Fundamentals of Combustion and Combustion Monitoring Chemicals

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INTRODUCTION

Combustion Reactions

Factors Influencing Combustion and Heat Transfer

Ash Reactions

- Effect of Alkali Compounds on Metals
- Effect of Alkali Compounds on Refractory
- Melting Points of Some Ash Constituents Relevant to Fireside Problems

Indexes of Coal Ash Fusibility

- Silica Ratio
- Schaefer Ratio
- Dolomite Ratio
- Effect of Individual Oxides on Fusion Temperature
- Ash Deformation & Fusion Temperatures
- Fouling Tendency & Fouling Factors

Mechanism of Fireside Deposit Formation

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HISTORY OF FIRE SIDE CHEMICALS

ACTION OF ALTRET- 95 SC SERIES OF COMBUSTION MONITORING CHEMICAL

- Catalytic Action
- Anti-fouling Effect
- Anti-emission Characteristics

OBJECTIVES OF PRESENT STUDY

RESULTS & DISCUSSION

CONCLUSIONS

INTRODUCTION :

- **Combustion Reactions :**

1. Heterogeneous Combustion :

$$C + \frac{1}{2} O_2 \rightarrow CO + 110.510 \ MJ$$

2. Homogeneous Combustion :

$$C + \frac{1}{2} O_2 \rightarrow CO_2 + 282.974 \ MJ$$

3. Heterogeneous Reactions :

$$C + \frac{1}{2} O_2 \rightarrow 2\,CO - 172.882 \ MJ$$

Hydrogen-Oxygen Reactions :

$$\frac{1}{2} H_2 + \frac{1}{2} O_2 \rightarrow OH$$

$$OH + \frac{1}{2} H_2 \rightarrow H_2O^l + 285.485 \ MJ$$

$$\rightarrow H_2O^g + 241.951 \ MJ$$

Water Gas Carbon Reactions :

$$C + H_2O^g \rightarrow CO + H_2 - 131.44 \ MJ$$

$$C + 2H_2O^g \rightarrow CO_2 + 2H_2 - 90.418 \ MJ$$

$$CO + H_2O^g \rightarrow CO_2 + H_2 + 41.023 \ MJ$$

Reaction Kinetics :

$$F + S \underset{K_3}{\overset{k_1}{\rightleftarrows}} (F.S.)_{ads} \underset{K_4}{\overset{k_2}{\rightleftarrows}} S + P$$

Overall Rate :

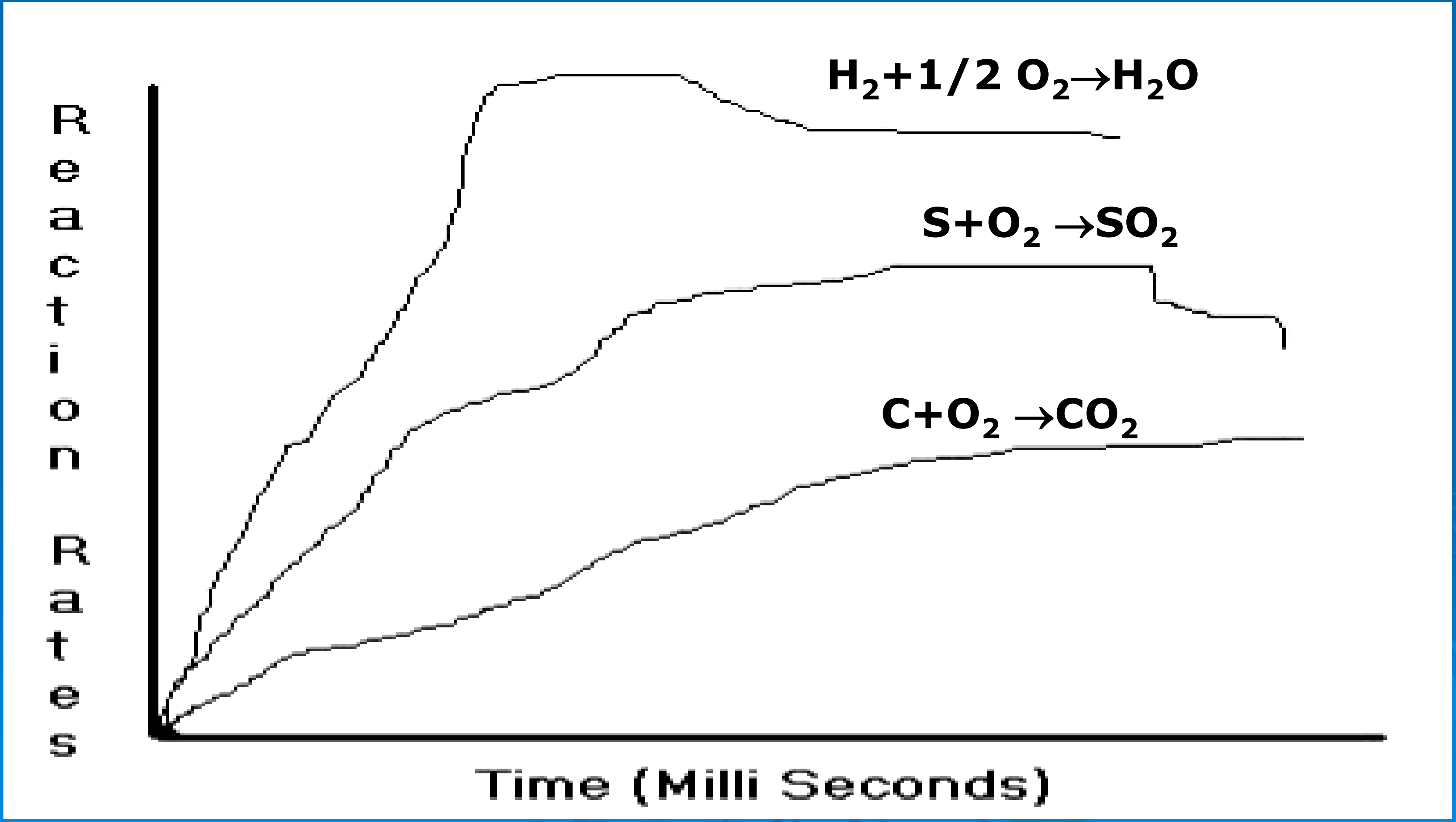
$$R = \frac{k_1.k_2.p_s}{k_1 p_s + k_2 + k_4 p_1}$$

K_i	=	Rate of i^{th} reaction
	=	ko, i $e^{-\Delta Ei/RT}$
Ko, i	=	Velocity constant for i^{th} step
p_s	=	Partial Pressure of Reacting Gas, atm.
P_1	=	Partial Pressure of Reaction product atm.
ΔE_i	=	Activation Energy of i^{th} step
R	=	Gas Constant
T	=	Temperature, K

Reaction Time/Burning Rate for Carbon Particle :

t_b	=	k.do^2, secs.
k	=	5000 for pulverised fuel
	=	f (EA, VM, MC, A, $\in$)

The Rate of Reactions Can be Represented as :



Factors Influencing the Combustion reactions/ Efficiency

Fuel Quality

Particle Size

Reaction Surface Area

Air-Fuel Mixing-Velocity-Turbulence

Residence Time-Velocity/Size of Furnace

Bed Height

Furnace Configuration

Excess Air Ratio

Factors Influencing Heat Transfer :

Water Side Scaling

Metal Resistance

Gas Side Fouling

Heat Transfer Coefficients :

- -Tube Size
- -Velocities
- -Reynolds No.
- -Nusselt's No.

Overall Heat Transfer Coefficient is given by

$$\frac{1}{u} = \frac{1}{h_g} + \frac{x_a}{K_a} + \frac{t}{K_t} \cdot \frac{d_o}{d_m} + \frac{x_c}{K_c} \cdot \frac{d_o}{d_i} + \frac{1}{h_w} \cdot \frac{d_o}{d_i}$$

Constituents of Coal Ash

Main
- Silica
- Alumina

Main
- Iron
- Calcium
- Magnesium
- Titanium
- Vanadium
- Sodium
- Potassium

Sodium, Potassium — Alkali Group of Metals

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Ash Reactions :

[a] Combustion of Sulphur :

$$S + O_2 \rightarrow SO_2$$

$$SO_2 + 1/2\ O_2 \rightarrow SO_3$$

[b] Ash Reactions with SO_3

Na_2O	+	SO_3	$\rightarrow$	Na_2SO_4
[in Ash]		[From Combustion]		[Sodium Sulphate]
Na_2O	+	$2SO_3$	$\rightarrow$	$Na_2S_2O_7$
[in Ash]		[From Combustion]		[Sodium PyroSulphate]

K_2O	+ SO_3	→	K_2SO_4
[in Ash]	[From Combustion]		[Potassium Sulphate]
K_2O	+ $2SO_3$	→	$K_2S_2O_7$
[in Ash]	[From Combustion]		[Potassium PyroSulphate]

The Melting Points of These Salts are :

Sodium Sulphate	:	880° C
Sodium PyroSulphate	:	401° C
Potassium Sulphate	:	1069° C
Potassium PyroSulphate	:	300° C

• EFFECT OF ALKALI COMPOUNDS ON METALS :

PyroSulphate, in particular, reacts very rapidly at temperatures above their melting points with protective iron oxide and iron to cause rapid corrosion of steels as per following reactions.

$$3Na_2S_2O_7 + Fe_2O_3 \rightarrow 2Na_3Fe(SO_4)_3$$

$$3K_2S_2O_7 + Fe_2O_3 \rightarrow 2K_3Fe(SO_4)_3$$

$$4Na_2S_2O_7 + 4Fe \rightarrow 4Na_2SO_4 + 3FeSO_4 + FeS$$

$$4K_2S_2O_7 + 4Fe \rightarrow 4K_2SO_4 + 3FeSO_4 + FeS$$

- **Effect of Alkali Compounds on Refractory**

Compound	Refractory Constituents	Temp °C	Results/Effect
Na_2O	Chromium	730	Liquid Formation
$Na_2\ CO_3$	Alumina	730	Volume Expansion
$Na_2\ SiO_4$	Alumina	750	Liquid Formation
Na	Silicate	800	Liquid Formation
$Na_2\ CO_3$	Magnesia	840	Volume Expansion
$Na_2\ CO_3$	Alumina	1090	Volume Expansion

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Melting Points of Some Constituents of Ash Relevant to Fireside Problem :

Effect of Chlorides	
Constituents	**Melting Point, °C**
NaCl	800
KCl	776
$CaCl_2$	772
$FeCl_3$	282
Effect of Alkali Metals & Sulphur	
Na_2CO_3	851
Na_2SO_4	880
K_2SO_4	1069
$MgSO_4$	1124
$Na_2S_2O_7$	401
$K_2S_2O_7$	300
$Na_3Fe(SO_4)_3$	624
$K_3Fe(SO_4)_3$	618
$Na_3Al(SO_4)_3$	646
$K_3Al(SO_4)_3$	695
Na_2SiO_2	800

Constituents	Melting Point, °C
Eutectics :	
Na_2SO_4 . NaCl	625
$3K_2S_2O_7$. $Na_2S_2O_7$	280
$Na_3Fe(SO_4)_3$. $K_3Fe(SO_4)_3$	552
FeO. FeS	940
Fe.FeS	965
$MgSO_4$ .Na_2SO_4	660
Na_2O – SiO_2.Na_2SO_4	635
NaCl . Na_2CO_3	633
Na_2SO_4 Na_2CO_3	828
Effect of Vanadium	
V_2O_5	690
$Na_2OV_2O_5$	630
Na_2O .3 V_2O_5	621
$5Na_2O$ .V_2O_4.$11V_2O_5$	535
$10Na_2O$. $7V_2O_5$	573
2MgO . V_2O_5	835
3 Mg O. V_2 O_5	1190

Effect of Individual Oxides on Fusion Temperature :

Oxides	Name of Oxides	Effect of Fusion Temperature Due to Increase in Oxide Content
SiO_2	Acidic	Decrease
Al_2O_3	Acidic	Increase
SO_3	Acidic	Decrease
$Ti\ O_2$	Acidic/Neutral	No Effect
$P_2\ O_3$	Acidic/Neutral	No Effect
$Fe_2\ O_5$	Basic	Decreases
$Ca\ O$	Basic	Increase
$Mg\ O$	Basic	Increase
Na_2O	Basic	Decrease
$K_2\ O$	Basic	Decrease
$Cr_2\ O_3$	Basic/Neutral	Increase

Ash Deformation & Fusion Temperature :

[Koristkii's Correlation]

T_d = Ash Deformation Temperatures

= $1094 + 42.5\ K_{fu}\ ^\circ C$

T_f = Ash Fusion Temperature

= $1139 + 48.6\ K_{fu}\ ^\circ C$

K_{fu} = Fusibility Coefficient

$$K_{fu} = \frac{SiO_2 + Al_2\ O_3}{CaO + MgO + Fe_2O_3}$$

Fouling Tendency :

Fouling tendency of coal can be judged from ash analysis by calculating a fouling factor given by :

$$Fouling\ \ Factor = \frac{[Fe_2O_3 + CaO + MgO + K_2O] \times Na_2O}{SiO_2 + Al_2O_3 + TiO_2}$$

All Constituents in %

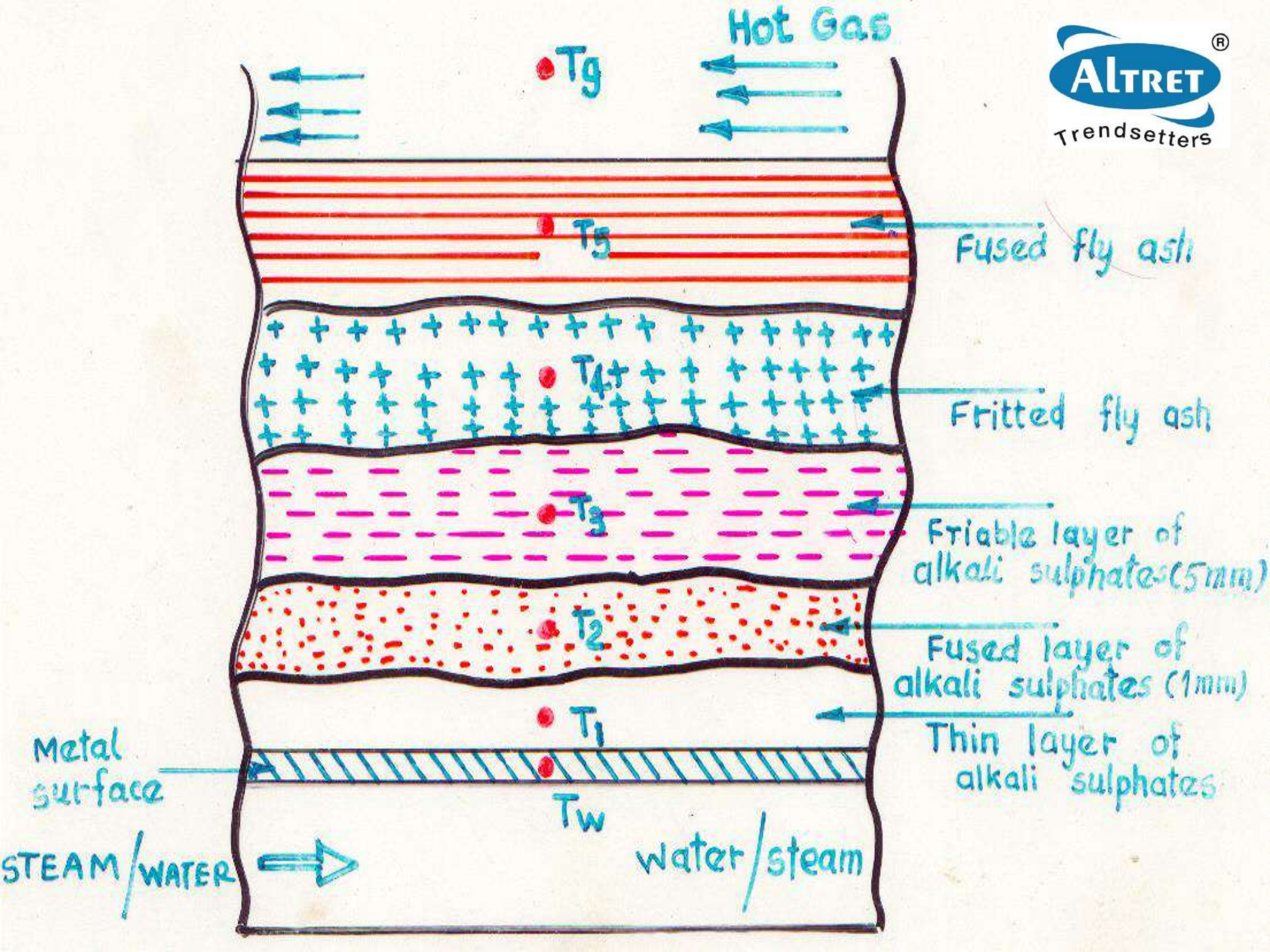
Table : Ash analysis of two British coals

Substances	Coal A Deposit Forming	Coal B Deposit Free
S in Coal, %	1.53	1.73
Ash in Coal, %	7.5	7.4
SiO_2 in Ash, %	46.3	40.6
Al_2O_3 in Ash, %	26.8	33.5
Fe_2O_3 in Ash, %	15.4	10.8
MgO in Ash, %	1.3	3.0
CaO in Ash, %	2.7	6.7
TiO_2 in Ash, %	1.0	0.8
Na_2O in Ash, %	2.2 **Total Alkali**	0.3 **Total Alkali**
K_2O in Ash, %	3.1 **5.3%**	0.8 **1.1%**
SO_3 in Ash, %	0.7	4.0
Fouling Factor	0.73	0.09

Mechanism of Deposit Formation

(W.M. Crane, BCURA Report No. 254, 1962)

- Alkali Sulphates & PyroSulphate has low melting point
- They have higher affinity towards high temperature metal surfaces.
- The higher forces of adhesion and preferred direction of orientation initiates deposit formation.
- W.M. Crane proposes a five layer deposit formation hypothesis.


Hot Gas
Tg
T5
Fused fly ash
T4
Fritted fly ash
T3
Friable layer of alkali sulphates (5mm)
T2
Fused layer of alkali sulphates (1mm)
T1
Thin layer of alkali sulphates
Metal surface
Tw
STEAM/WATER
water/steam

FIRE SIDE TREATMENT

WHAT ?

Monitoring the combustion

Why ?

- To improve combustion efficiency.
- To reduce fouling.
- To reduce clinker formation.
- To reduce pollution.

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HISTORY OF FIRESIDE TREATMENT :

- In early seventies problem of hard clinker formation with steam coal was a major area of concern.
- Sodium chloride & Vanadium based fuel additives tend to soften the clinker.
- But after a decade problem of metal sponge $Na_2OV_2O_5$ observed.
- In eighties with better understanding of combustion, fouling, eutectic structure of ash, Ammonium Chloride, Magnesium Oxide, Nitrate & Oxychlorate based Compounds came in to existence. They worked well, but offered higher NO_x emissions.
- Much work on better combustion catalyst and anti-emissions catalyst proceeded at a rapid rate due to increased demand of higher efficiencies at lower emission levels in nineties.

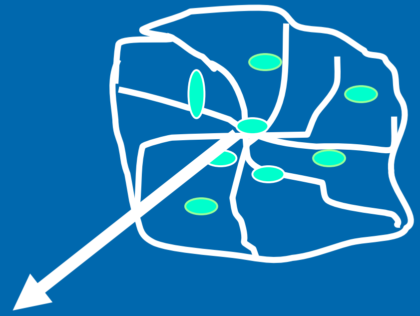
ALTRET 95 COMBUSTION MONITORING CHEMICAL (C.M.C)™ IS A NOVEL COMBUSTION CATALYST DEVELOPED BY THE AUTHOR.

IT HAS THREE DISTINCT EFECTS

- *Catalytic Effect*
- *Anti Fouling Effect*
- *Anti-Emission Effect*

CATALYTIC ACTION OF ALTRET-95 CMC

- **Provide Better Pore Surface Area**



Normal Coal Particle **Catalyzed Coal Particle**

- **Improved Oxygen Penetration :**

The high velocity cobalt and iron catalyst penetrates the coal particle and enhance the micro surface area for reaction. The oxychlorate provides ionic oxygen for catalytic combustion and all the major reactions get enhanced. The nitrate decomposition provides N_2 O_2 which catalyses gas phase reactions and volatiles combustion. The presence of CO enhance gas solid reactions. The sequences of reactions may be represented as :

- *Nitrate De Composition :*

$$2NO_3 \rightarrow N_2O_2 + 2O_2$$

- *Gas Phase Reactions*

$$H_2 + 2\overline{O} \xrightarrow{N_2O_2} 2\overline{O}\,\overline{H}$$

$$2\overline{O}\,\overline{H} + H_2 \xrightarrow{N_2O_2} 2H_2O$$

$$CO + \overline{O} \xrightarrow{N_2O_2} CO_2$$

- *VolatileCombustion*

$$C_xH_y + (x+y)\overline{O} \xrightarrow{N_2O_2} XO + y\overline{O}\,\overline{H} + \frac{z}{2}O_2$$

- *Gas – Solid Reactions*

$$S + 2\overline{O} \xrightarrow{Co} SO_2$$

$$C + \overline{O} \xrightarrow{Co} CO$$

ANTIFOULING ACTIONOF ALTRET-95 CMC

- Antifouling effect may be obtained by the following route :

@ By changing preferred direction of orientation of particle.

@ By forming a protective layer of vapours on surfaces.

@ By retarding ash reactions leading to formation of Sodium and Potassium Sulphates and PyroSulphate.

NH_4Cl & $Mg(OH)_2$ vapours has very high affinity towards SO_3 and they form ammonium and magnesium sulfates which has much higher melting points than that of sodium and Potassium Sulfates

@ By increasing Ash Fusion temperature through changing the Eutectic Structure of ash.

$$3Na_2O\ V_2\ O_5 + 3MgO \rightarrow 3Mg\ OV_2\ O_5 + 3Na_2O$$

[Parent Eutectic m.p.621°C] [Modified Eutectic m.p. 1243 °C]

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ANTI-EMISSION ACTION OF ALTRET-95 CMC

- **Control of Co :**

$$CO + \frac{1}{2} O_2 \xrightarrow[Oxdn.\ \ Catalyst]{Co\,\&\,N_2\,O_2} CO_2$$

- **Control of NO_x :**

$$2\,NO_x \xrightarrow[\mathrm{Re}dn.\ \ Catalyst]{Co\,\&\,N_2O_2} N_2 + XO_2$$

- **Control of Particulate Emissions :**

- The Parent ash in fuel & unburnt carbon will appear as particulate emissions in stack
- The only solution is to increase collections efficiency of ESP

Collection Efficiency = $1-e^{-wk}$

k	=	Specific Collection Area = A/Q
A	=	Projected area of electrodes, m^2
Q	=	Volume flow of gas, m^3/s
w	=	Effective migration velocity, m/s.

- ALTRET – 95 CMC promotes formation of magnesium and ammonium sulphates which increases “ASH CONDUCTIVITY” which enhance “EFFECTIVE MIGRATION VELOCITY”& Hence improves ESP Collection Efficiency.

OBJECTIVES OF PRESENT WORK :

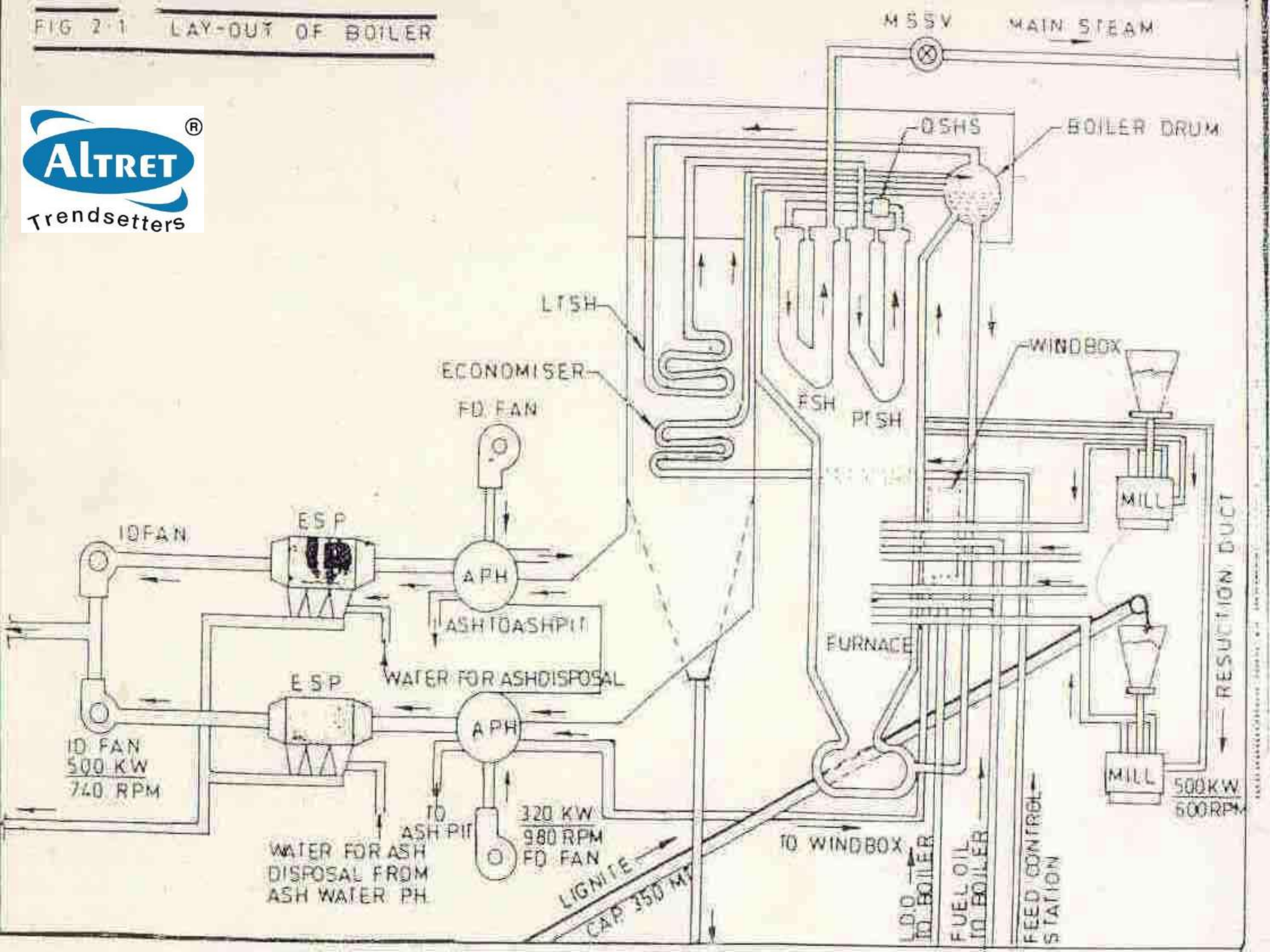
- To quantify the performance improvement in large power plants through use of ALTRET- 95 Combustion Monitoring Chemical.
- To establish the quantitative of influence ALTRET-95 Combustion Monitoring Chemical in reducing stack emissions in large power station.

CASE STUDY

KLTPS

PANANDHRO

FIG 2·1 LAY-OUT OF BOILER



BOILER DETAILS

- **BOILER TYPE** : Pulverised Fuel
- **MAKE** : BHEL
- **CAPACITY** : 325 TPH
- **PRESSURE** : 90 kg/cm^2
- **FUEL** : Lignite

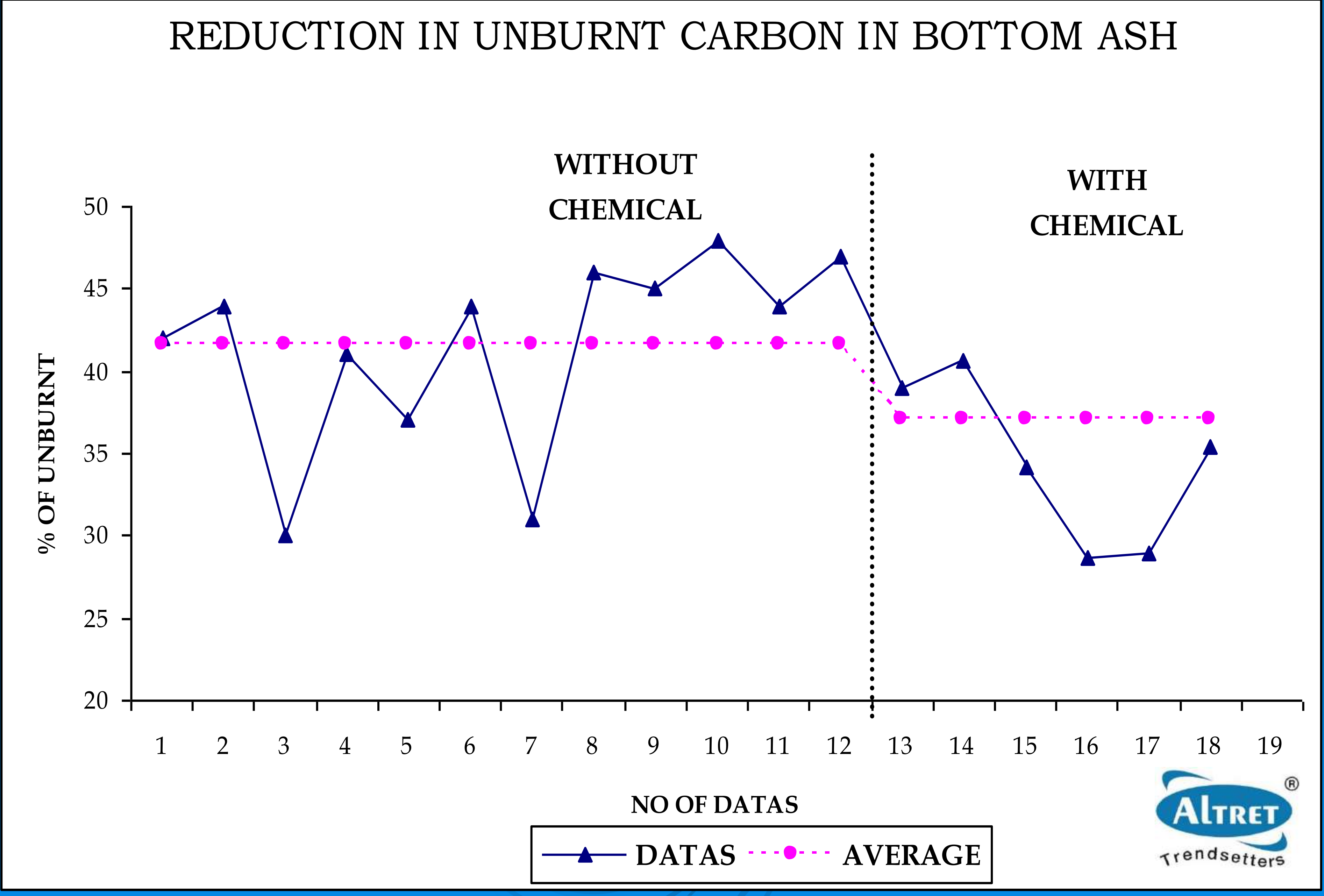
PROBLEM FACED

- Heavy Clinkering in Furnace Zone
- Heavy Fouling in Resuction Duct
- Excess SO_2 due to high S % in lignite

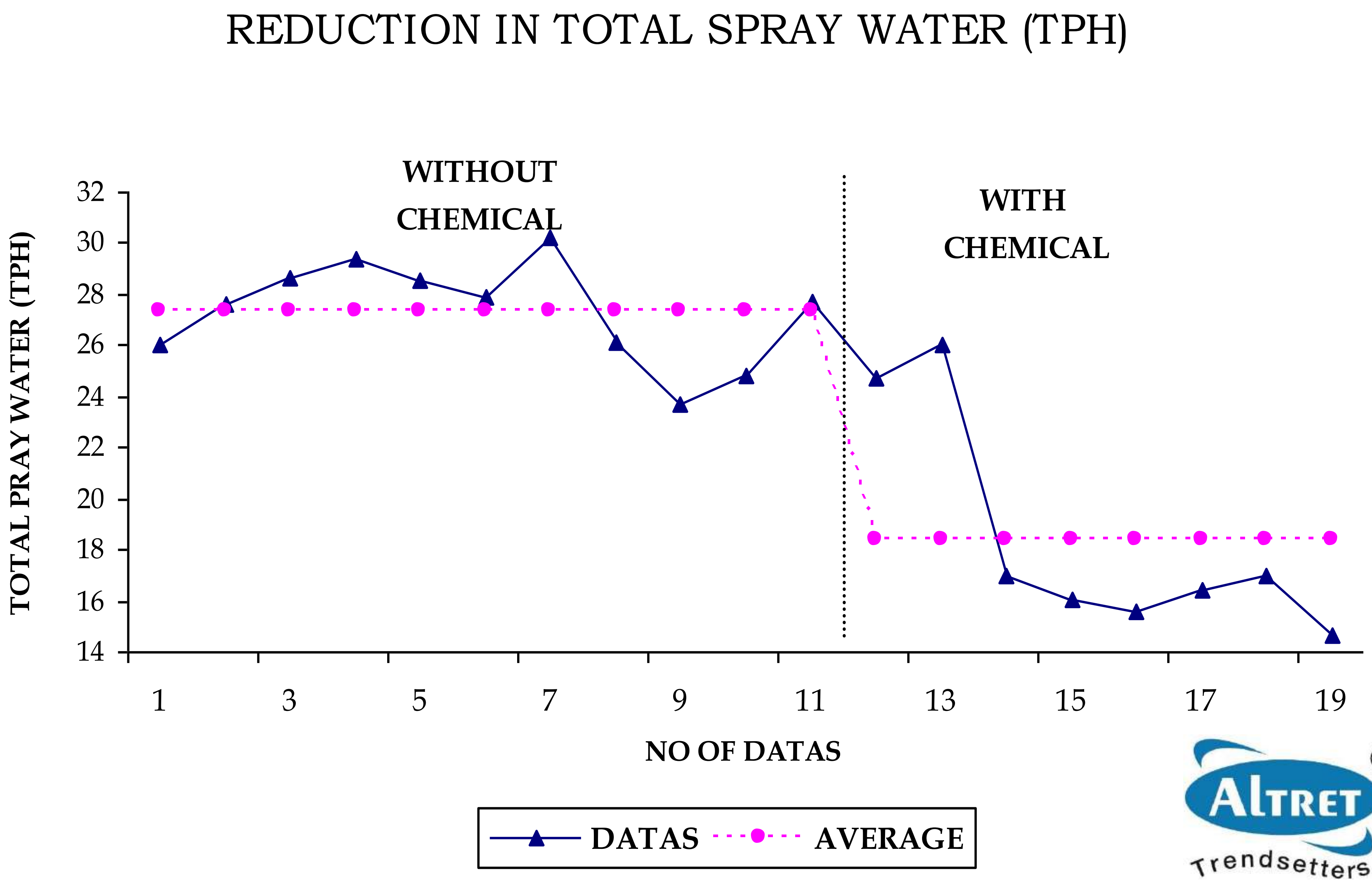
SOLUTION

- Chemical suggested: “ALTRET” 95 SCA
- Dosage: 40 ppm

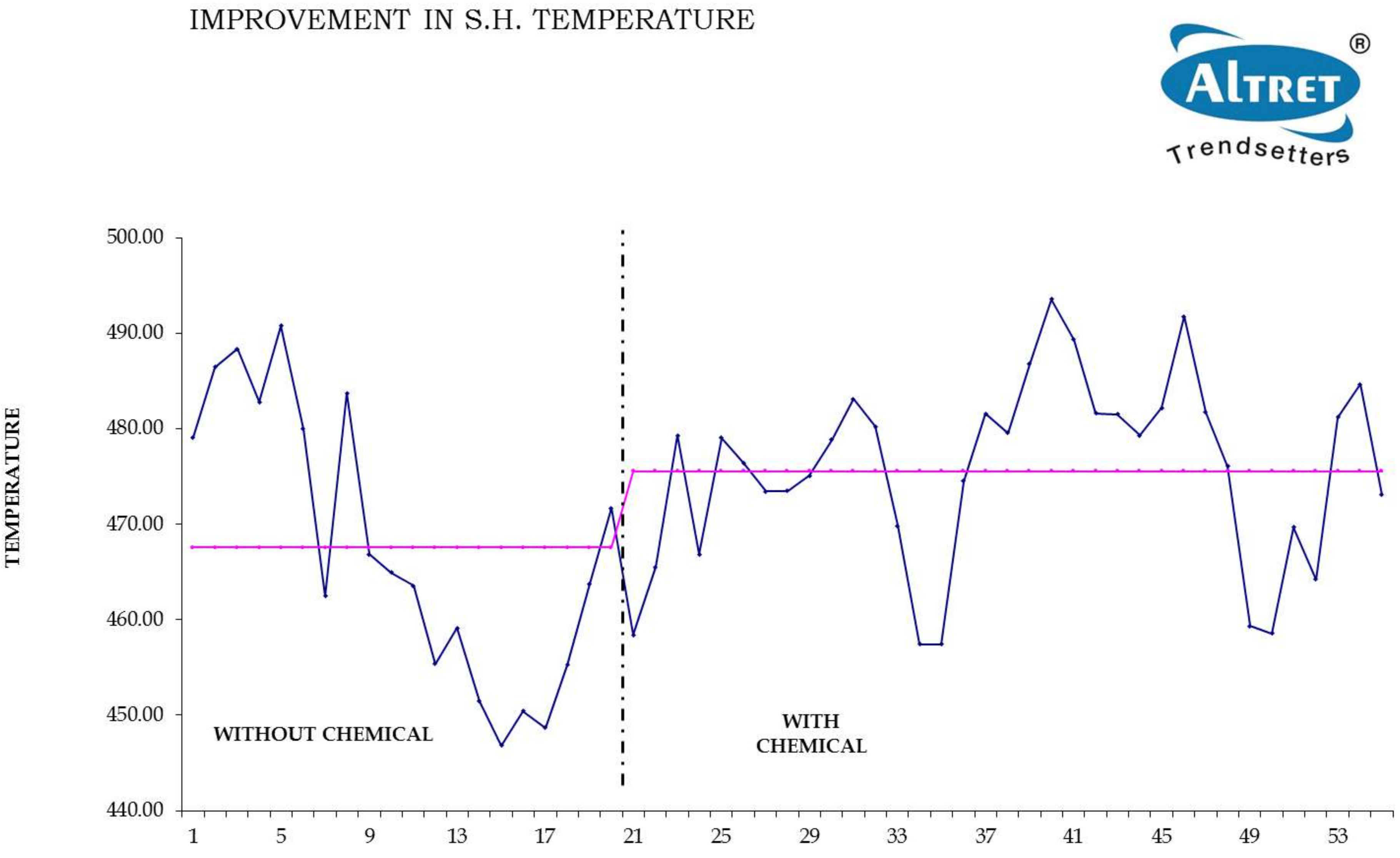
Catalytic Effect



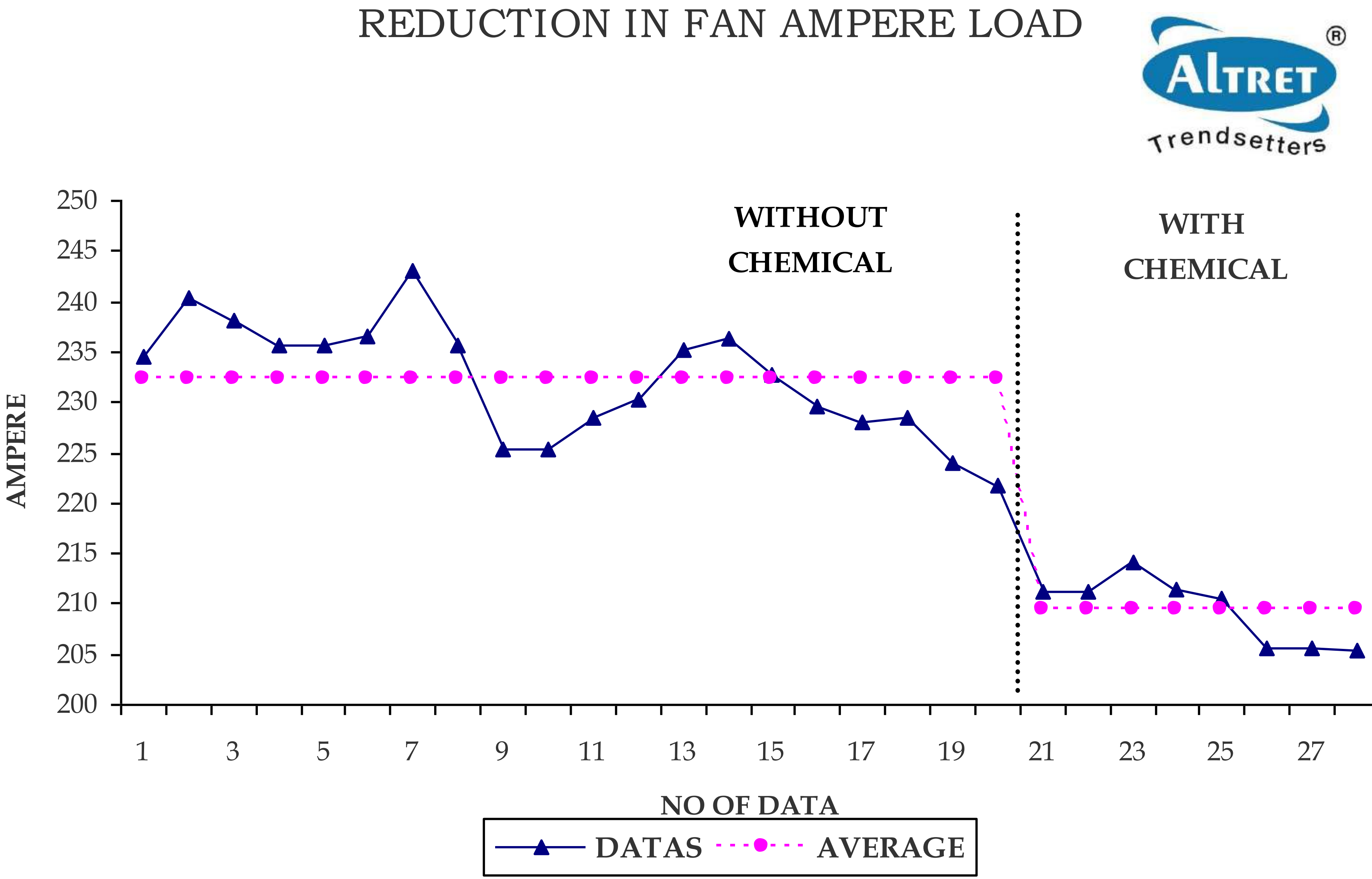
Catalytic Effect



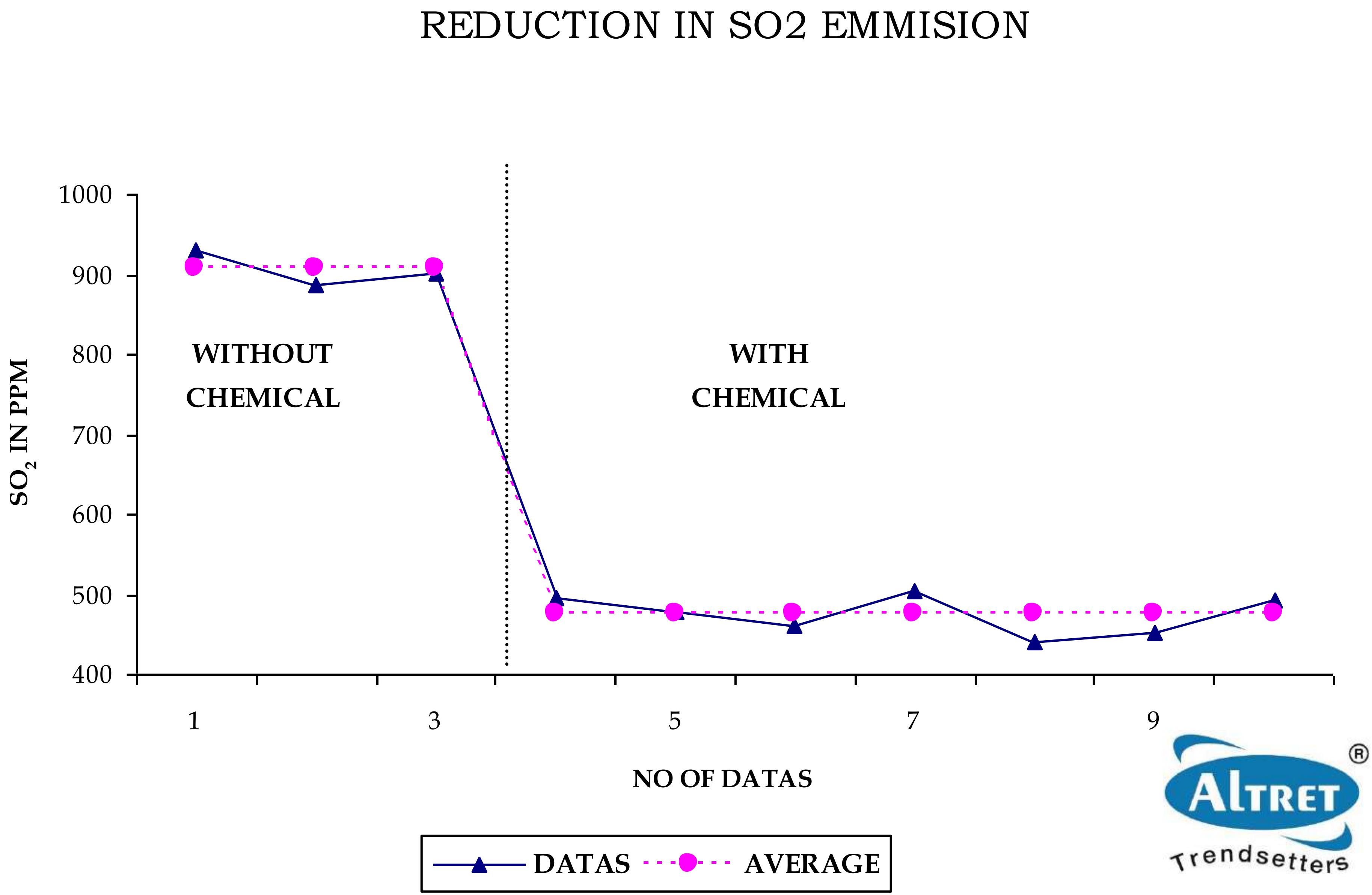
Anti-Fouling Effect



Anti-Fouling Effect



Anti-Emission Effect



RESULTS

Parameter	W/O Chem.	With Chem.	% Improvement
Aux. Power Consumption	105.78	102.39	3.21
Boiler Eff. (%)	74.13	75.96	2.74
Generation Eff. (%)	24.19	24.79	2.51
SO_2 (ppm)	708.98	540.36	23.78
SPM	93.04	64.27	30.92
Fuel Savings (T/Yr)	13,788.50		
Net Eco. Savings (Rs/Yr)	11.977 lacs		

CONCLUSION

- The benefits observed are quite high due to:
  - Longer boiler availability
  - Reduction in down time
  - Reduction in oil consumption
  - Reduced boiler outage due to reduction in clinker formation
  - More M.W.H generation due to reduction in fouling and cleaning time.

CASE STUDY

TATA CHEMICALS LTD.

MITHAPUR

BOILER DETAIL

SPECIFICATIONS	CEHP – 2	HPB - 3
Make	Combustion Engineering - USA	LLB - Germany
Type	P.F. Fired	C.F.B.C.
Fuel	Enviro Coal	75% Petcoke + 25% Enviro Coal
Steaming Rate	136 T/h	185 T/h
Working Pressure	105 Kg/cm^2	105 Kg/cm^2
Max. Steam Temperature	510 – 515 °C	560 °C
Fuel Consumption	500 T/day	525 T/day

PROBLEM FACED

- Heavy Clinker formation in Super Heater Region.
- Higher Unburnt Carbon
- Require Higher Boiler Efficiency
- Excess SO_2 due to high S % in Pet-coke

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SOLUTION

For CEHP # 2 Boiler – 100 % Enviro Coal

A Precise dosage of "ALTRET" 95 SC Combustion Monitoring Chemical (CMC)™ is suggested @40 ppm

For HPB # 3 Boiler, Dual Fuel Fired

(Petcoke- 75% + Enviro Coal 25%)

On Petcoke @ 50 ppm of "ALTRET" 95 R &

On Enviro Coal @ 70 ppm of "ALTRET" 95 SCA

BOILER
CEHP # 2
EVALUATION

Fig . - 1 : LOAD OF CEHP # 2

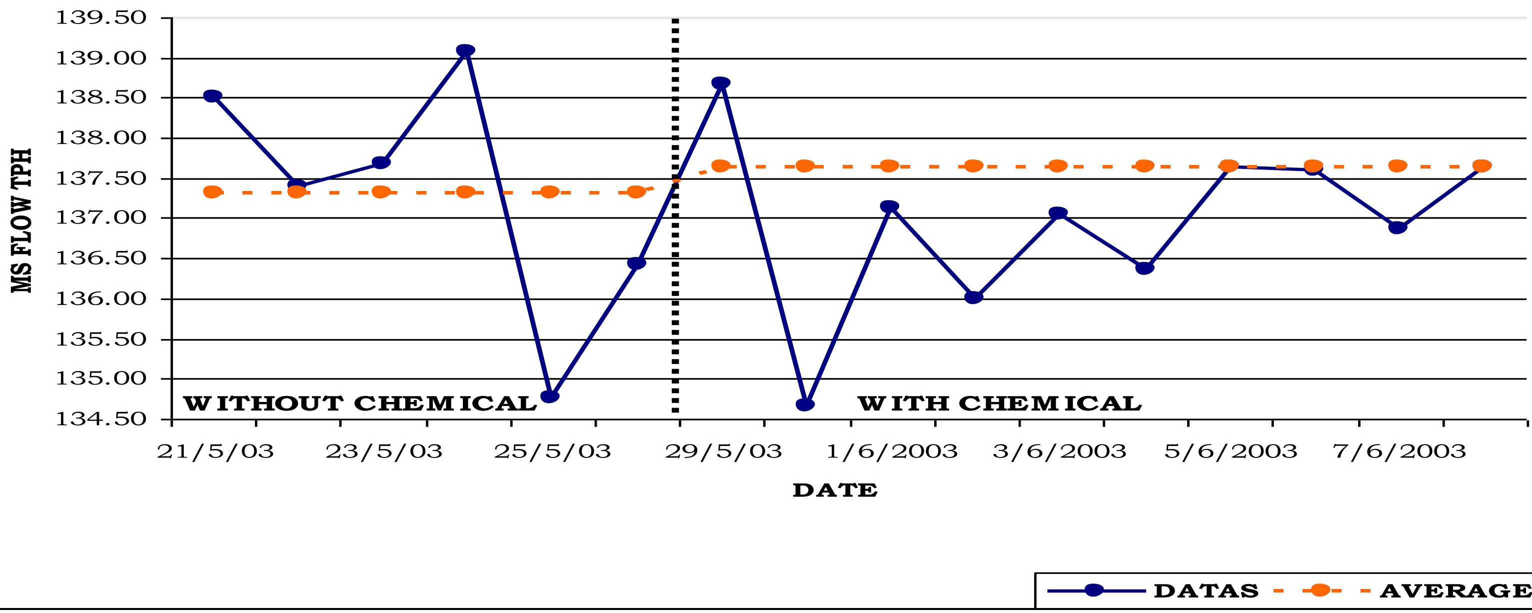


Fig. - 2 : MAIN STEAM PRESSURE OF CEHP # 2

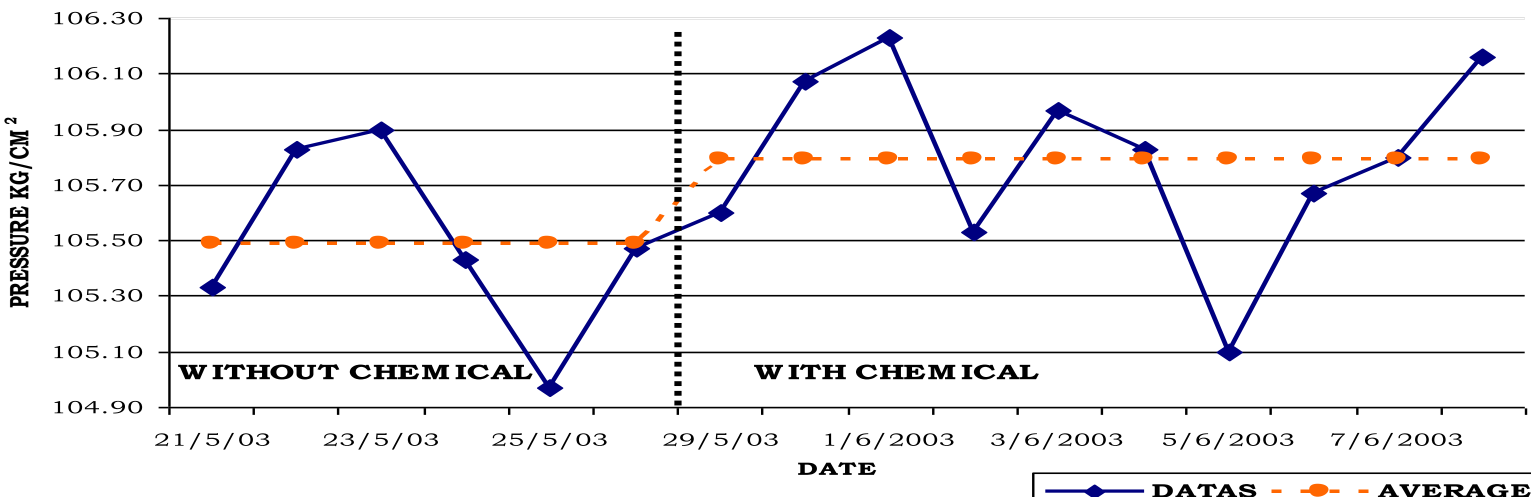


Fig.- 3 : MAIN STEAM TEMERATURE CEHP # 2

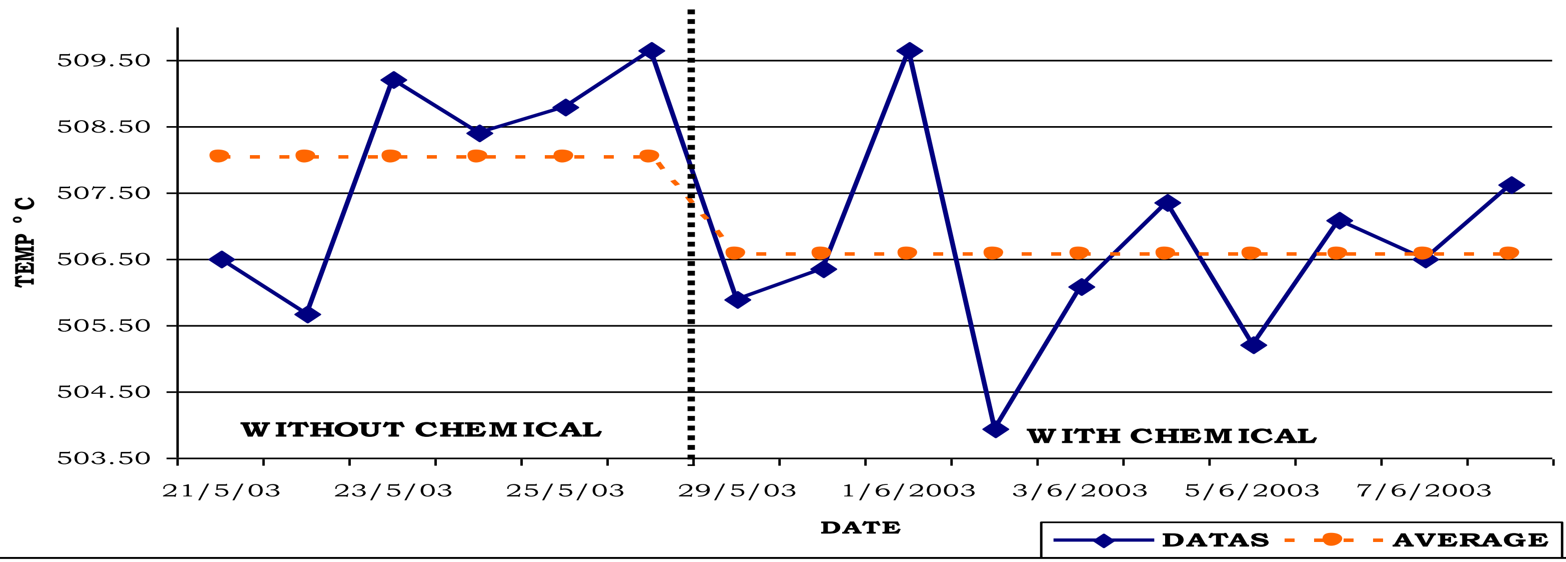
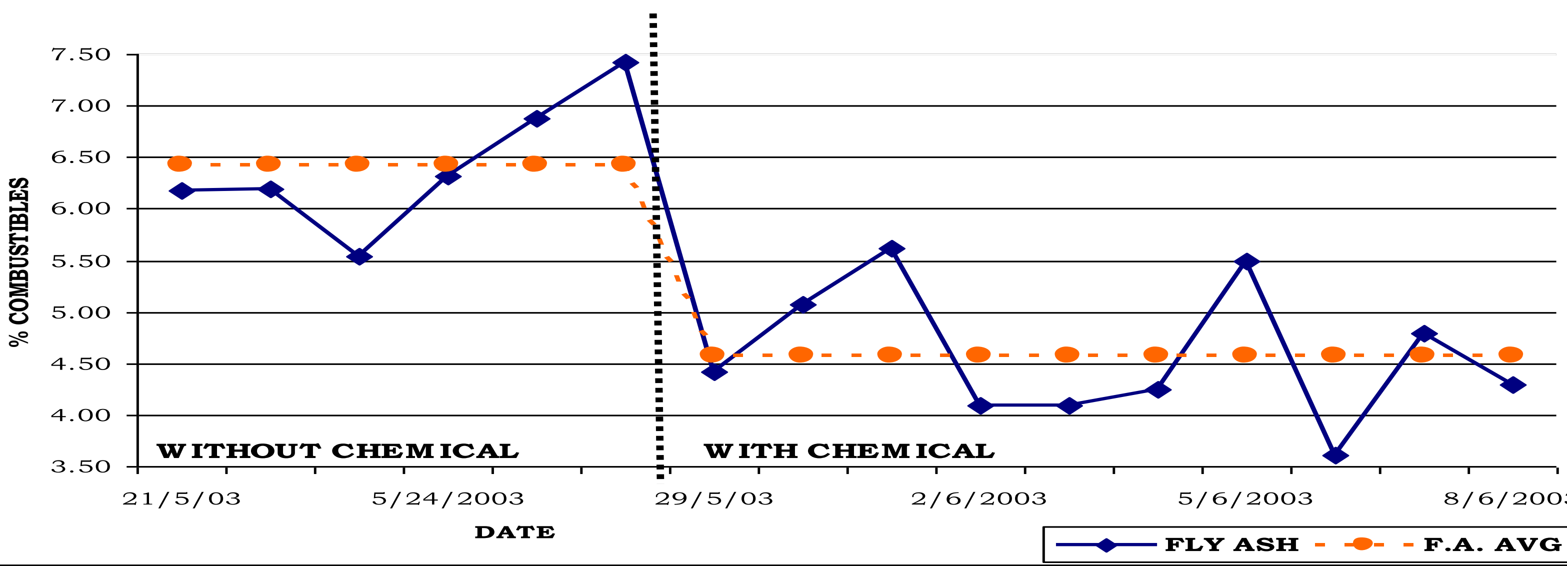


Fig. - 4: REDCUTION IN UNBURNT CARBON IN FLY ASH IN CEHP # 2



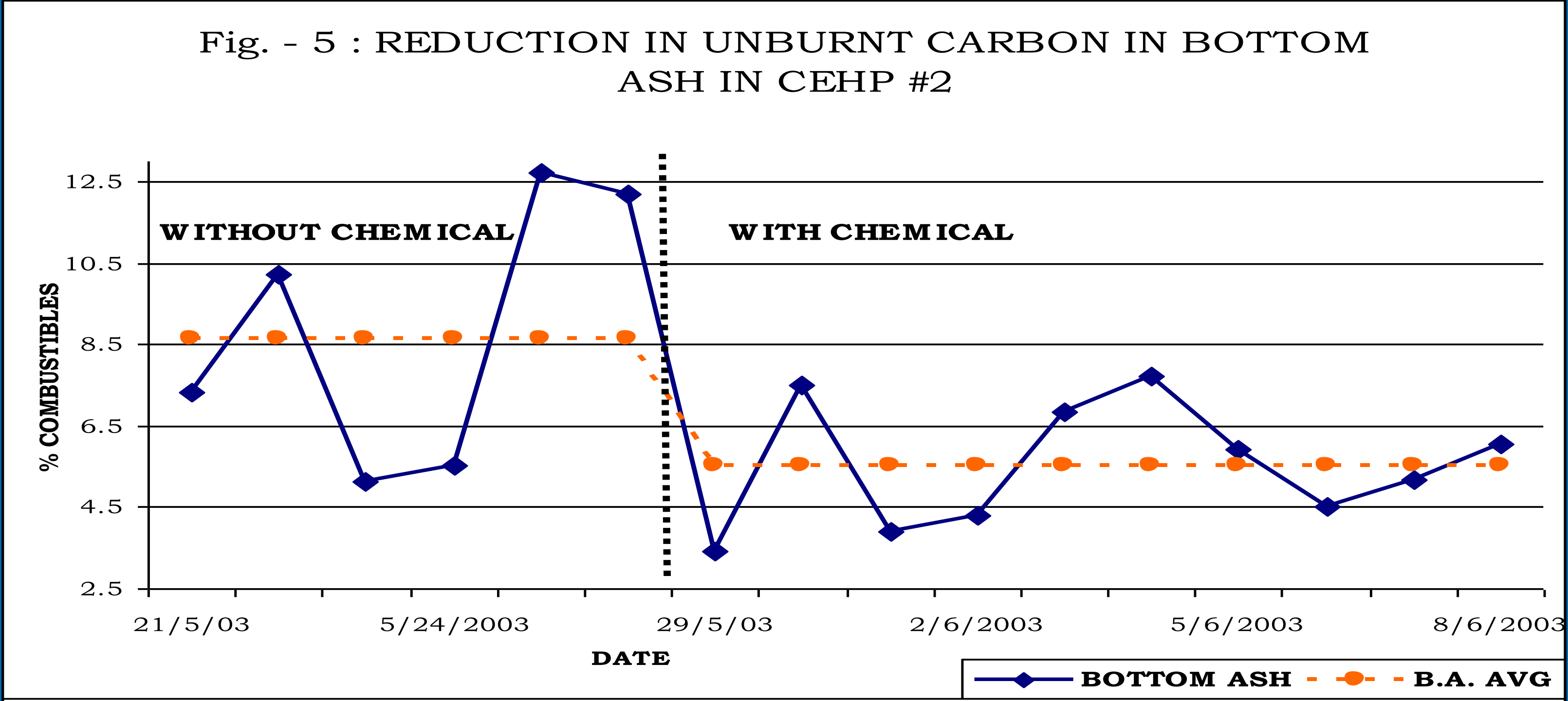


Fig. - 5 : REDUCTION IN UNBURNT CARBON IN BOTTOM ASH IN CEHP #2
WITHOUT CHEMICAL
WITH CHEMICAL
% COMBUSTIBLES
12.5
10.5
8.5
6.5
4.5
2.5
21/5/03
5/24/2003
29/5/03
2/6/2003
5/6/2003
8/6/2003
DATE
BOTTOM ASH
B.A. AVG

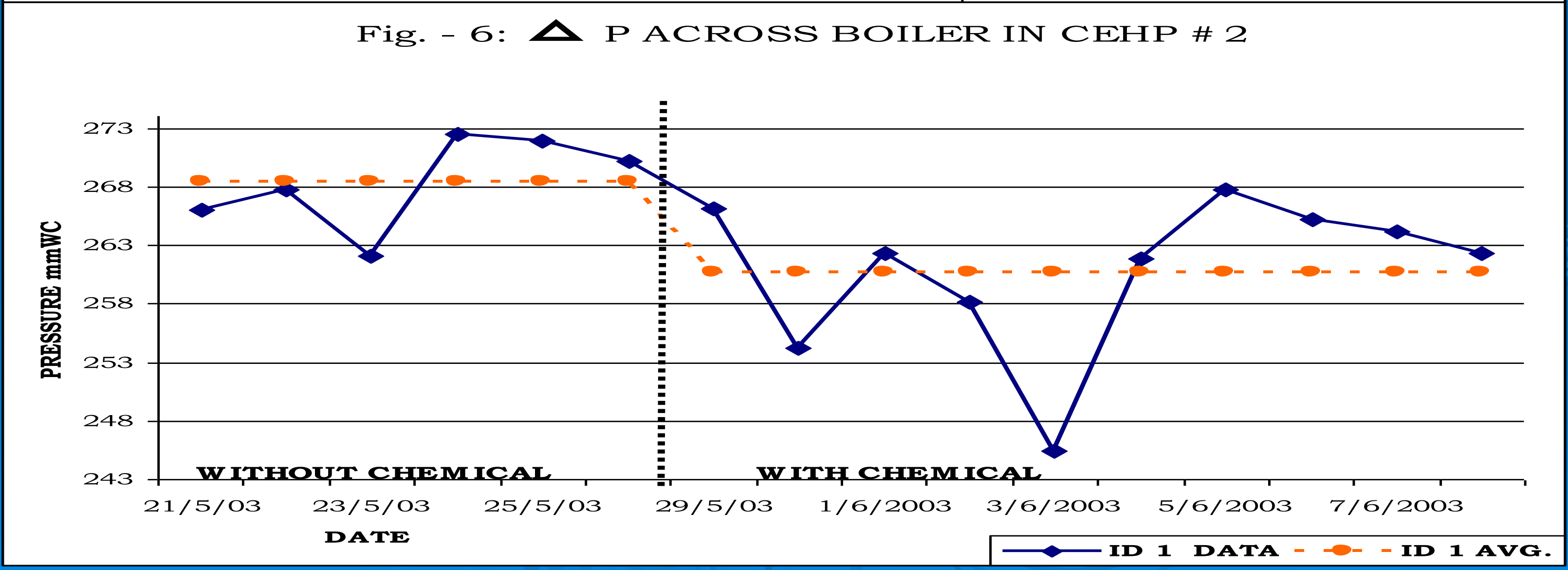


Fig. - 6: P ACROSS BOILER IN CEHP # 2
PRESSURE mmWC
273
268
263
258
253
248
243
WITHOUT CHEMICAL
WITH CHEMICAL
21/5/03
23/5/03
25/5/03
29/5/03
1/6/2003
3/6/2003
5/6/2003
7/6/2003
DATE
ID 1 DATA
ID 1 AVG.

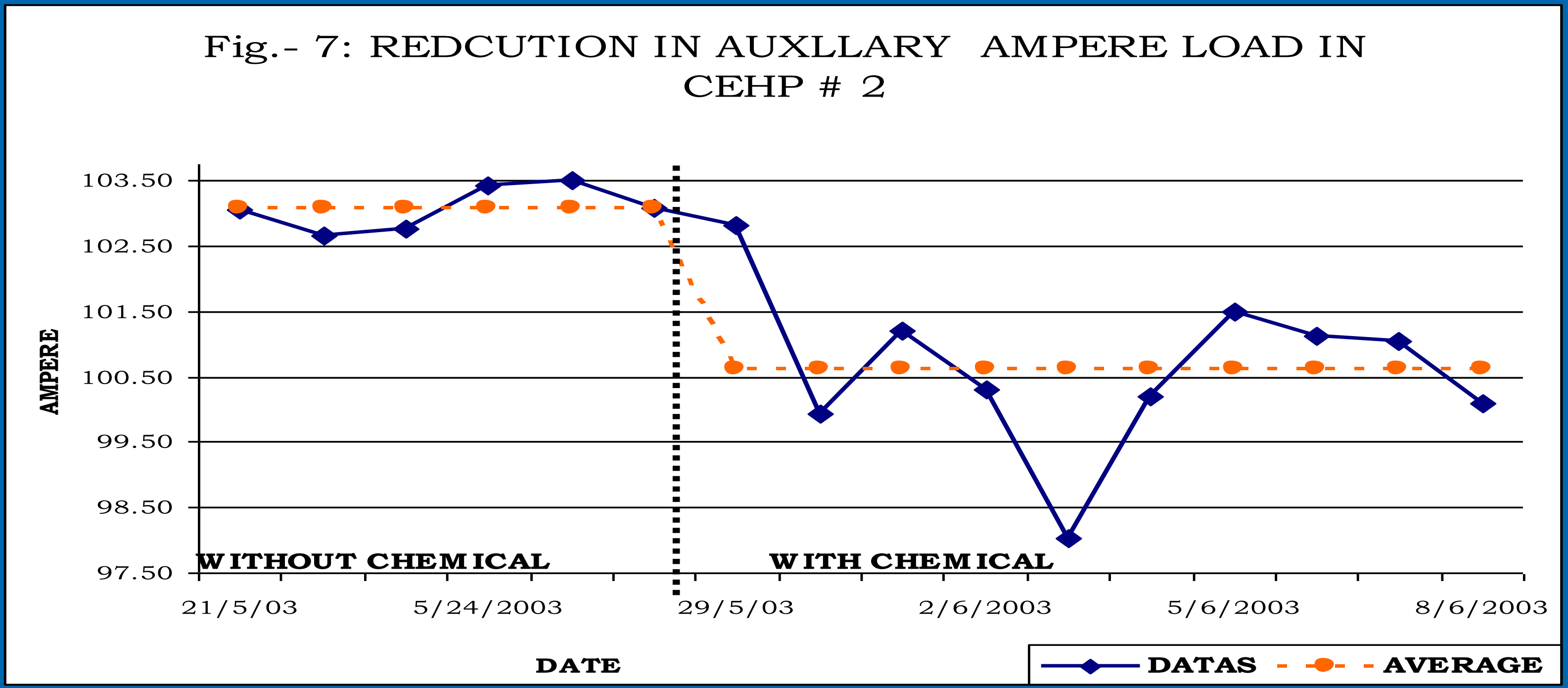


Fig.- 7: REDCUTION IN AUXLLARY AMPERE LOAD IN CEHP # 2
103.50
102.50
101.50
100.50
99.50
98.50
97.50
AMPERE
WITHOUT CHEMICAL
WITH CHEMICAL
21/5/03
5/24/2003
29/5/03
2/6/2003
5/6/2003
8/6/2003
DATE
DATAS
AVERAGE

Fig. - 9 : IMPROVEMENT IN S.E.E IN CEHP # 2

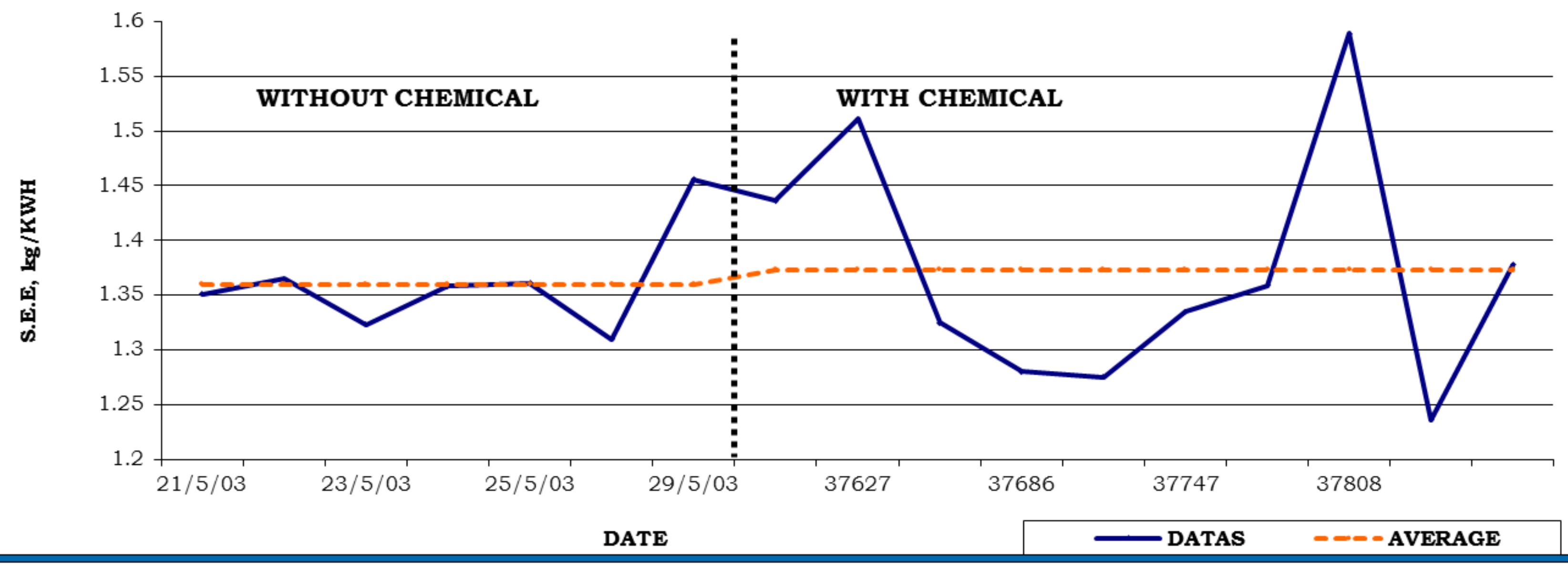
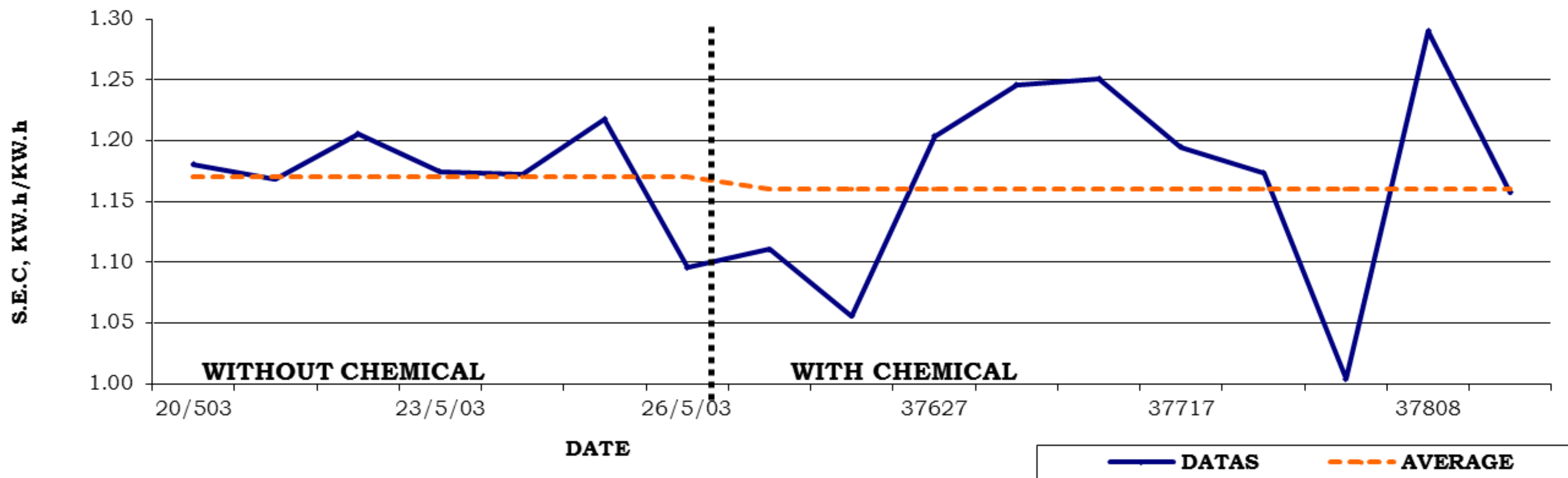


Fig. - 10: REDUCTION IN S.E.C IN CEHP # 2



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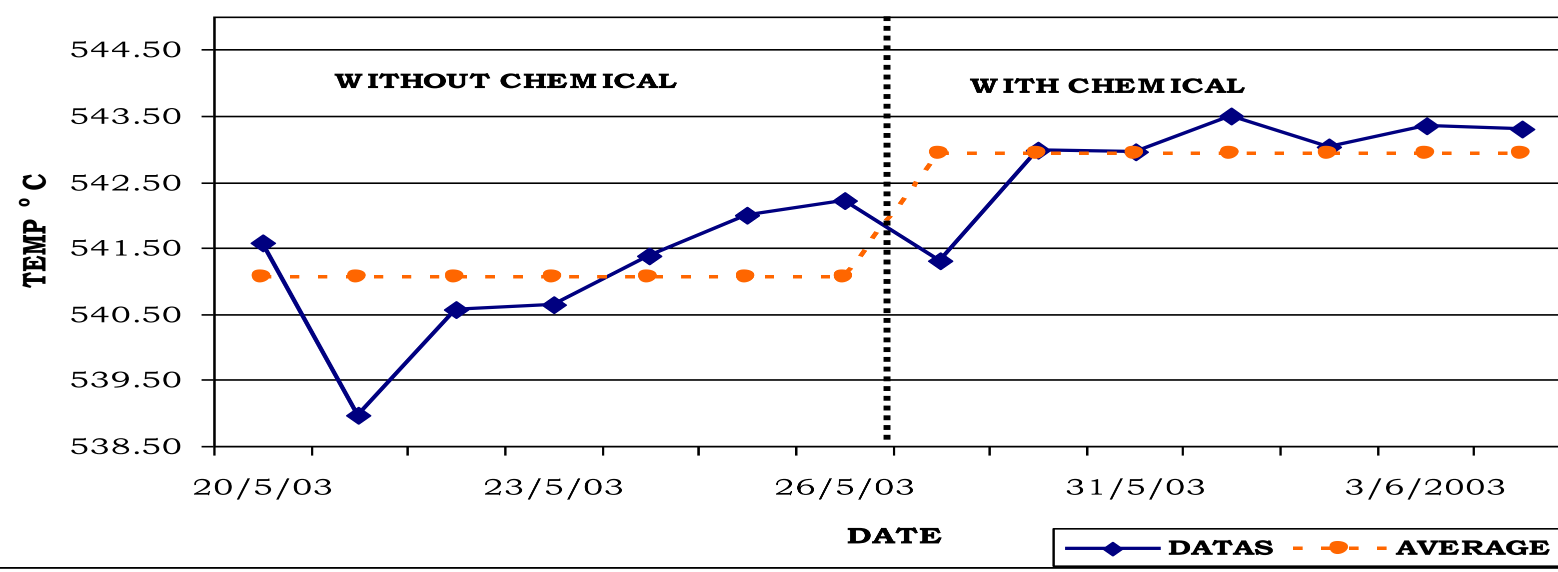
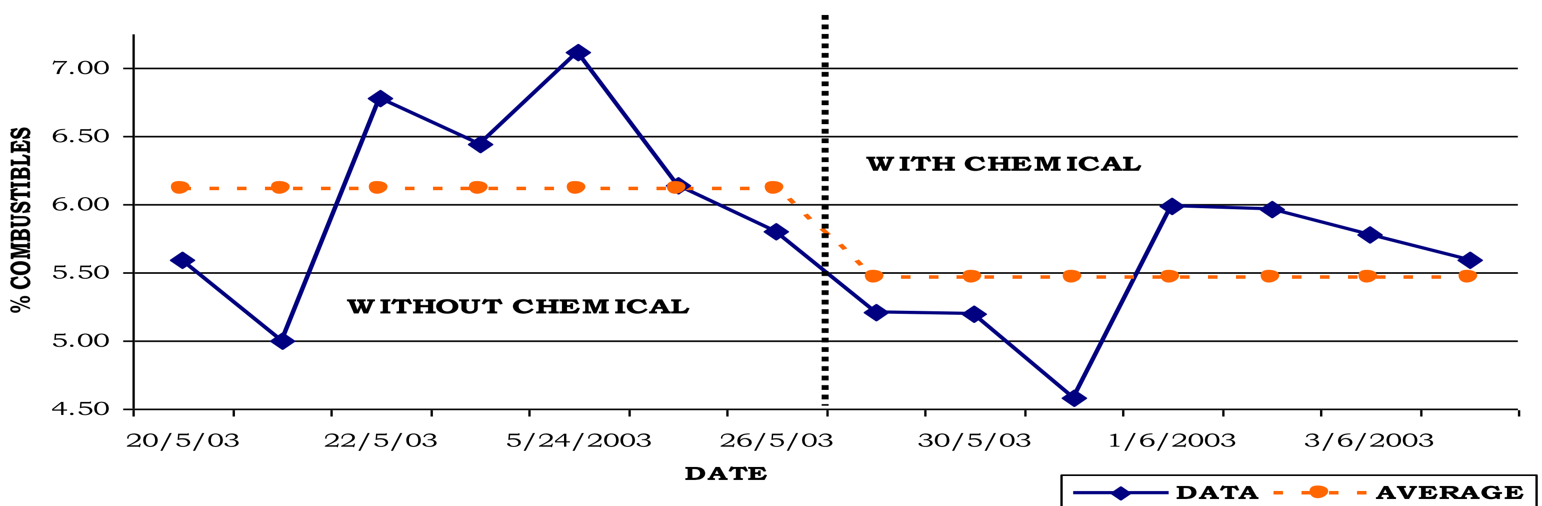
BOILER
HPB # 3
EVALUATION

Fig. - 13 : MAIN STEAM TEMERATURE IN HPB # 3



Fi.g - 14 : REDUCTION IN UNBURNT CARBON LEVEL IN FLY ASH IN HPB # 3



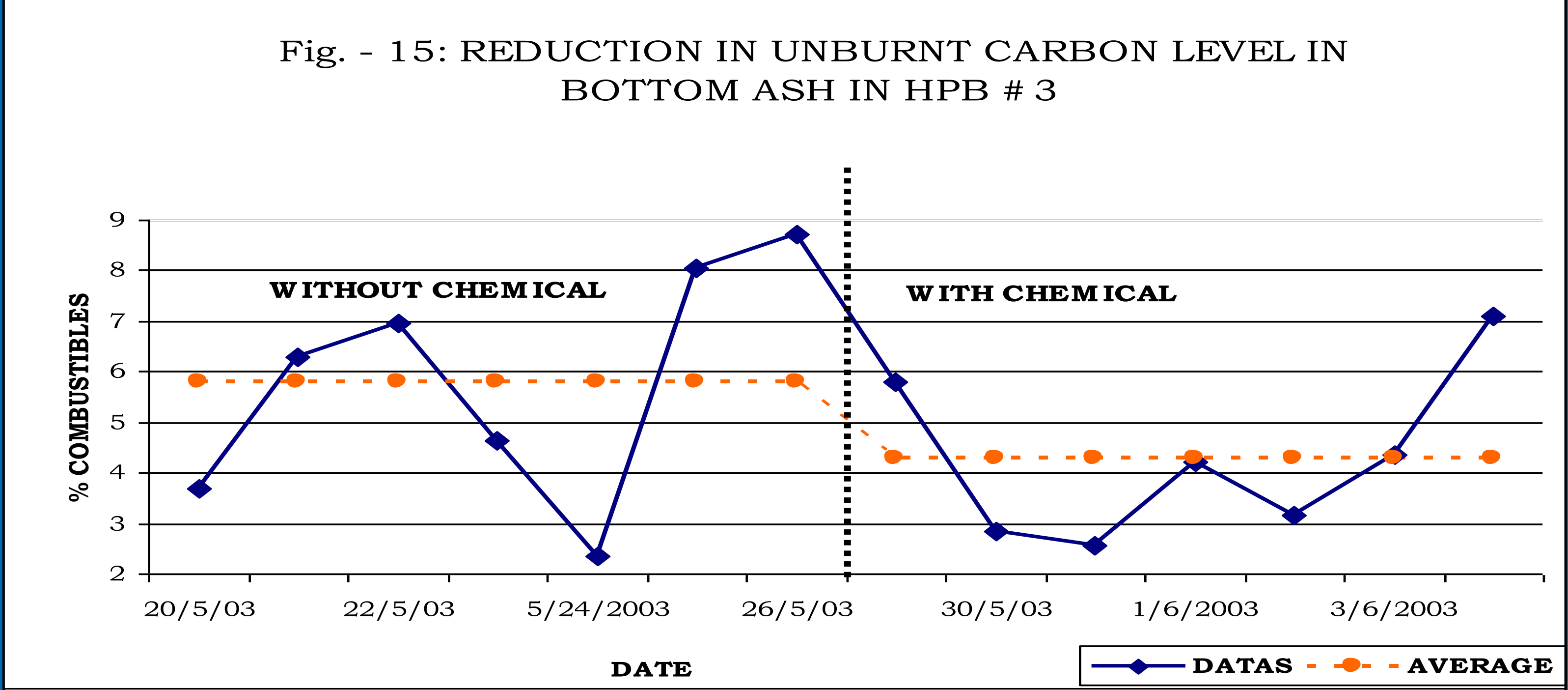


Fig. - 15: REDUCTION IN UNBURNT CARBON LEVEL IN BOTTOM ASH IN HPB # 3
% COMBUSTIBLES
WITHOUT CHEMICAL
WITH CHEMICAL
9
8
7
6
5
4
3
2
20/5/03
22/5/03
5/24/2003
26/5/03
30/5/03
1/6/2003
3/6/2003
DATE
DATAS
AVERAGE

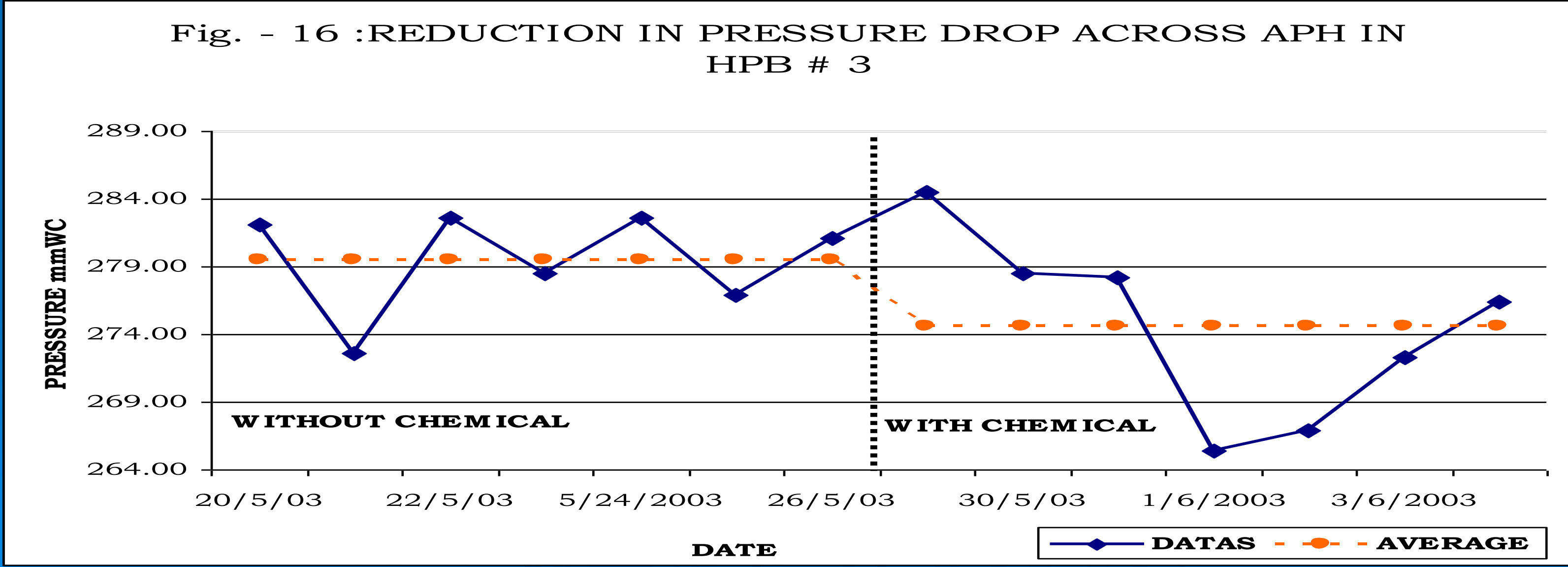


Fig. - 16 :REDUCTION IN PRESSURE DROP ACROSS APH IN HPB # 3
PRESSURE mmWC
289.00
284.00
279.00
274.00
269.00
264.00
WITHOUT CHEMICAL
WITH CHEMICAL
20/5/03
22/5/03
5/24/2003
26/5/03
30/5/03
1/6/2003
3/6/2003
DATE
DATAS
AVERAGE

Fig. -17: REDUCTION IN AUXILLARY POWER CONSUMPTION IN HPB # 3

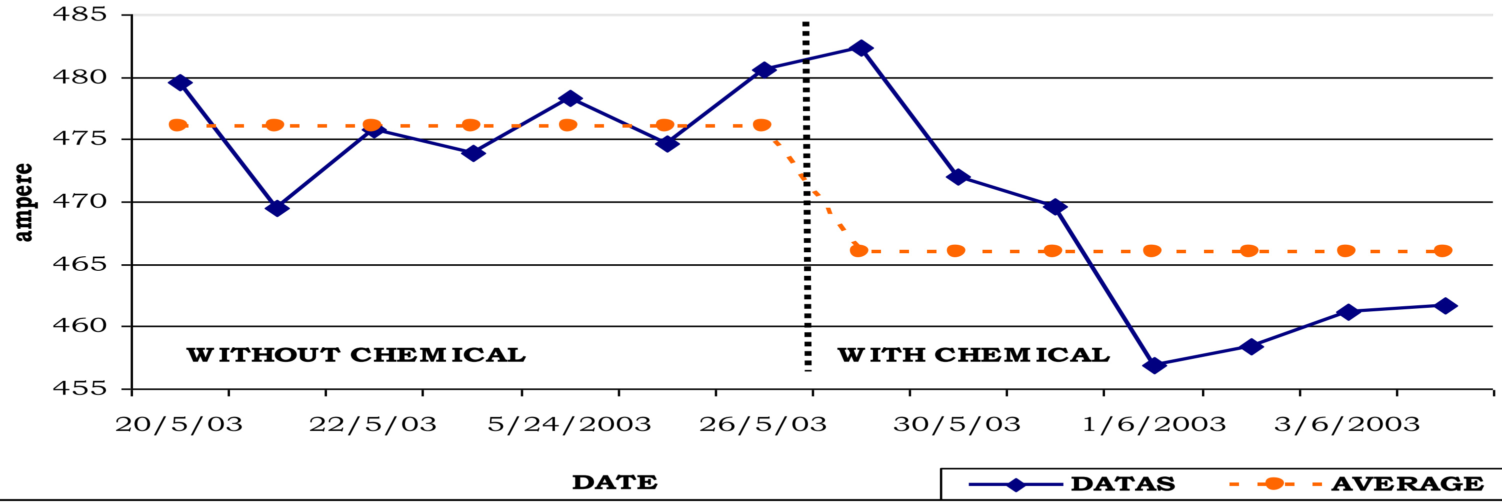


Fig. - 18 : REDUCTION IN CHIMNEY GAS OUTLET TEMP. IN HPB # 3

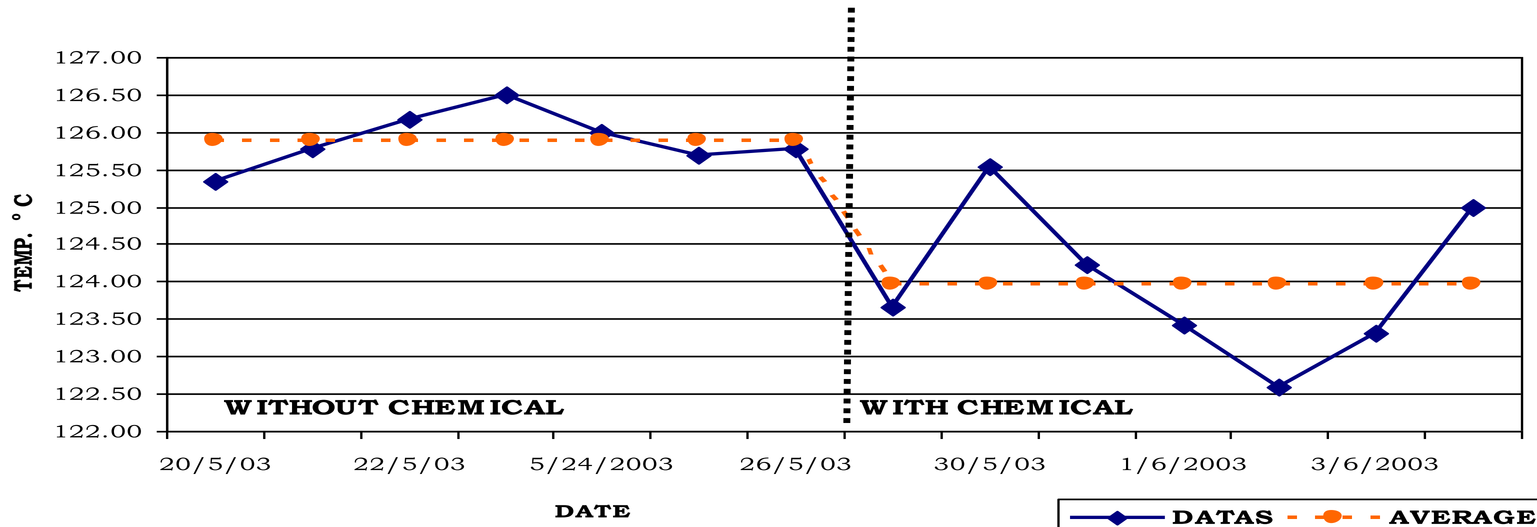


Fig. - 19 : EFFECT ON REDUCTION IN SO_2 LEVELS IN HPB # 3

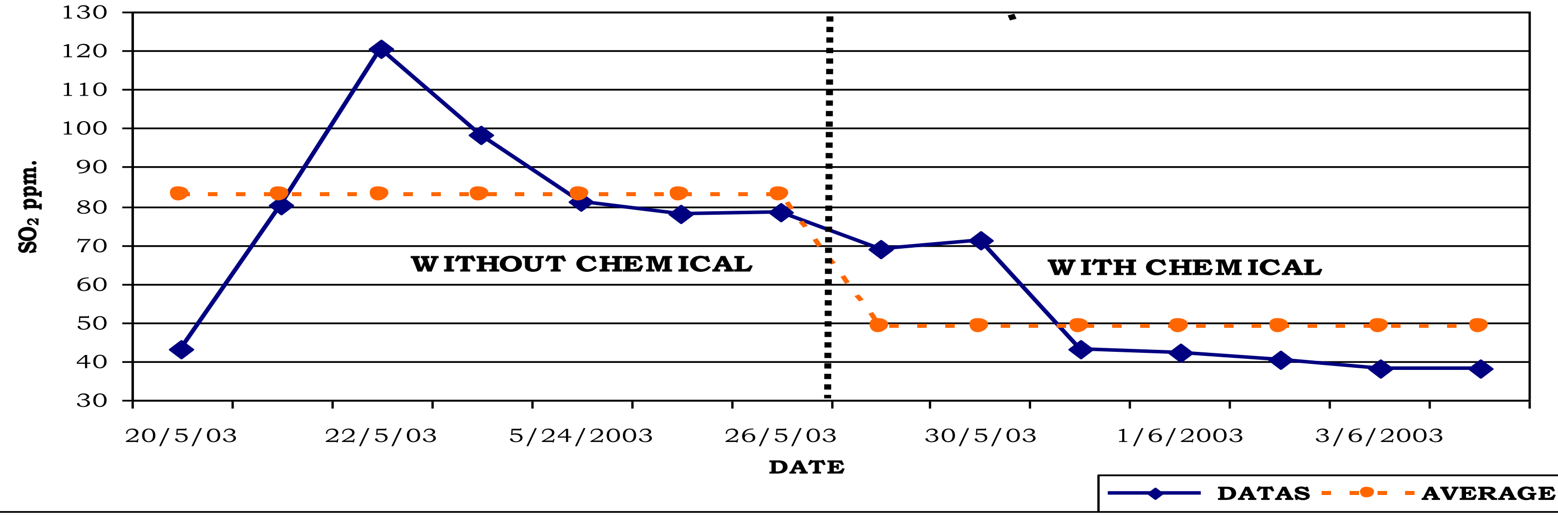


Fig. -20: EFFECT ON REDUCTION IN CO LEVELS IN HPB# 3

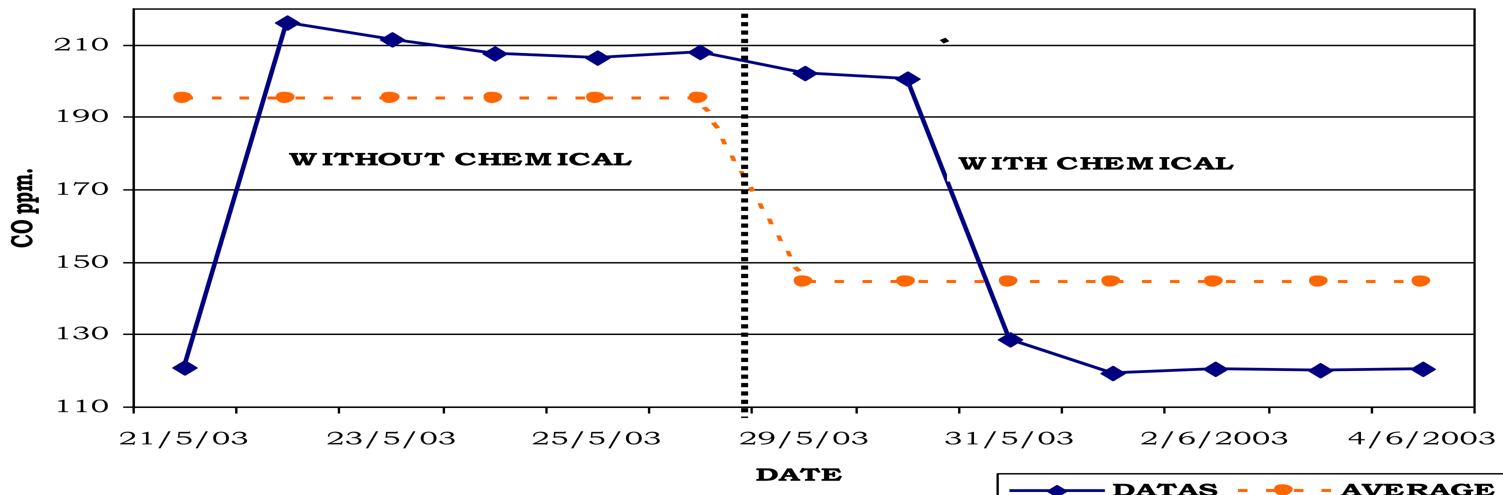


Fig. - 21 : REDUCTION IN LIME STONE FEEDING IN HPB # 3

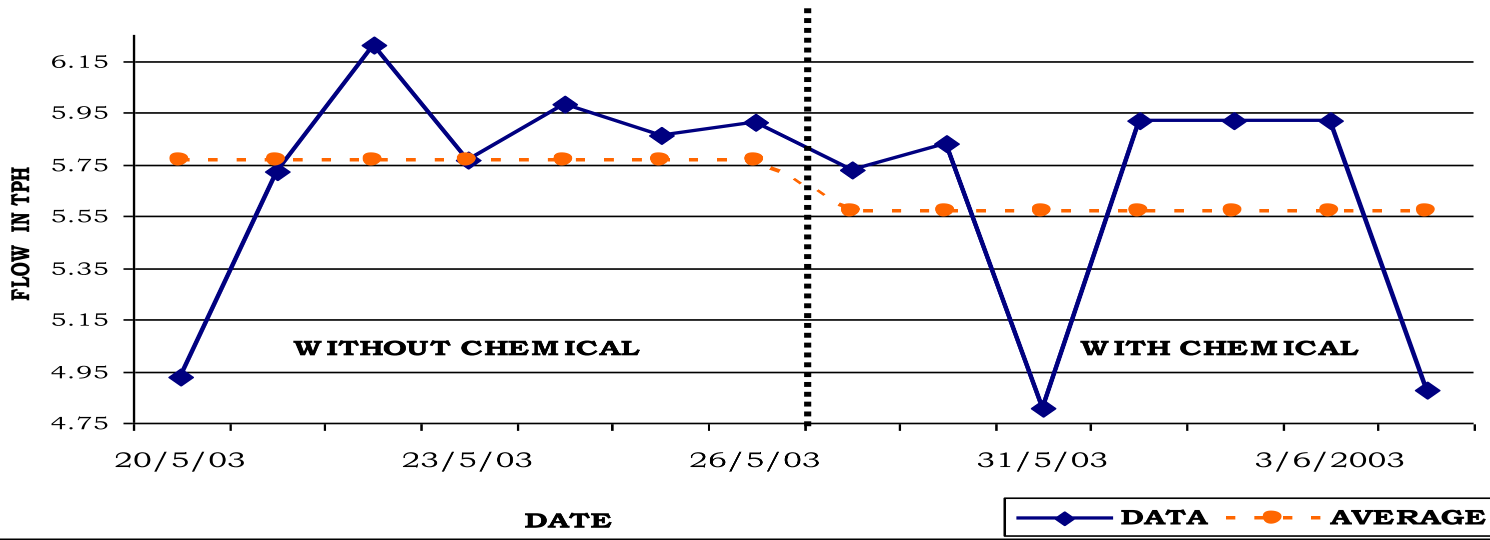
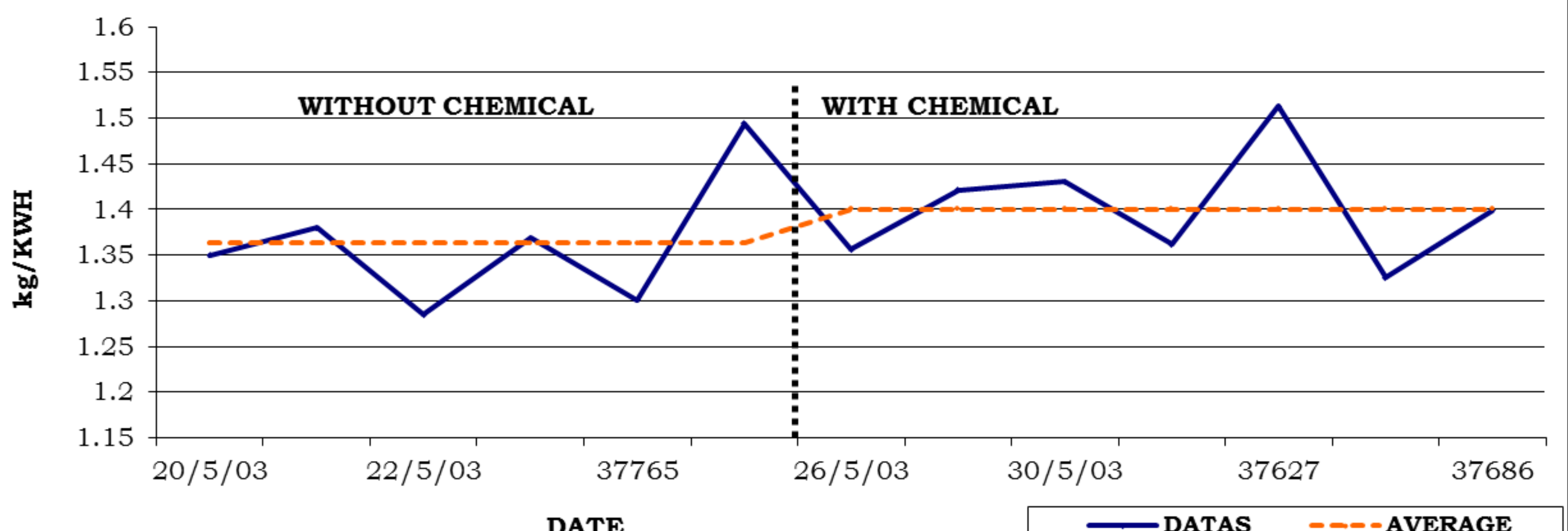


Fig.- 22 : IMPROVEMENT IN S.E.E IN HPB # 3



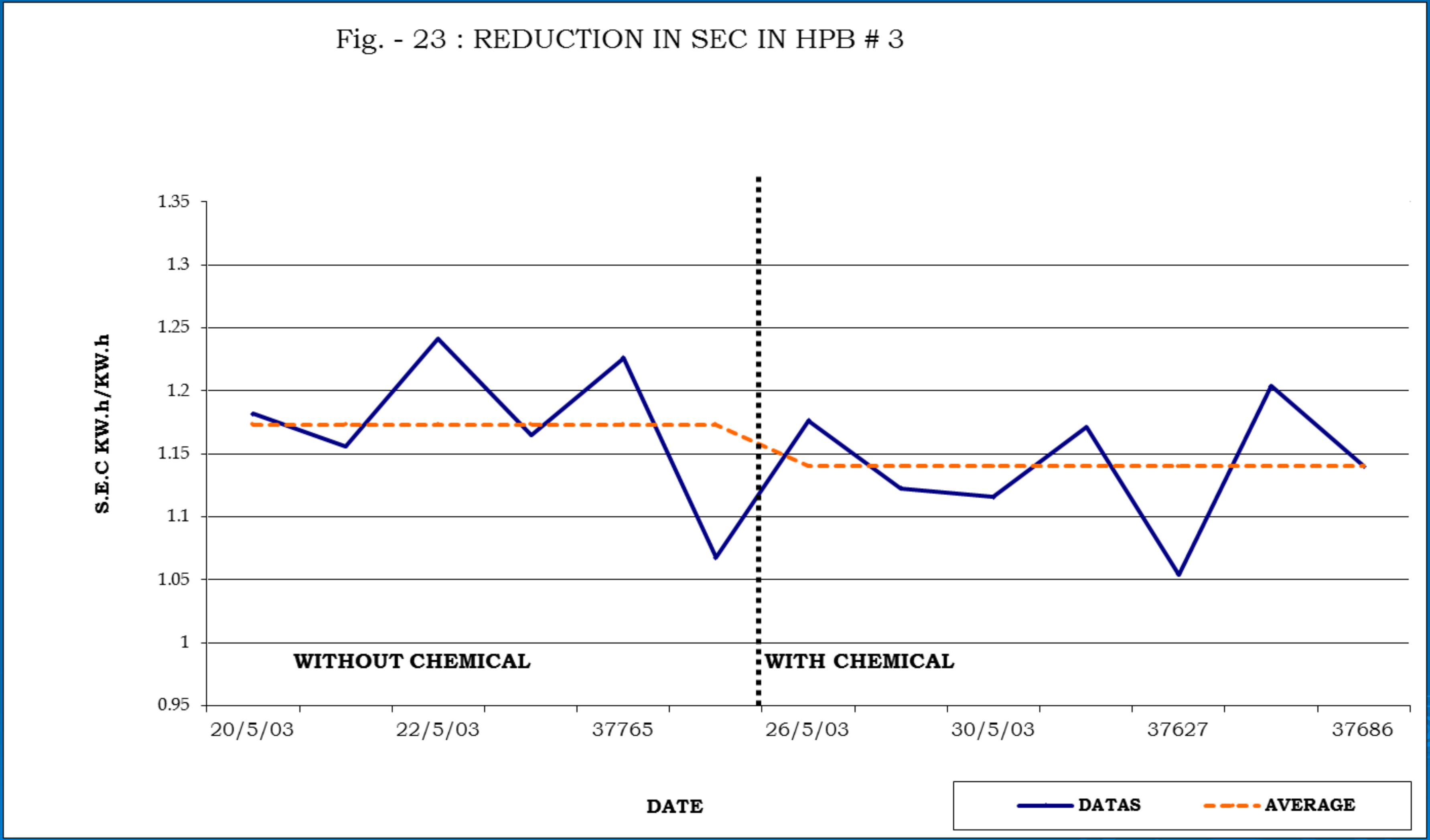


Fig. - 23 : REDUCTION IN SEC IN HPB # 3
S.E.C KW.h/KW.h
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
WITHOUT CHEMICAL
WITH CHEMICAL
20/5/03
22/5/03
37765
26/5/03
30/5/03
37627
37686
DATE
DATAS
AVERAGE

RESULTS

CEHP # 2	WITHOUT CHEMCIAL	WITH CHEMCIAL
CV Kcal/kg	5120.43	5054.7
M_{fuel} TPD	517.00	521.00
M_{steam} TPD	3274.43	3277.6
Δ h kJ/kg	2883.99	2876.76
Q_{in} MW	128.24	127.534
Q_{out} MW	109.30	109.13
S.E.E kg/KWH	1.36066	1.372
S.E.C KWH/kg	1.173	1.162
BOILER EFFICIENCY %	85.302	86.042

RESULTS

HPB # 3	WITHOUT CHEMCIAL	WITH CHEMCIAL
CV Kcal/kg	7023.50	7011.57
M_{fuel} TPD	520.86	512.29
M_{steam} TPD	4496.86	4431.16
Δ h kJ/kg	2966.34	2970.29
Q_{in} MW	153.21	173.33
Q_{out} MW	154.39	152.34
S.E.E kg/KWH	1.3937	1.4044
S.E.C KWH/kg	1.15751	1.13774
BOILER EFFICIENCY %	87.373	88.047

ALTRET® Trendsetters

ECONOMIC ANALYSIS

TABLE- A - 5 :- ECONOMIC ANALYSIS: CEHP # 2

I.) SAVING DUE TO REDUCTION IN FUEL CONSUMPTION

1.)	FUEL SAVING BY DIRECT METHOD:	0.94%
2.)	FUEL SAVING BY INDIRECT METHOD:	0.37%
3.)	AVERAGE FUEL SAVINGS CONSIDERING BOTH METHOD	0.65%
4.)	Avg. Fuel Consumption (TPD)	500.00
5.)	Fuel savings (TPD)	3.25
6.)	Economic savings per day (Fuel cost @ Rs. 1900.00/Ton)	Rs.6175.00

II.) SAVING DUE TO REDUCTION IN AUXILLARY POWER

Altret Trendsetters ®

1.)	Total Ampere Load Reduction	2.465	Ampere
2.)	Total reduction in KWH/Day	36.146	KWH/Day
	$P = 1.73$ V.I. $\cos \varphi$		
	$V = 415$ volts $\cos \varphi = 0.85$		
3.)	Total economic savings @ Rs. 0.50/KWH	Rs. 18.07	per day
4.)	**TOTAL ECONOMIC SAVINGS :** **I .(6) + II .(3)**	Rs. 6193.07	Per day
5.)	Chemical cost (@ 40 ppm & Rs. 285.00/kg)	Rs. 5700.00	per day
6.)	Net Economic savings	Rs. 493.07	Per day
7.)	Net Annual savings	[illegible]	

TABLE- B - 5 :- ECONOMIC ANALYSIS: HPB # 3

I.) SAVING DUE TO REDUCTION IN FUEL CONSUMPTION

1.)	FUEL SAVING BY DIRECT METHOD:	1.67%
2.)	FUEL SAVING BY INDIRECT METHOD:	0. 554%
3.)	AVERAGE FUEL SAVINGS CONSIDERING BOTHMETHOD	1.107%
4.)	Avg. Fuel Consumption (TPD)	525.00
5.)	Fuel savings (TPD)	5.118
6.)	Economic savings per day (Fuel cost @ Rs. 1900.00/Ton)	Rs.9724.20

II.) SAVING DUE TO REDUCTION IN AUXILLARY POWER

1.)	Total Ampere Load Reduction	13.06	Amp.
2.)	Total reduction in KWH/Day	191.50	KWH/Day

$P = 1.73$ V.I. $\cos \varphi$

$V = 415$ volts $\cos \varphi = 0.85$

3.)	Total economic savings @ Rs. 0.50/KWH	Rs. 95.75	per day

III.) SAVING DUE TO REDUCTION IN LIME STONE ADDITION

1.)	Average Reduction In Lime Stone addition	4.80	TPD
2.)	Saving due to reduction in Lime stone (@ Rs. 2000.00 Tons)	Rs. 9600.00	
3.)	**TOTAL ECONOMIC SAVINGS : I .(6)+II.(3)+III.(2)**	Rs. 19,419.95	Per day
4.)	Chemical cost (367.50 TPD Petcoke @ 50 ppm ÄLTRET"95 R & Rs. 365.00/kg) (158.5 TPD Coal @ 70 ppm ÄLTRET"95 SCA & Rs.234.00/kg)	Rs. 9303.11	per day
6.)	Net Economic savings	Rs. 10,116.00	Per day
7.)	Net Annual savings	**Rs. 35,40,600.00 /Yr.**	

CONCLUSION

- The benefits observed are quite high due to:
  - Longer boiler availability
  - Reduction in down time
  - Reduction in oil consumption
  - Reduced boiler outage due to reduction in clinker formation
  - More M.W.H generation due to reduction in fouling and cleaning time.

CASE STUDY

MANIKGARH CEMENT

CHANDRAPUR

BOILER DETAILS

- **BOILER TYPE** : F.B.C
- **MAKE** : CVL
- **CAPACITY** : 30 TPH
- **PRESSURE** : 32 kg/cm^2
- **FUEL** : Coal

PROBLEM FACED

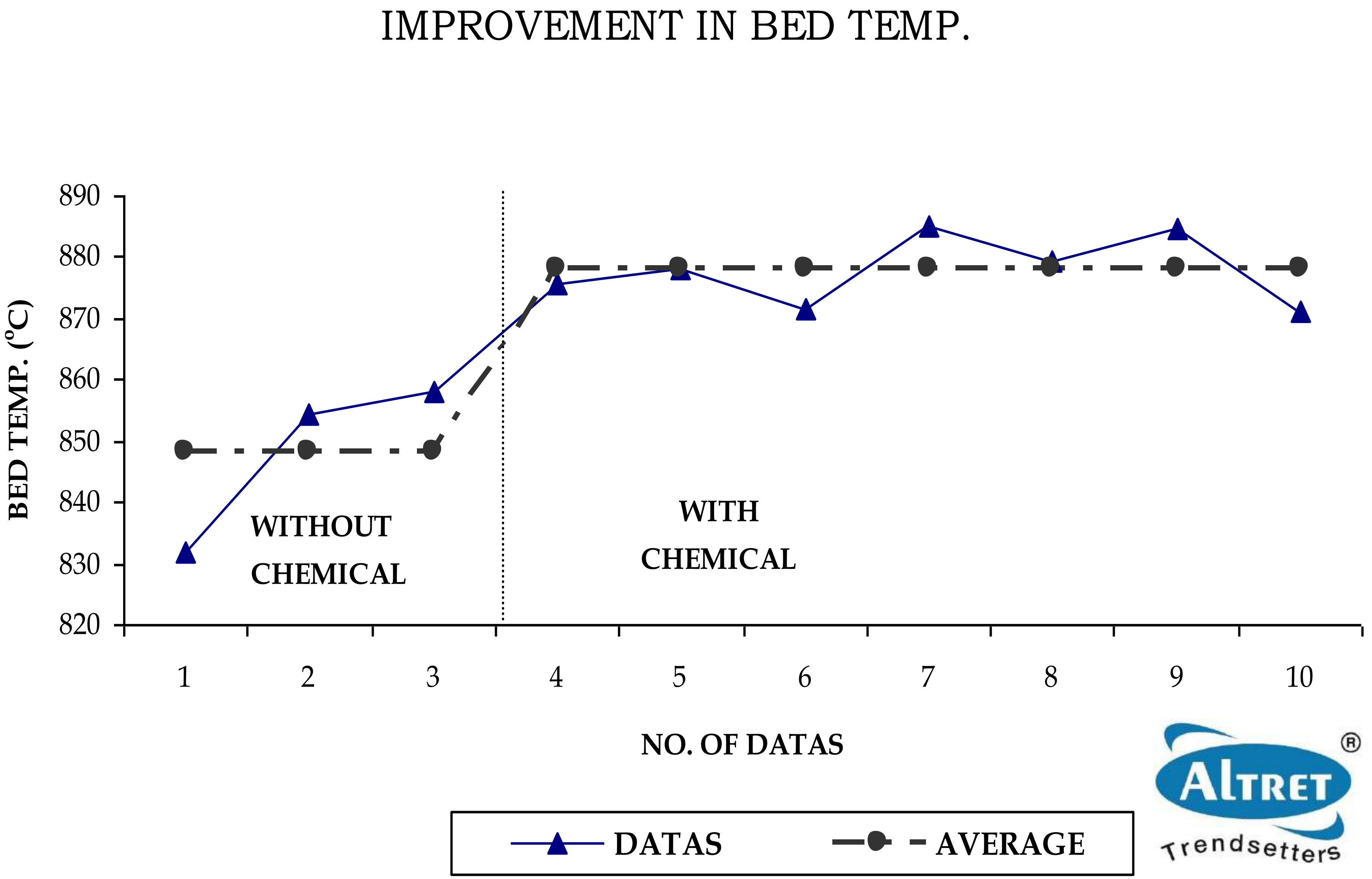
- Higher Unburnt Carbon in Bottom & Fly Ash

- Require improvement in Boiler Efficiency

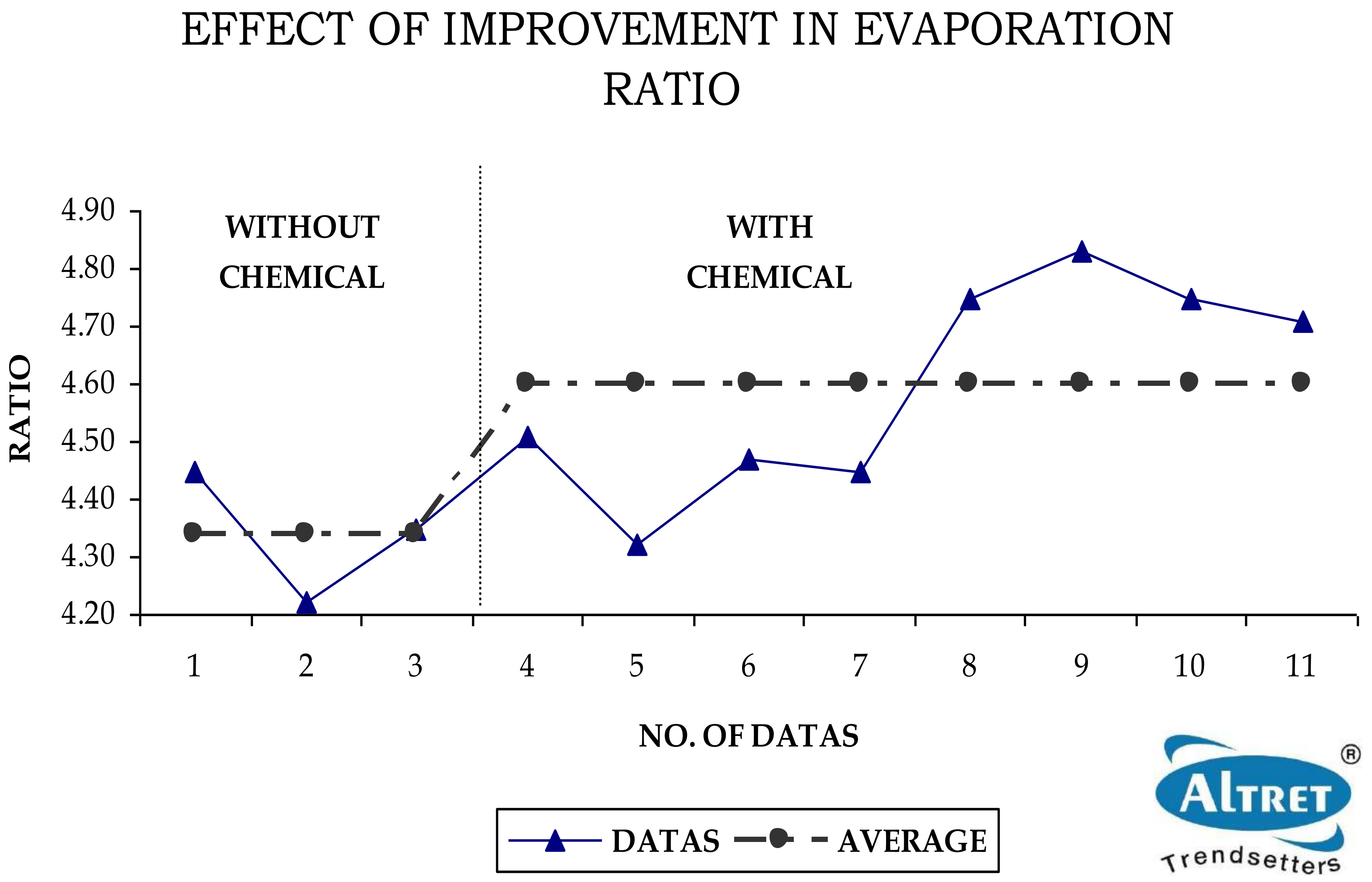
SOLUTION

- Chemical suggested: “ALTRET” 95 SCA
- Dosage: 50 ppm

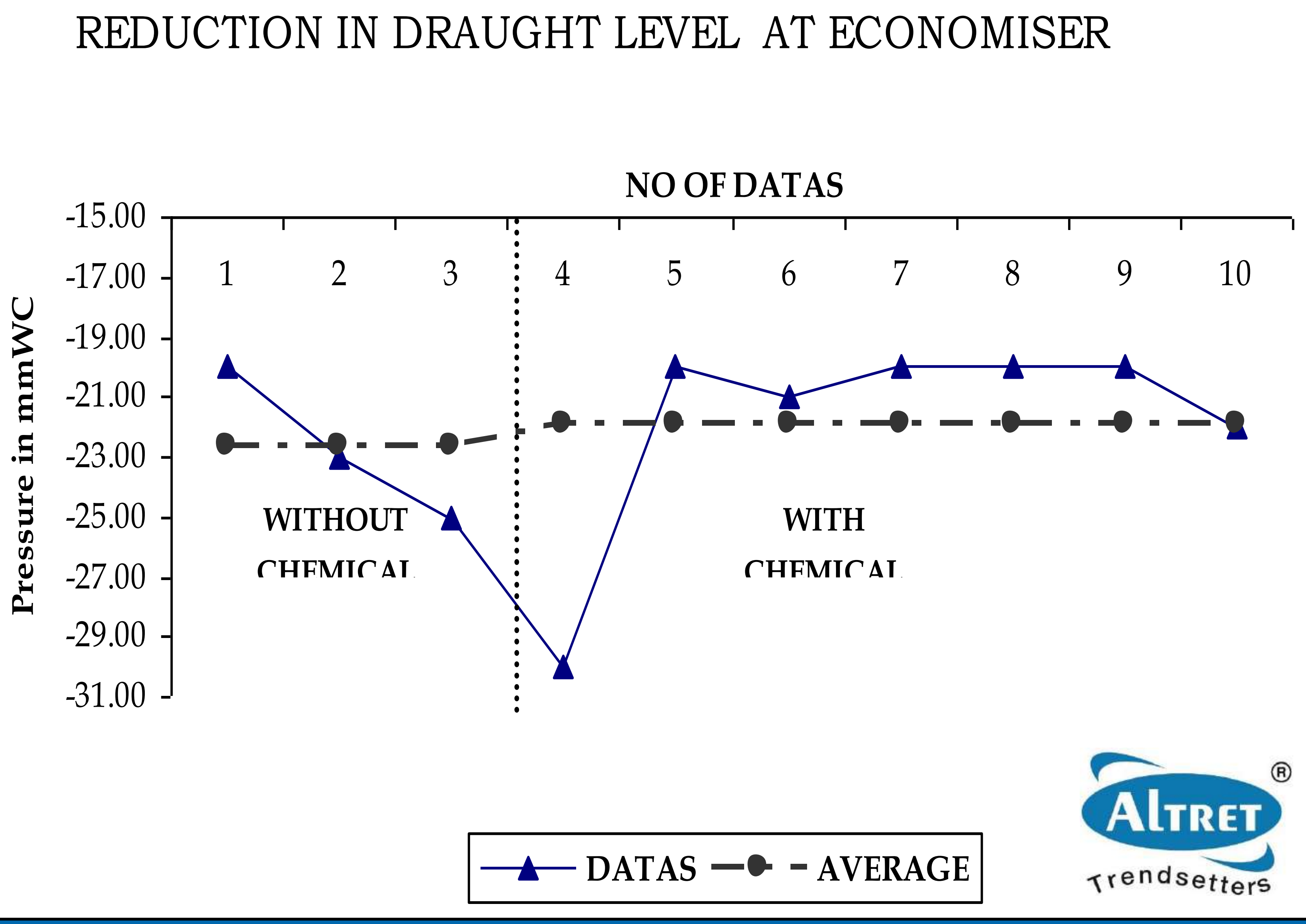
Catalytic Effect



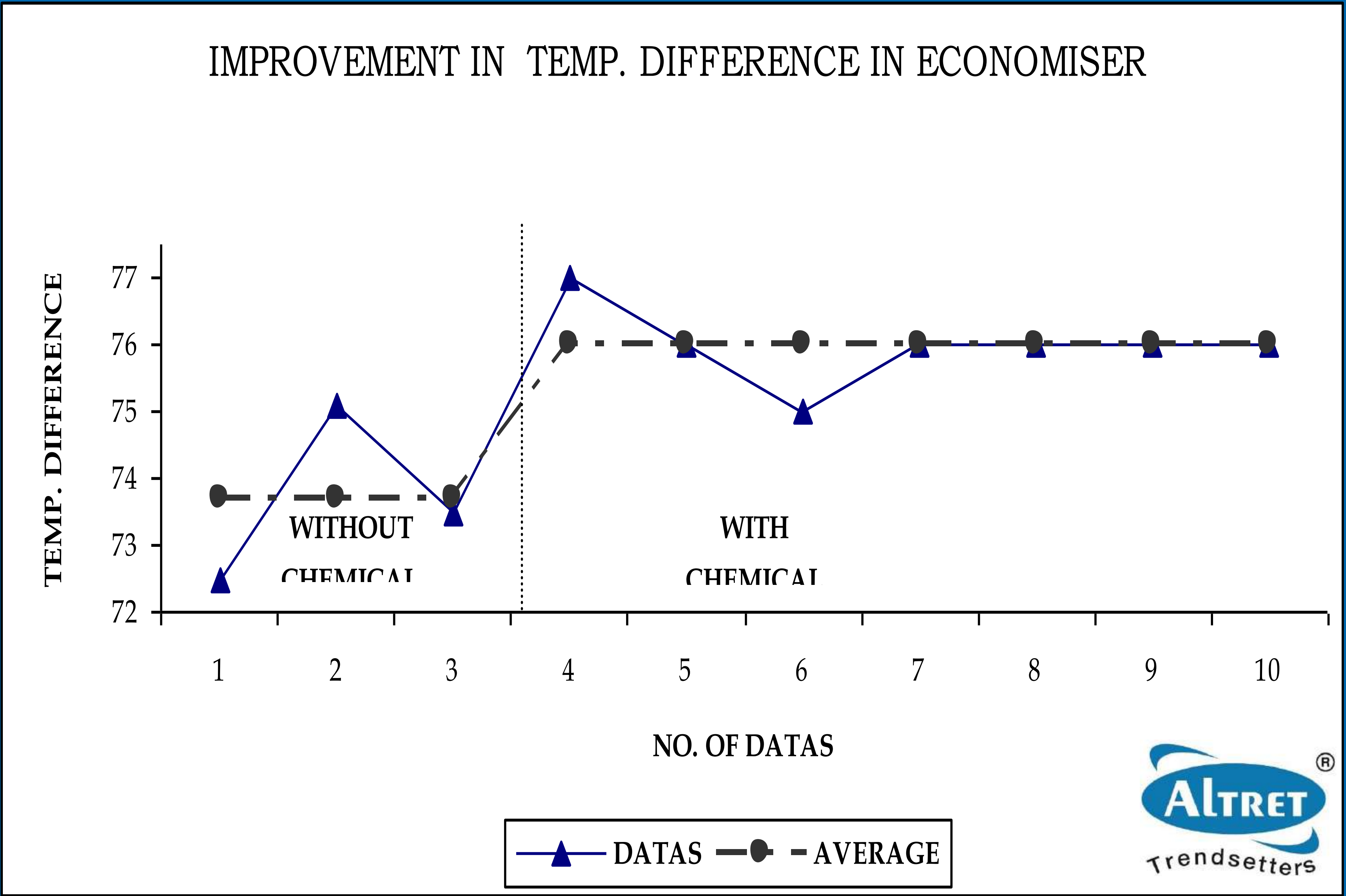
Catalytic Effect



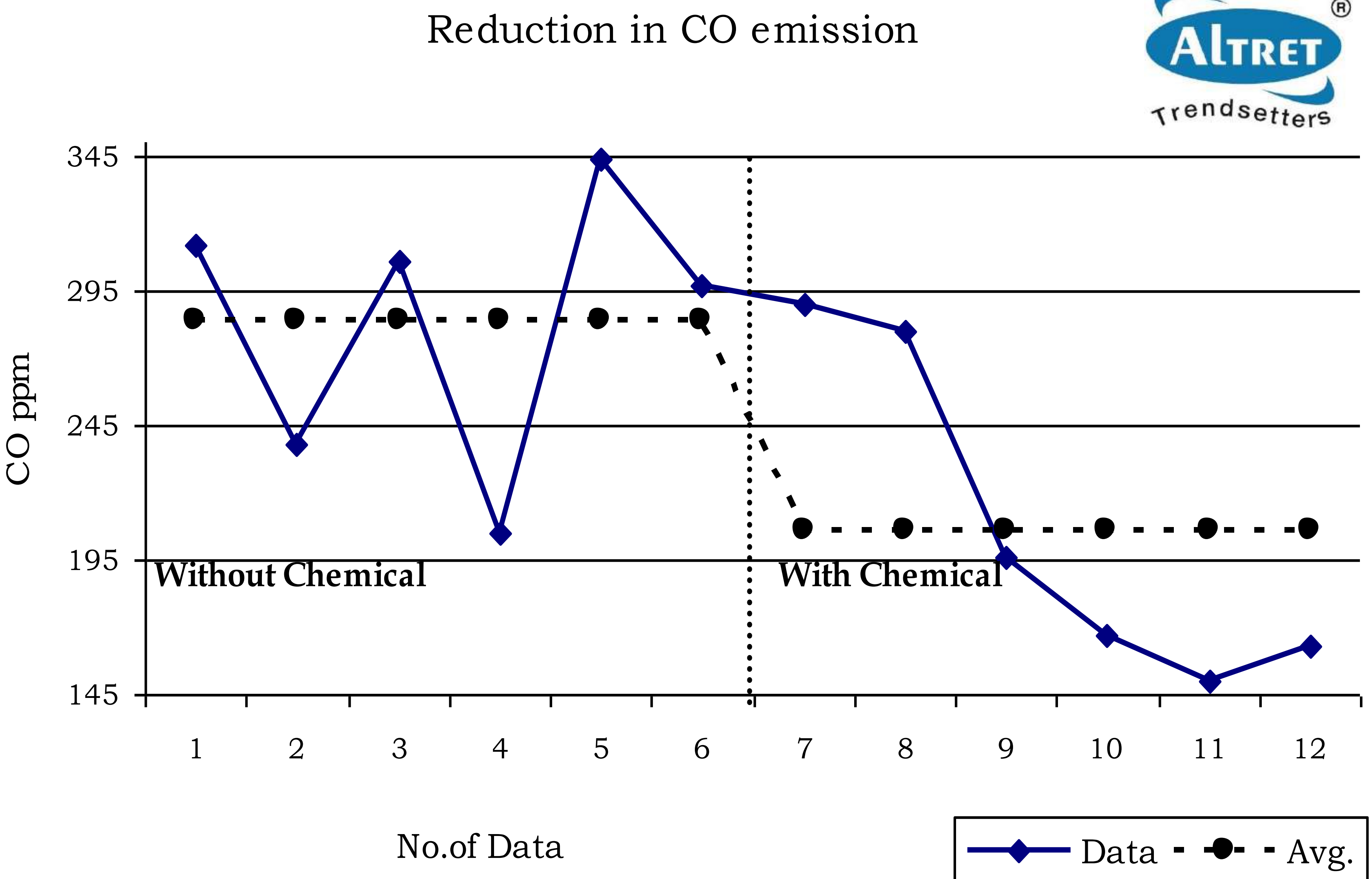
Anti-Fouling Effect



Anti-Fouling Effect



Anti-Emission Effect



RESULTS

Parameter	W/O Chem.	With Chem.	% Improvement
Boiler Eff. (%)	84.74	85.68	1.109
Combustion Eff. (%)	78.00	79.80	2.30
Evaporation Ratio	4.34	4.60	5.99
Unburnt Carbon in Bottom Ash (%)	6.89	5.49	20.31
Unburnt Carbon in Fly Ash (%)	7.97	6.30	20.95
Fuel Savings (T/Yr)	900		
Net Eco. Savings (Rs./Yr)	6,28,320/-		

CONCLUSION

- Reduction in feeder RPM & improved boiler and combustion efficiency and also by reduction in unburnt carbon shows a definite reduction in fuel consumption.

THANK YOU

- **Indexes of Coal Ash Fusibility :**

1. *Silica Ratio (SR):*

$$SR = \frac{SiO_2}{SiO_2 + Fe_2O_3 + CaO + Mg}$$

$$SR \leq 0.5 : Fouling\ \ Inevitable$$

2. *Schaefer's Ratio (SCR):*

$$SCR = \frac{Al_2O_3}{SiO_2} \times \frac{[SiO_2 + Al_2O_3]}{[Fe_2O_3 + 0.6\{CaO + MgO + Na_2O + K_2O\}]}$$

$$SCR \leq 0.1 : Fouling\ \ Inevitable$$

3. *Dolomite Ratio (DR):*

$$DR = \frac{CaO + MgO}{Fe_2O_3 + CaO + MgO + Na_2 + K_2O}$$

$$DR \leq 0.5 : Fouling\ \ Inevitable$$

METHODOLOGY AND MEASUREMENTS :

To increase the correct qualitative and quantitative influence of “ALTRET” 95SAC combustion catalyst in reducing unburnt carbon levels in ash, fouling of heat transfer surfaces, clinkering and SO_2 emissions, two stages of investigations were planned on Lignite based Unit No.1 & Unit No. 3 of 70 MW capacity each at KLTPS, GEB, Panandhro, Gujarat. Boiler of Unit No. 1 is essentially multi-tier, tangentially fired PF boiler employing beater wheel type mills and generating steam at 94 kg/cm^2 pressure, 515°C temperature and 325 T/h flow rate. The boiler of Unit No. 3 is a single tier, PF boiler having the same rated parameters.

- **Stage- I : Base Data Generation :**

During the first stage of trial various data on boiler parameters and emission characteristics was collected from 15^{th} July 2001 to 12^{th} August 2001 [for about 500 hours] without use of any fuel additive. This data forms the basis for comparison.

The data collected include hourly variation of steam pressure, steam temperature , feed water flow rates, steam generation rates, various temperature levels and draft levels. The SO_2 emissions were measured once or twice in a day as per the convenience. The hourly data of boiler parameters so collected is transformed in daily averages and finally to an overall average over a trial period. [One overall average data point represents the average of about 500 hourly data points]. This data formed not only the base data but provided sufficient insight on the actual operations of both the boilers.

- **Stage- II : Data Generation with Combustion Catalyst :**

In the second stage of trial, "ALTRET" 95 SCA combustion catalyst was dosed at 20ppm level [30gms/tonne of lignite] from 14th August 2001 to 4th Sept. 2001 and the data was collected in a similar way as in stage- I.

The water quality, fuel quality, unburnt carbon levels in ash and SO_2 emissions were regularly measured as per relevant standards [18-31] for both stages of trial. The samples o lignite from each mill feeders were collected twice in a day from Unit No. 1 & Unit No. 3. the daily samples so collected were mixed and its proximate analysis and GCV were evaluated for both the boiler. The overall average values are given below in Table-1.

Table – 1 Overall Average Lignite Quality During both Stages of Trial

Sr. No	Parameters	Unit No.1		Unit No. 3	
		Stage- I	Stage-II	Stage – I	Stage-II
1.	Total Moisture, %	34.85	33.29	33.18	31.75
2.	Fixed Carbon, %	19.7	18.23	21.17	19.12
3.	Volatile, Matter, %	27.89	26.04	29.68	27.61
4.	Ash Content, %	17.56	22.44	15.97	21.52
5.	Sulphur, %	1.93	2.204	1.93	2.204
6.	GCV, MJ/kg	11.886	11.309	13.024	11.677

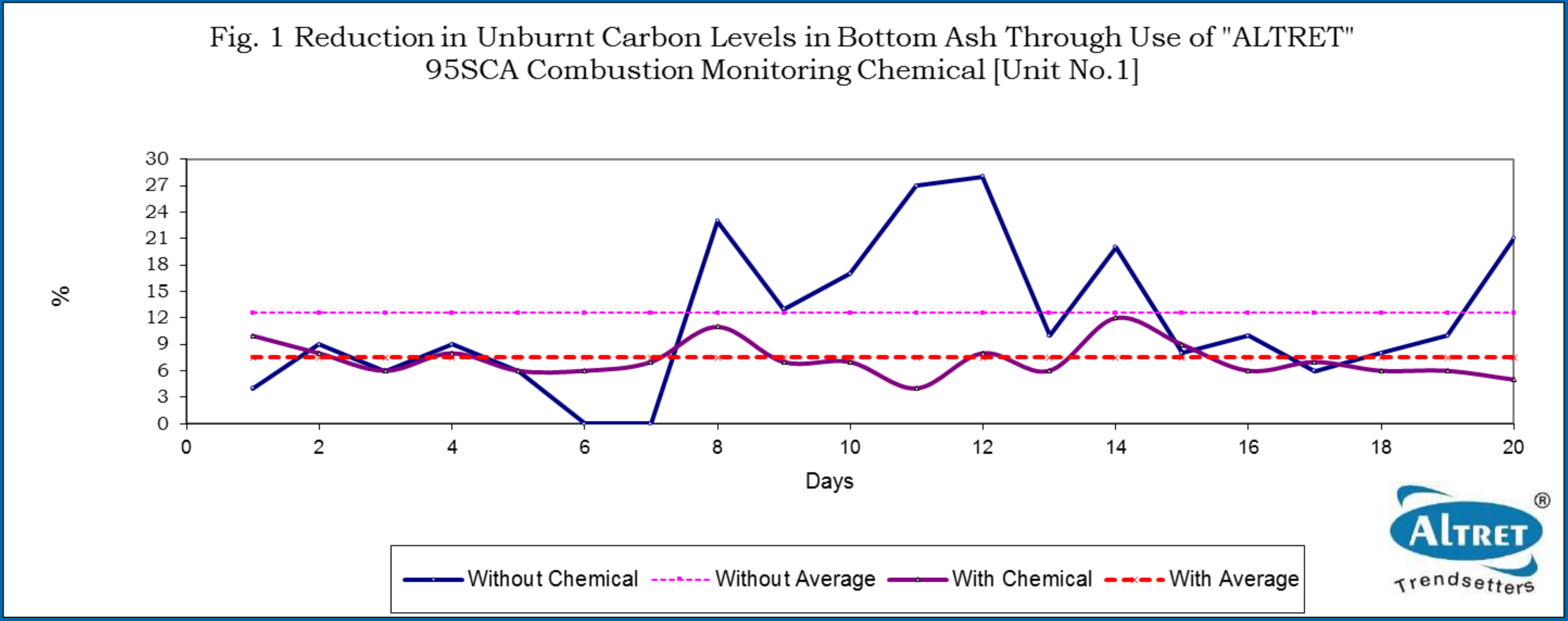
ALTRET® Trendsetters

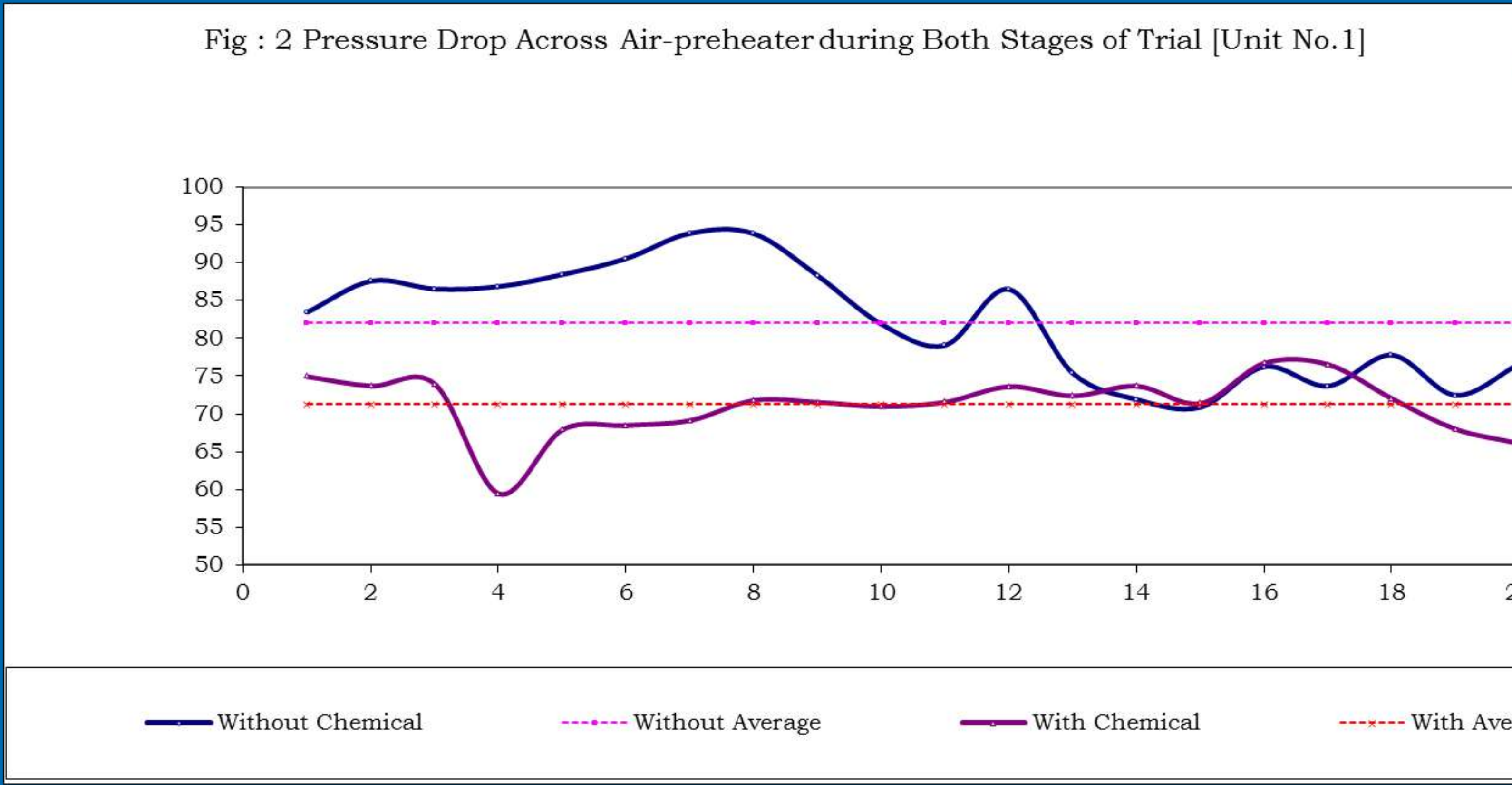
RESULTS & DISCUSSION :

- **Catalytic Effect :**

The catalytic effect of "ALTRET" 95 SCA fuel additive may be ascertained by reduction in unburnt carbon levels in ash. Fig. 1 shows the variation of unburnt carbon in bottom ash of Unit No. 1. it is observed that average unburnt carbon is reduced from 12.59% to 7.56% indicating a relative decrease by 39.95 through the use of "ALTRET" 95 SCA Combustion Monitoring Chemical. It is also worth to mote here that this decrease is achieved in spite of the fact that the fuel contains more ash in second stage of trial. There is also marginal reduction in unburnt carbon levels in bottom ash of Unit No. 3 The reduction in Unit No. 3 is marginal which is due to problem of single tier firing.

This reduction in unburnt carbon levels in bottom ash clearly signifies catalytic effect of this fuel additive which improves reaction area & oxygen penetration. Due to such multiple chain action, the unburnt carbon levels in ash reduces.





- **Anti Fouling Effect :**

Fig. 2 & 3 shows the pressure drop across air pre-heater and boiler respectively in Unit No. 1. In boiler No. 1 the pressure across air-pre-heater is reduced from 82.07 mm of H_2O to 71.26mm of H_2O by about 13.17% while across the boiler as a whole it reduced from 196.39 mm of H_2O to 188.16 mm of H_2O indicating a reduction by 4.19%.

Anti-emission characteristics :

Fig. 8 and Fig. 9 highlights the influence of "ALTRET" 95 SCA combustion monitoring chemical on SO_2 emission in Unit No. 1 & unit No. 3, respectively.

A remarkable decrease from 1242.35 ppm to 994.54ppm i.e. 19.95% in Unit No. 1 & from 1243.41 ppm to 946.52ppm indicating a decrease by 23.88% in Unit No. 3 is observed through use of "ALTRET" 95 SCa combustion monitoring chemical.

Further, it is worth to mention here that during second stage of trial, sulphur content was higher [2.204% in second stage] as compared to that in 1st stage [1.93% in 1st stage]. If one assumes same sulphur content in fuel, SO_2 emission may be reduced by about 40%.

Fig. 8 Influence of "ALTRET" 95SCA Combustion Monitoring Chemical on SO_2 Emissions [Unit No.1]

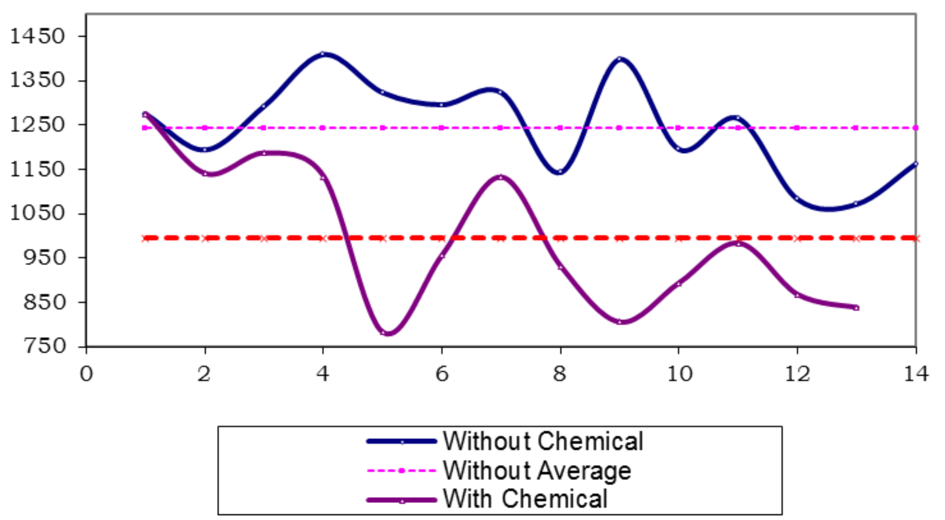


Fig. 9 Influence of "ALTRET" 95SCA Combustion Monitoring Chemical on SO_2 Emissions [Unit No.3]