Study And Performance Analysis of Electro Static Precipitator In 210 MW Mettur Thermal Power Station – I

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Abstract- *Emissions standards are becoming more stringer, as a result new retrofit/technique are being applied in the existing power plant in India. Electrostatic precipitators (ESP) are used to control fly ash emitting from the boilers of the power plants. The coals burned in power plant in India to generate the power are characterized by low calorific value (3500-4500) Kcal/Kg., and high ash content (35-45) %. Thus compared to U.S and European coals, Indian coal generates about 6 to 7 times more ash for collection for similar electricity generation. Besides low sulphur content (<0.5), result in the resistivity of fly ash being 100-1000 times higher than that generated elsewhere. Thus ESP's in India, despite being much larger, have lower collection efficiencies than the ESP's in U.S/Europe. In this paper we discuss some methods which are being applied in different power plants in India to improve the collection efficiencies of ESP.*

Keywords- Electro Static Precipitator, Performance, Mettur Thermal Power Station – I, Ammonia spray.

I. INTRODUCTION

The availability of electrical energy and it's per capital consumption is regarded as an index of national standard of living in present day civilization. The flourishing power generation industry is a sigh of growing gross national products which reflects prosperity of the people. Energy has become synonyms with progress. Therefore the energy is considered a basic input for any country for keeping the wheels of its economy moving. Next to food the fuel power are the most important items on which national standard of life depends. Therefore every stride has been made to increase the power potential of the nation once the requirement of the food is fulfilled. The production of food also increases with an increase in power. Therefore, the increase in power potential of nation is considered most important among all. The energy in the form of electricity is most desired as it is easy to transport, easy to control, clean in its surroundings and can be easily converted of electricity in the total energy of consumption of country shown a consistent increase in the past year. As the requirement of electricity power is increasing the number of power stations.

II. LITERATURE SURVEY

Coal fired power plants provided 45% of electricity needs in developing countries in 2002, which is likely to increase to 47% in 2030. In fact coal reserves are significantly more abundant and more wide widely and evenly dispersed, as compared to other fossil fuels. Oil and gas reserves are more lightly concentrated in Middle East and the Former Soviet Union. Coal is well positioned to make a valuable contribution to global energy security. For meeting the rising demand of electricity to meet the industrial production needs, India, too is making massive investment in Power Sector.

The total installed capacity, which was slightly more than 100,00MW in March 2001, is expelled to reach around 215,000MW in the year 2011-12. The contribution of coal based thermal plants, which is 58% today (2003) is likely to remain significant (53%) in 2011-12 as well, when coal based installed power capacities will reach around 115,000 MW. In order to maintain clean environment in and around the power plants, stringent emission standards are enforced by the Pollution Control Boards for the power plants. In India, there are 83 coals based thermal power plants out of which 4 plants are closed. 55 plants comply with emission standards and 23 plants are yet to comply with emission stands Electrostatic Precipitators (ESPs) are used to control the fly ash emission from the boilers of the plant. The percentage of utility boilers equipped with ESPs in India is 99.5% (320 out of 325). The present emission standards for particle emission for a 210MW or more utility boiler are 150mg/nm³, which is likely to revise to 100 mg/nm³ soon. It is estimated that a sum of Rs 1740 Crore (USD 400 Million) will be require to meet the new emission standards for the existing plant. The design, operation and performance of ESP largely depend on the properties of coal burnt and fly ash generated. The properties of coal used in different plants across the country vary widely. In many of the power plants in India the ash contents of coal are as high as 45% and coal have low calorific value. Thus, compared to US and Australia coals, Indian coal generated about 6 to 7 times more ash for collection for generating a unit kWh of electricity. Besides, low sulphur contents (0.5%) result in resistivity of fly ash being 2 to 3 order of magnitude higher than that generated elsewhere. The higher value of electrical resistivity results in development of back corona even at much lower current densities and generation of sparks at much lower voltages.

As a result the ESPs in India, despite being much larger, has lower collection efficiencies than that used in US/ Europe .The reduction in size (lower capital cost) and improvement in collection efficiencies of ESPs are major challenge for power industries in India. The performance of old ESPs can be improved by taking number of retrofit measures for which systematic studies are required. The results reported in the paper are based on the investigations carried out of at different power plant run by National Thermal Power Plant Corporation (NTPC) India. Source investigations were carried out at BTPS, Delhi. The emissions levels were brought down by using intermittent charging units to power the ESP units. Some results based on the investigation are used here, while more details have been provided elsewhere. Fly ash samples were collected from the different power plants for various conditions of operations (e.g. before and after flue gas conditioning with ammonia etc).The fly ash resistivity measurements for different samples were carried out at ash resistivity measurement laboratory at Centre for Energy studies, IIT Delhi India as per IEEE standard (548-1984 norms). A laser based size particle analyser was used to determine the particle size distribution in various ranges. In the following sections we briefly describe these investigations. It is possible to reduce the emissions from the existing ESP by adopting either or any one of the following methods (i) water fogging (ii) intermittent charging (iii) ammonia dosing (iv) Sodium conditioning of flue before feeding to boiler. While there is limited reduction in emission level due to water fogging, quite appreciable reduction in observed in emission level due to intermitted charging of the fields in ESP. Other method e.g.

Ammonia dosing and Sodium conditioning of fuel hold great promise to reduce the emission levels in significant way. It is possible to achieve emission levels less than 100 mg/Nm^3 in existing power plants in Indian by adopting these methods. SO3 conditioning of flue gases is another promising process but results based on such method are not available in India. An electrostatic precipitator is a large, industrial emission-control unit. It supersedes in many way to the previously used bag filter system and is designed to trap and remove dust particles efficiently and effectively from the exhaust gas stream of an industrial process. Precipitators are used in these industries. (1) Power/Electric (2) Cement (3) Chemical (4) Metals In many thermal power plants, fly ash generated in the coal combustion process is carried as dust in the exhaust gases. These dust laden gases are allowed to pass through an electrostatic precipitator that collects most of the dust. Cleaned gas then passes out of the precipitator and then through a stack to the atmosphere. Precipitators typically collected 99.9% or more of the dust from the gas stream. Precipitator functions by electro-statically charging the dust particles in the gas stream coming out of the boiler after coal combustion. The charged particles are then attracted to and deposited on the collector plates. When enough dust has accumulated, the collectors are hammered to dislodge the dust, causing it to fall with the force of gravity to hoppers below. The dust is then removed by a conveyor, slurry form, vacuum trapped system etc. for disposal or recycling. Depending upon dust characteristics, coal composition (primarily ash content) and the gas volume to be treated, there are many different sizes, types and designs of electrostatic precipitators. Very large power plants may actually have multiple precipitators for each unit.

III. EVALUATION OF ELECTRO STATIC PRECIPITATOR PERFORMANCE

The performance of the E.S.P is evaluation with the ENVIROTECH 620 stack sampler. The result is expressed in milligrams.

Total suspended particles present in flue gas is =2 S.P.M

Suspended particulate matter = (W2-W1) ×10^6/Qm × t

Where,

Q=V× An ×60 ×1000

V-Gas velocity in m/s

An- Area of nozzle, m^2

V-0.55

W_2 = Weight of Thimble after the sampling test.

W_1 = Weight of Thimble after the sampling test.

IV. MATERIALS AND METHODS

As the performance of the E.S.P is not up to the Government Norms. We have suggested some solution to improve the performance of the E.S.P. The solutions are:

- Improving the collection area.
- Providing the Rapping mechanism to very field.
- Reducing the storage time of the dust hoppers.
- To distribute the gas with uniform velocity.
- Spraying Ammonia before the E.S.P.

4.1 Collecting Area

Collection area of the electro static precipitator is based on the no of collecting electrodes and flow rate. Collection area of the electro static precipitator can be calculation below: The Collection area = H× L ×N× 2/V.

Where,
H = Height of the collecting plate.
L = Length of the collecting plate.
N = No. of collecting plate.
V = Flow rate of the gas.

The specific collection area of the E.S.P = 12.5× 0.4 ×5292× 2/ 363.1= 145.7 m^2/pass. The collection area of the E.S.P can be increased by installing the extra collecting electrodes in between the gap in the walk of the E.S.P. Current No. of collecting electrode pre field -49. If No. of collecting electrode is installed as per the suggestion then the extra No. of electrodes will be = 49 × 6 =1 Pass = 49 × 6 × 2 =2 Pass = 588. Now the collecting area of the E.S.P. = 12.5 × 0.4 × 5880 × 2/363.1= 161.9 m^2. Thus collecting area of the E.S.P can be increased by installing the extra collecting electrode inside the E.S.P. By this way be construction and design of the E.S.P no need to change; only the extra electrodes are insulating. The performance of the E.S.P after installing the extra collecting electrodes. If we consider the designing collection are is the 100%. Then the % of collecting area will be 161.9/145.7× 100 = 111.18%. There force the collecting area of the E.S.P can be increased by 11%. Thus by increased the collection area the performance of the E.S.P can be improved.

4.2 Collecting Electrode Rapping Mechanism

The Rapping is the periodic agitation or vibration of the discharge wires and collecting electrodes with hammer called Rappers. Rapping is done with the automatic control device. As the result of rapping dust particles slough away from the electrode. Surface and drop into the collection hoppers. The CERM used in E.S.P at Mettur Thermal Power Station. The field in parallel is connected by a single shaft and the rapping mechanism built on it. By this way the rapping is done on two fields at the same time. If the Rapping mechanism failed due to any reasons the Rapping in the two fields will be stopped. This will decrease the performance of the E.S.P to avoid this problems, collecting electrode rapping mechanism can be adopted for every field. To obtain this the system is not required to change A CERM can be installed at the other end of the shaft. By this way the failure of one rapping mechanism will not affect the performance of the E.S.P. The basic formula for the efficiency of electrostatic precipitator is y = 100 (1 - e^{-k}) Where; y = collecting efficiency, percent k = a factor. Fig.3 shows the graph of y = 100(1 - e^{-k}) and it can be used mine the size ratio of precipitators. For example, how much larger must a tor to be for an efficiency of 99% compared to one for 98%. k for 98% = 3.75 k for 99% = 4.60, So increase in size = 4.60/1.23= 3.75. In other words, it will be 23% larger.

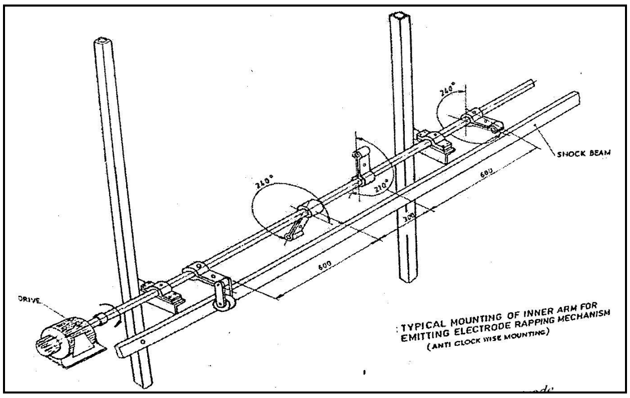


Figure 1 Mechanism used for Rapping of collecting Electrode

4.3 Ash Resistivity

If the combustion is poor it may be that the dust,, will contain an abnormal amount of carbon. The effect of this is to make the dust electrically conductive. Thus, the effectiveness, of the field is reduced and it could result in it being necessary to reduce the power input to the precipitator to prevent flashover from the highly charged dust layer. High resistivity is regarded as more 1×10^{3} ohm cm. Deposition of high-resistance dust on the discharge electrodes has the effect of reducing the corona discharge and so is particularly undesirable. The sulphur content of the fuel plays a key role in determining whether the resistivity of the dust will be high or low. The sulphur burns to sulphur dioxide (SO_2), but a tiny proportion becomes sulphur trioxide (SO_3) as it passes through the furnace.

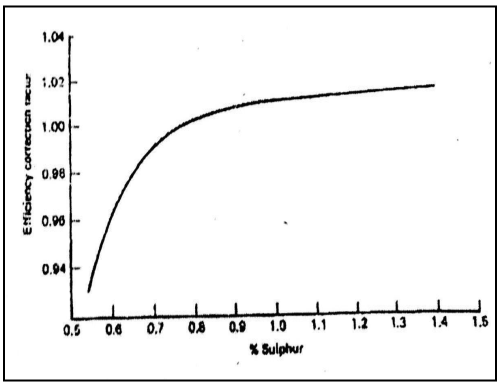


Figure 2 Percentage of Sulphur Curve

4.4 Maintaining the Constant Carrier Gas Velocity

The efficiency of the collector increases with the decrease of gas and decrease with increase of the gas velocity. The ionized particulates follow the path of the resultant of two mutually perpendicular force electrostatic force and gas flow. If the electrostatic force > force exerted by gas flow, the particle will traverse the path AB and get deposited on the collector plate. If on the other hand electrostatic force > force exerted by gas flow, the particle will follow the flow the more curved path AC and escape precipitation. So the gas velocity should be maintained as low. This is to avoid turbulence in the inter electrode space and its hopper. Also limitation of higher gas velocity is imposed by the residence time required for particles charging and collection.

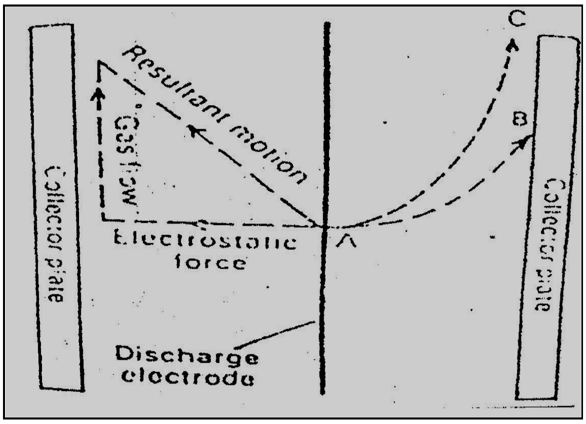


Figure 3 Distribution of Gas velocity

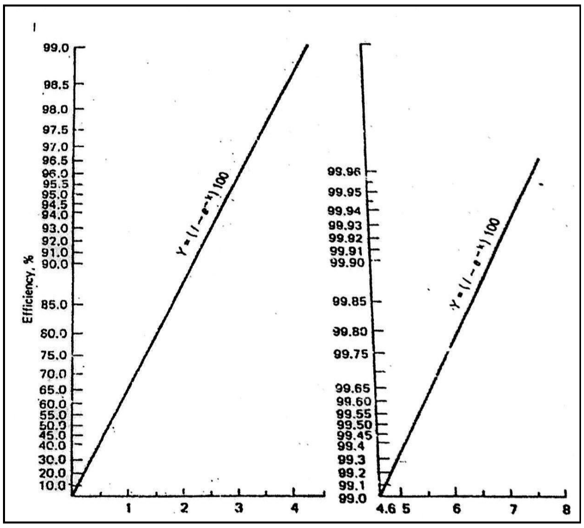


Figure 4 Efficiency curve for ESP

4.5 Spraying Ammonia in Front of E.S.P

In this efficiency is taken in literature papers the particles with higher resistivity will reduce the performance of the E.S.P. This problem can be cured with the help of gas conditioning. Efficiency of E.S.P η=1-exp (-Ws x A/Q). Where, A- Area of plate/wire, Ws- Migration Velocity, Q- Gas Flow Rate, From NTPC Power Station we find, A= Area of the plate=18.55 m^2, Q=Gas flow rate inlet=287.28m^3/s, Ws=Migration velocity of gaseous=59.0m/s, Then, η=1-exp (-59.0 x 18.55/278.28) =98%, Now velocity of the gas can be calculated by the equation, v=Q/A =15.48 m/s, Volume of the precipitator can calculate by, A/V=2/S Where, S is the distance between the two plates. The specific consumption gas rates 0.82ton/MW/hr. It required the electric load 39MW. From the quality parameter of coal we find that, it contains ash will approximately (0.625 i,e. 62.5%). Fly Ash=0.92=92%. Now the inlet dust concentration can be calculated, Inlet dust concentration= 39*1000000*0.82*0.92*0.625)/3600*287.78 17.870gm/m^3. Out dust concentration Dust collection efficiency can be define as —Ratio of difference in the load to inlet load. Dust collection efficiency = (Inlet-Outlet)/Inlet = (17.87*1000-347.78)/17.87*1000 = 98%. To determine the pollutant level in chimney probe is used to take the sample. It was observation that the in sample SPM 350μg/m^3, Sox 165μg/m^3 and NOx155μg/m^3 respectively. But According to Central Pollution Control Board the permissible limit of pollutant in Industrial area are 250μg/m^3, SOx 150μg/m^3 and NO_x 150μg/m^3. So it was cross the permissible limit.

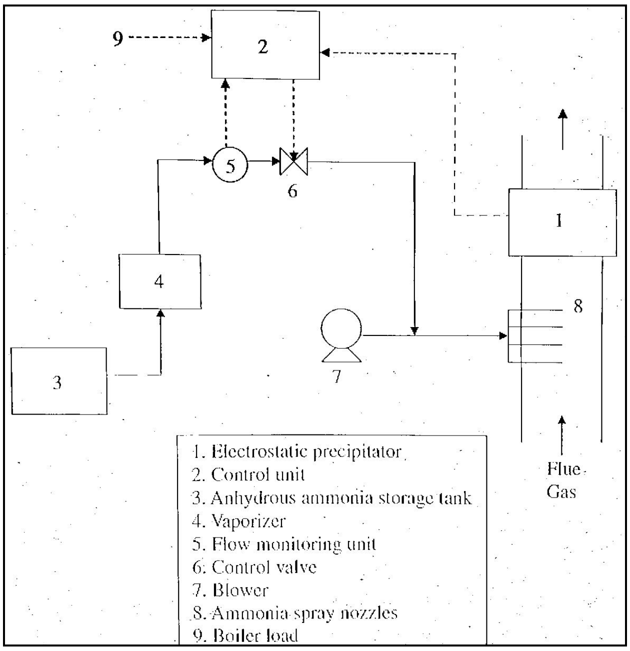
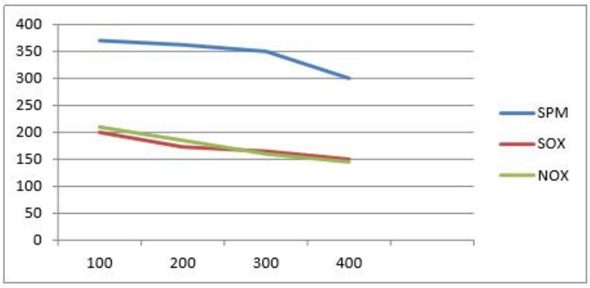
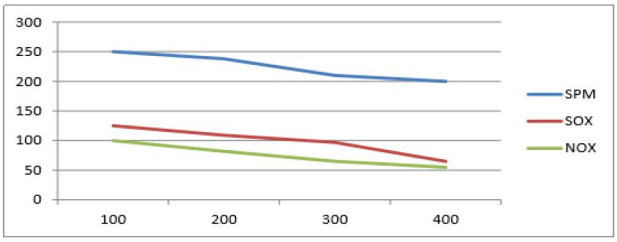


Figure 5 Layout of Ammonia Spray



SPM(mg/nm³)	SOX(mg/nm³)	NOX(mg/nm³)
370	200	210
362	173	185
350	165	160
300	150	145

Figure 6 Pollution level of SO_X and NO_X before Ammonia Spray



SPM(mg/nm³)	SOX(mg/nm³)	NOX(mg/nm³)
250	125	100
238	109	82
210	97	65
200	65	55

Figure 7 Pollution level of SO_X and NO_X after Ammonia Spray

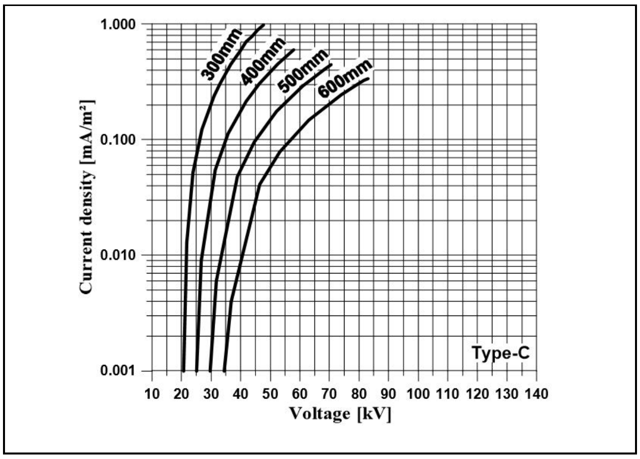


Figure 8 Current density curves for different collector plate thickness

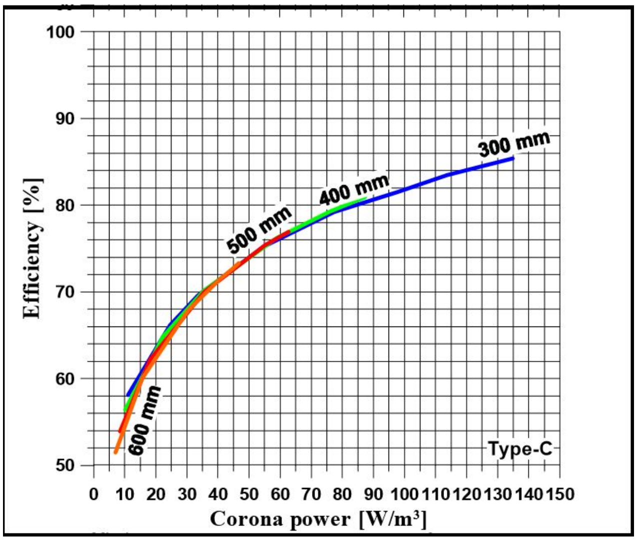


Figure 9 E.S.P efficiency curves for different collector plate thickness

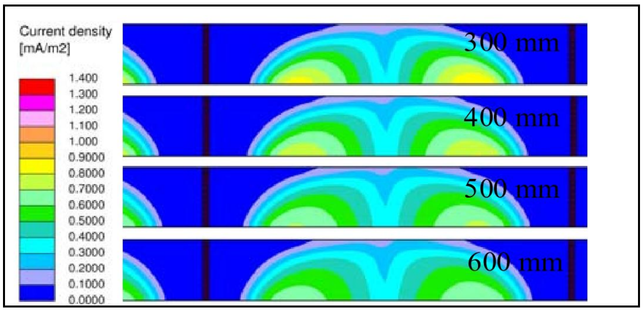


Figure 10 Current density levels for different collector plate thickness

4.6 Gas Conditioning

Gas conditioning is the process of injecting small amount of conditioning agents. Here the conditioning agent is Ammonia. This is used for High-sulpur, coals. Usually ash particles carry some sulphate on their surface. It will increase the performance. Sulphates have higher electrical conductivity and lower electrical resistivity. Hence deposited Sulphates on particulates will lend to better electrical performance in E.S.P. The presence of Sulphate (SO) should be in between the limit, of 10 to 20 ppm. High Sulphur coals will yield a greater amount of SO_3 then that required maintaining resistivity of dust particles below the critical level. The following reaction will be occurring: H_2O $2NH_3$. SO_3 H_2 SO_4 ----- (NH_4) $2SO_4$. This excess SO_3 is absorbed on dust particles and reduces their resistivity below the desired range. Hence ammonia in combination with steam is injected to the flue gas to take care of this excess SO).Steam also added with the ammonia and will be sprayed at the inlet of the E.S.P.

V. CONCLUSION

It is possible to reduce the emission from the existing ESP by adopting either or any one of the following methods improving the collection area. Providing the Rapping mechanism to very field reducing the storage time of the dust hopper. To distribute the gas with uniform velocity spraying ammonia before the E.S.P. Other methods e.g. Ammonia dosing of fuel hold grater promise to reduce the emission levels in significant way. It is possible to achieve emission levels less than 100 mg /mm^3 in existing power plants in India by adopting these methods.

REFERENCES

[1] Arauzo, I., 1996 ―Optimizacion del consumo de auxiliaries de caldera centrales termicas. Chapter 2: Precipitadores electrostatics. Ph.D. Thesis, Mechanical Engineering Department, University of Zaragoza.
[2] ASME, 1964. ―Steam Generating Unit‖ ASME Power Test Codes, PTC 4.1, 1964, reaffirmed in 1974. The American Society of Mechanical Engineering.
[3] Blume, L.F., Boyajian, A., Camili, G., Lennox, T.c., Minneci, S., Monstsinger, V.M., 1951. ―Transformer Engineering. A treatise on Theory, Operation and application of Transformer. 2nd.ed, John Wiley & Sons, 1951.
[4] Chandra A, some investigation on ESP unit: Determination and Improvements of collection efficiency, proceedings 7th International conference on Electrostatic Precipitation, pp 499-507, 1998.
[5] E coal. The quarterly newsletter of World institute Vol54, July 2005. 6. G.A.Kallio, D.E.Stock, Interaction of electrostatic and fluid dynamic fields in wire-plate electrostatic precipitator, J.Fluid Mech.240 (1992).
[6] G.Cooperma, A new theory of precipitator efficiency, Atmos. Environ.5 (1971)541}551.
[7] High light 2004, Parivesh, published by CPCB, Ministry of Environment & Forest Feb 2005.
[8] H.J. White, Industrial Electrostatic Precipitation, Addison-Wesley, Reading, MA, 1963.
[9] Merchant, G.H. Jr., ‗Evaluation of Sodium Conditioning, Water Fogging and Coal Washing for Environmental Performance Improvement of ESP‘s at BALCO Captive Power Plant‘ Research Report under USA - India: Green House Gas Pollution Prevention Project (September 1999).