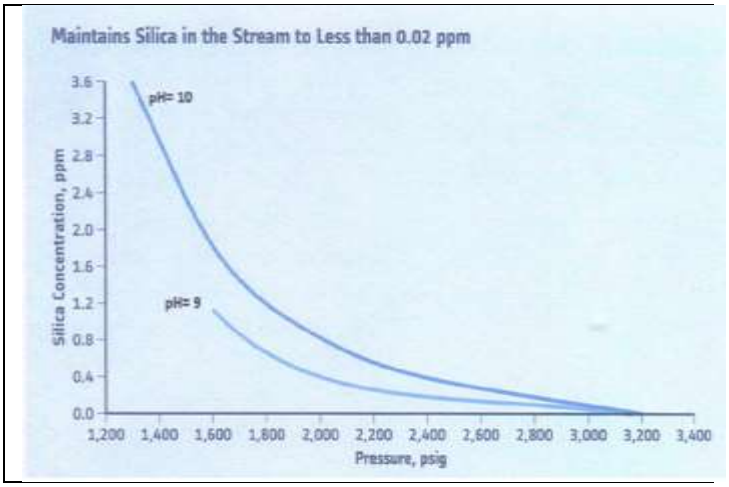


Exhibit –1

The situation is very grim in super & ultra super critical boilers, as colloidal silica will be converted to reactive silica in water wall tubes and beyond super critical pointof i.e in dry mode operation of unit, there are significant chances that silica will be carried over directly along with steam to turbine depending on the unit operating temperature and pressure. Hence in super & ultra super critical units, suitable pre-treatment of raw water and demineralization unit i.e CPU in condensate cycle is critical to maintain boiler silica levels within operating regime.

In drum type units, continuous boiler blow downs needs to be operated as silica tends to volatilize along with steam at high pressure & temperature and gets carried over along with the stream to the turbine blades. The silica so reached along with the steam gets deposited on the turbine specifically on Low pressure turbine blades and leads to failure of turbine blades. A typical silica deposits on turbine blades is shown in Exhibit - 2

Exhibit – 2

4.0 CASE STUDY – "CONTROLLING THE ISSUE OF COLLOIDAL SILICA USING POLYDADMAC AND IMPROVING THE BOILER CYCLE CHEMISTRY PARAMETERS AT MOUDA STAGE – I"

At NTPC – Mouda, the requirement of raw water is met from weinganga river at upstream of Gosikhurd dam, for which NTPC has set up makeup water pump house at a distance of approx. 30 KM from plant at Pimpri. At approx. 5 – 6 Km upstream of pimpri pump house, Nag river which carries the domestic & industrial waste of Nagpur city meets the weinganga river and adds biological load in the water body. The impact of this biological load is less in monsoon & post monsoon season, but poses a major challenge in spring & summer season when the raw water quality is worst in terms of ionic load and biological load..The raw water of Mouda carries significant amount of colloidal silica as shown in various water samples analyzed at NETRA lab as per Exhibit – 3.0

Sample	Total Silica (ppm)	Reactive Silica (ppm)	Colloidal Silica (ppm)
Raw Water	26.9	15.5	11.4
Clarified Water-1	21.5	15.0	6.5
Clarified water-2	26.5	16.8	9.7

Exhibit 3.0

The colloidal silica as per exhibit 3.0 is sufficient to carry over from DM Plant to boiler cycle and affect the boiler parameters.

4.1 VARIOUS IMPACTS OF COLLOIDAL SILICA ON WATER SYSTEM EXPERIENCED BY NTPC – MOUDA INCLUDES;

- **High cycle Make up**
  - Colloidal silica is not effectively removed in pre – treatment plant& DM Plant.
  - Carryover of colloidal silica from DM Plant to boiler drum. Hence blow down is given to maintain drum silica as per drum pressure curve**,** resulting in high cycle make up consumption
- **Heat loss due to continuous CBD operation**
  - CBD is being opened to maintain drum silica levels as per DP curve, which was resulting in huge heat & efficiency loss of boiler in both units.
- **Difficulty in achieving boiler cycle chemistry parameters of silica**
  - Colloidal silica gets converted to reactive silica at high temp & pressure in boiler cycle and drum silica was maintaining in the range of 100 – 250 ppb.
- **Reduced Output of DM Plant**
  - As silica has increased in raw water and is the controlling factor in calculation of output between regeneration (OBR), the OBR of DM Plant has also reduced.
- **Requirement of 100 % CPU operation**
  - To maintain drum silica levels , we have to keep both CPU vessels in service against design of 50 % CPU operation. This was resulting in frequent regeneration of CPU and increased chemical cost.
- **Delay in Unit Light Up**
  - Unit light up was occasionally getting delayed as Main steam was taking more time to achieve desired purity levels and continuous steam dumping was required resulting in loss of water, heat and fuel.
- **Turbine deposits**
  - Minor deposits of silica are also observed in turbine during overhaul [as per NETRA turbine deposit analysis report]

4.2 DEVELOPMENT OF SOLUTION

A team comprising of representatives of NETRA, Engg, OS – Chemistry & Site suggested following methodologies to overcome the problem of colloidal silica .

- **Use of selective imported SBA Resin:-** Lab trial run of using Purolite SBA resin at NETRA indicated significant reduction in colloidal silica and TOC content. Based on this, a pilot study of using Purolite SBA resin was carried out in one DM stream to assess the actual performance of this selective resin in controlling the colloidal silica and TOC in DM Plant. There was marginal reduction in colloidal silica in Purolite SBA resin, however no improvement in TOC control.

- **Pilot study of Membranes**:- As membrane based technology is a proven & highly effective in reducing the colloidal particles like silica and removing bacteria / virus & TOC constituents, pilot study using UF + RO membranes was also reviewed, but it is associated with high capital & operating cost.

- **Use of Poly DADMAC based polyelectrolyte:**- Site was already using Alum (Approx 40 ppm) & PAC (approx 40 – 60 ppm) in clarifiers, however to further control the colloidal silica, Jar tests were carried out at site using a new Poly electrolyte (Liquid Poly DADMAC) at different dosing rates [optimized at 5 – 7 ppm] in combination with Alum & PAC and results are as mentioned in Exhibit – 4.0

S No	Alum dosage	PAC Dosage	Total Silica (ppm)	Reactive Silica (ppm)	Colloidal Silica (ppm)
1	40 ppm	40 ppm	14.5	11.6	2.9
2	40 ppm	50 ppm	14.0	12.3	1.7
3	**40 ppm**	**60 ppm**	**12.8**	**11.3**	**1.5**
4	40 ppm	70 ppm	13.0	11.5	1.5
5	40 ppm	80 ppm	13.3	11.8	1.5
6	50 ppm	40 ppm	15.4	12.2	3.2
7	60 ppm	40 ppm	15.5	12.5	3.0
8	70 ppm	40 ppm	15.5	12.3	3.2
9	80 ppm	40 ppm	15.6	12.4	3.2

Exhibit – 4.0

As is evident from Exhibit – 4.0, a combination of 40 ppm alum + 60 ppm PAC + 5 – 7 ppm of poly DADMAC was quite effective in controlling the colloidal silica. ***polyDADMAC is not new to industrial water treatment application, but has been emerged as one of the popular and acceptable choice among industrial segment to control Colloidal Silica in pre treatment plant.*** Although UF + RO membrane and ion selective resin based technologies are also adopted by industries across the globe which have claimed to be quite effective in controlling the colloidal silica, however the capital and operational cost of these technologies have pulled them behind the chemical based control of colloidal silica using polyDADMAC.

4.3RESULTS ACHIEVED

Based on lab based Jar test results,40 % active content polyDADMAC dosing was initiated in CW Clarifierfor DM plant. One CW clarifier [with larger capacity] was dedicated for DM plant to increase the retention time in clarifier and improving the clarification process to reduce colloidal silica carry over to DM Plant.

PolyDADMAC dosing in CW Clarifier inlet channel

After continuous dosing of polyDADMAC, following improvements were observed in various systems;-

- Improvement in Clarifier water quality [Exhibit – 5.0].
- Significant reduction in drum silica levels achieved. With unit at base or part load operation, the drum silica levels which were earlier maintaining in the range of 150 – 300 ppb has reduced to less than 100 ppb.
- Opening of blow down from drum has reduced significantly. Earlier continuous blow down @ 10 – 20 % were opened to maintain drum silica levels. Now drum silica levels are maintained less than 100 ppb without any blow down from drum.
- DM cycle make up consumption has reduced by approx 20 % in view of reduction in CBD openings.
- Operational life cycle of CPU vessel has increased with single CPU in operation.
- Regeneration Chemical consumption has reduced in DM Plant and CPU.
- Steam purity clearance time requirement during unit start up has reduced.
- Improvement in Boiler cycle chemistry parameters [Reduction in ACC of boiler cycle to less than 0.1 uS/cm]

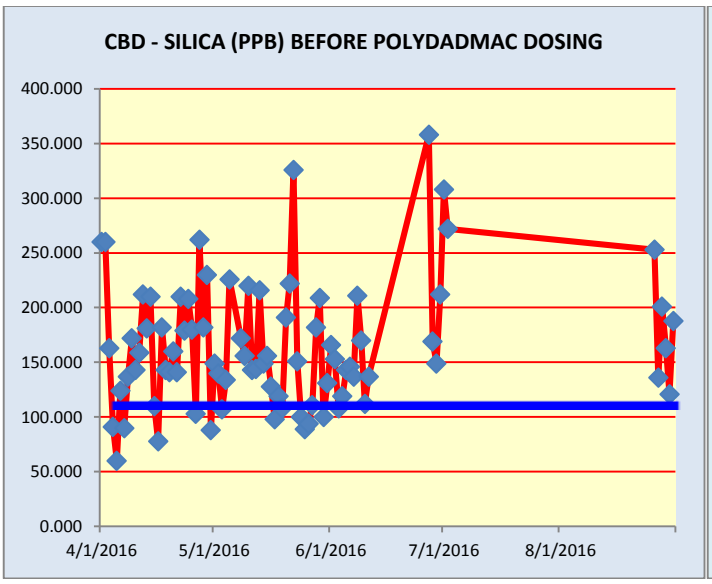
Improvement in CW Clarifier water quality after polyDADMAC dosing

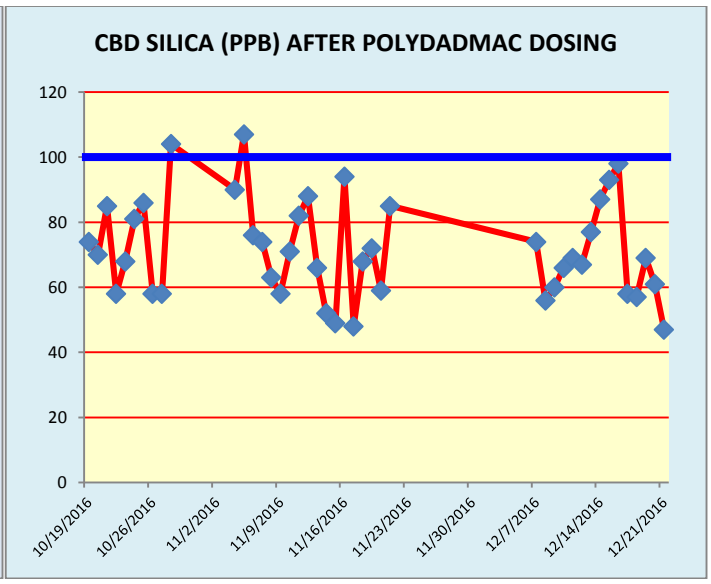
Consistent reduction in Clarifier & Filtered water Turbidity and Drum Silica achieved after polyDADMAC Dosing is shown in table at Exhibit -5.0

Date	Time (Hrs)	Clarifier -1 Turbidity (NTU)	Filtered water Turbidity (NTU)	U # 1 Load (MW)	U # 1 Drum Silica (ppb)
LIMIT		**10**	**2**		**100**
19.10.16	11:00	2.35	0.83	501	85
19.10.16	15:00	2.23	0.65	434	74
20.10.16	11:00	2.74	0.73	494	64
20.10.16	15:00	2.66	0.79	498	70
21.10.16	11:00	1.35	0.65	499	79
21.10.16	23:00	2.1	0.43	467	65
22.10.16	11:00	2.72	0.86	479	58
22.10.16	23:00	2.0	0.39	470	50
23.10.16	11:00	1.43	0.45	502	58
23.10.16	15:00	1.48	0.56	500	68
24.10.16	11:00	2.1	0.68	503	63

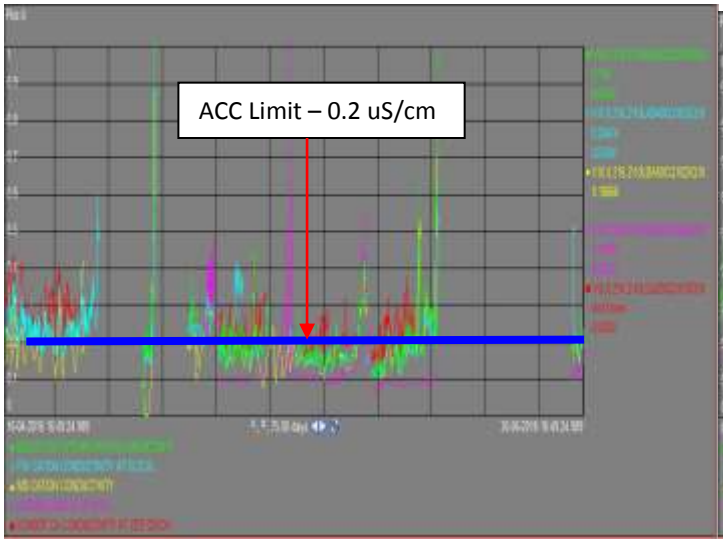
Exhibit – 5.0

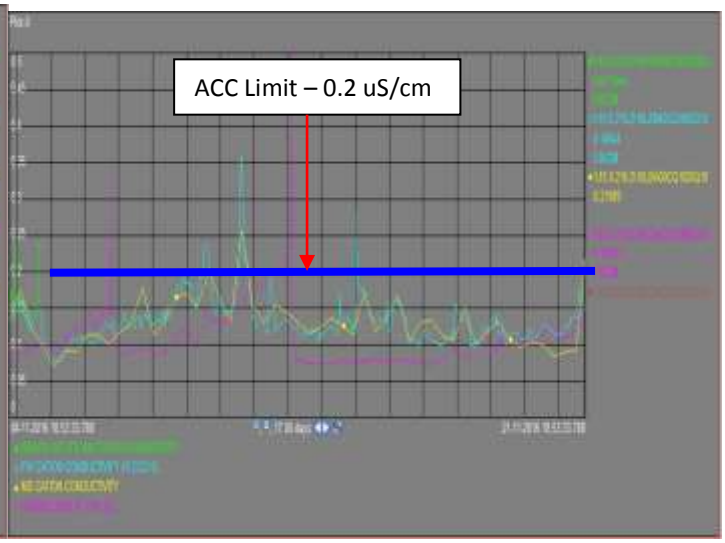
Boiler Drum Silica Levels before and AfterpolyDADMAC dosing comparison Graphs





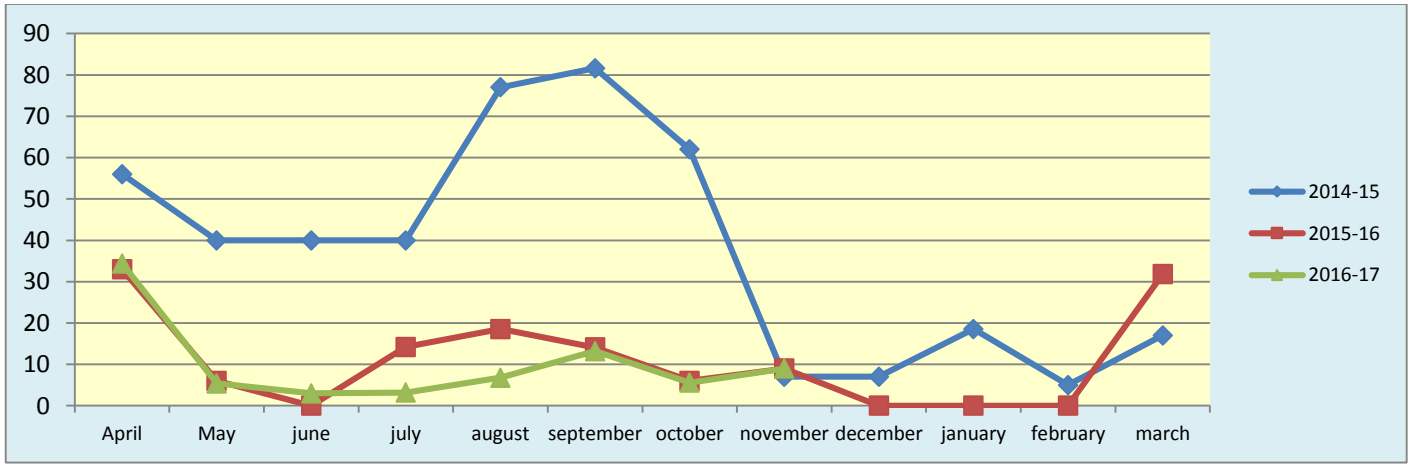
Improvement in ACC in Boiler Cycle Chemistry before and AfterpolyDADMAC dosing comparison Graphs





ACC Before Dosing ***ACC After Dosing***

Reduction in CBD Opening Hours in 2016-17 after dosing of polyDADMAC



5.0 CONCLUSION

NTPC being a leader in the power generation sector in India has been a role model in every aspect for its competitors. However to sustain in unfavorable market scenario of less schedule with part load operation of many of its units, NTPC has to revisit its strategies and approachesby putting more focus on reducing the O&M cost by improving the efficiency of various processes of its units. ***The measures suggested in the paper to use polyDADMAC chemical in pre treatment plant can definitely contribute in mitigating the colloidal silica issues in PT Plant and avoid its carry over through DM water to boiler cycle. These measures will improve the boiler efficiency by reducing the heat loss through CBD openings and also reduction in cycle make up water consumption. For plants having high colloidal silica in raw water and with super or ultra super critical units, polyDADMAC will be an innovative & sustainable solution to operate units effectively with controlled chemistry regime.***

In line with above, based on colloidal silica contents in raw water of new & existing units, NTPC should review & recommend the usage of polyDADMAC chemical for controlling the colloidal silica in pre treatment plant and necessary dosing systems can be engineered in design phase itself for upcoming units. polyDADMAC is an cost effective and environment friendly chemical for controlling the colloidal silica in pre treatment plant to meet the desired boiler cycle chemistry parameters. The measures taken up at NTPC Mouda will contribute significantly in improving the operational boiler efficiency, reducing the O&M cost and raising the merit order rating of NTPC Mouda units, thereby facilitation of NTPC company in leading the power sector with growth in a sustainable manner.

6.0 ACKNOWLEDGEMENT:

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