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Coal Extraction System with Pulse Jet Bag Filter

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Abstract

Air pollutants are added into the atmosphere from variety of sources that change the composition of the atmosphere and affect the biotic environment. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is getting adversely affected. In Mettur thermal power station (MTPS) primary fuel is coal. The requirement of coal per day 14000 tons. The coal transported through railway wagons has been unloaded in wagon Tripler. From the wagon Tripler During the coal unloading activity, enormous coal has been extracted from the coal transfer chute, which in turn polluted the entire coal handling area. Hence, to tide over the problem, it is necessary to go for effective coal control measures in MTPS. In pulse jet bag filter, the coal that is disc lodged from a row of bags may be picked up by the adjacent row of bags as the latter is under suction. The coal may remain is suspended condition- especially if it is light and / or fine - the reverse upward gas flow not allowing the coal to settle in the hopper. This phenomenon is called fluidization of coal. The coal particles are sucked from the suction point and allowed to the bag filter. The air from the suction point is made to fall on the baffle plate and then it is allowed to the bags. This air goes to the bottom of the bag, then it comes out on the top of the bag there all the coal particles are collected on the outer surface of the bag. Then the cleaned air is sent out through the chimney.

Keywords: Chute,Wagon Tripler,MTPS,Pulse jet bag,Hopper,Chimney, RAV,Solenoid Valve.

Introduction

A Coal extraction system used to extract the coal, which emanate or produced during any process in industries. The Coal which is extracted by the coal extraction system has been collected and disposal in such a way to maintain continuous process of manufacturing and to maintain a good working environment, and to control the pollution in the working area [1].

The coal extraction system consists of suction blower, suction points, ducts, coal separation unit, chimney, etc.

In Mettur thermal power plant station there are 12nos of the coal extraction system are used in coal handling plant, to extract the coal which are emanated during the process of coal handling plant.

Each coal extraction system in Mettur thermal plant station consists of two ducts. The inlet duct is connected to the

suction points and outlet duct is connected to the chimney. There are about five suction points in each coal extraction system. These suction points are placed on the top of the conveyor belt and an apron feeder discharge chute. The blower has created the vacuum inside the duct. Due to this vacuum in the suction pipe coal from the conveyor belt and discharge chute has been extracted and transmitted to dry cyclone separator[2].

In cyclone separator the coal particles are separated and pure air sent to the blower and separated coal particles and transmitted to the hopper[21][22]. The hopper is placed below the cyclone separator for the collection of coal particles which were filtered by the cyclone separator. The cyclone separator separates the coal from the air and dumps the coal into the hopper[3].

Hopper is attached to the rotary air lock feeder. This rotary air lock feeder is fitted at the bottom of the hopper which is used to arrest the entry of atmospheric air into the hopper and it is discharges the coal particle, from the hopper[23][24].

This rotary lock feeder is driven by motor with gear box for the removal of coal, which is collected at the hopper.

The air along with some coal particles entered into blower has been discharged through the chimney which is fitted with a nozzle at the top as per chimney calculation[4]

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Components of coal extraction system in Mtps

The coal extraction system mainly consists of a blower, motor, chimney, coal, cyclone separator, hopper. Rotary air
lock feeder, suction points and conveyor belts etc.The detailed specification and arrangement each of the above equipment as being described below.

Motor

Coal extraction system MTPS the three phase induction motor is used to run the blower and it sucks the coal from the coal transfer chutes. This motor needs 415 volts,50c/s 3 phase A.C power supply to run the blower.V-belts are used for power transmission from the motor to the blower. The belt has 7 grooves and type of that is c158 motor runs at
1435 rpm.

Blower

The Blower is connected with the 3 phase induction motor.the fan wheel which is used in the blower is attached to the motor which makes this fan wheel to rotate at high speed and sucks the air from the atmosphere through the inlet and releases the air through outlet . Due to the function of the blower vacuum I created at the suction side of the ducts .

Suction points

There are 5 suction points in the coal extraction system. These suction points are placed on various conveyor belts. The first and second suction points are placed on the belt feeder discharge chutes at conveyor 6A and 6B. Third suction point is placed on the conveyor 1 to 4 discharge chutes at the conveyor head end. The Fourth suction point is placed on the apron feeder discharge chutes at the conveyor tail end[5]. The fifth suction point is placed on the apron discharge chute at apron feeder. These suction points are placed above the conveyor belt. Coal is dumped on the conveyor belt. This belt made to move with the help of the pulley which is attached with the motor. Then these coals are dropped from the conveyor belt at a certain distance to another conveyor belt. During this process the coal particles which emanated from coal is extracted in the suction points.

Dry cyclone separator

Cyclone separator is a conical spaced apparatus. The ducts from the suction points are attached to the parallel pipe which is placed inside the conical shell. The bottom of the shell is attached to the hopper and the top end of the shell is attached to the inlet of the blower duct . Conical separation is a method of discharging particulates from an air without the application of filters by vortex separation. Rotational operation and application of gravity are used to separate the mixtures of air coal. The method can also be used to separate fine coal particles[6]. By using the vacuum air which is created by the blower at the suction points makes the coal particles to suck from the coal[7].

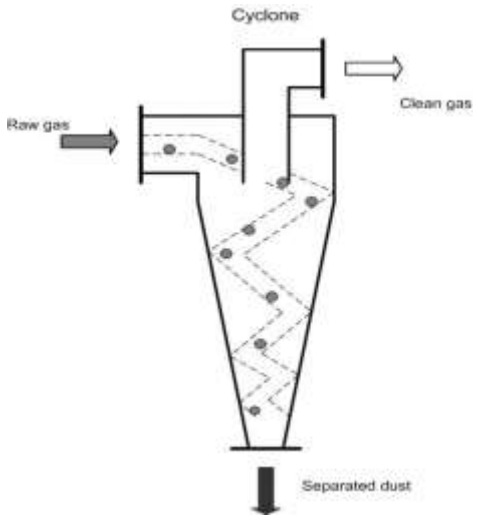

Fig 1.3 Dry cyclone separator

Hopper

The separated coals in cyclone separator enter into the hopper. Hoppers are rectangular in cross section but have sides that the slope at about a 60 angle. Slanted sides make it easier to remove coal. The hopper is made up of a 6mm MS plate.

Fig 1.4 Hopper

Rotary air lock feeder

The rotary air lock feeder used to discharge coal particles from a hopper, Maintain the operating pressure in the system. The motor in rotary air lock feeder has been fitted with reduction gear box of ratio 1:86:25.The speed of the rotary air lock feeder is 16

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rpm.The sprocket and chain have been used to drive the feeder. The rotary air lock feeder is fitted at the bottom of the hopper to arrest the entry of air into the hopper.\ from the atmosphere and it discharges the coal particle from the hopper as a caked shape.

Fig 1.5 Rotary air lock feeder

Chimney

The height of the chimney in MTPS is 11mts and diameter 800mm.It is made up of 6mm mild steel sheet. It is attached to the outlet of the blower and a nozzle arrangement is fitted at the top of the chimney. Nozzle increases the velocity of the cleaned air from the blower to the atmosphere, These chimneys are used for smoothly venting out of filtered air from the blower to atmosphere. The chimneys are long in length and also it is decided according to the outlet pressure of the blower.

Experimental method

In coal extraction system the three phase induction motor is used to run the blower and the blower in turn created negative pressure on the suction side of the ducts and due to this duct exerted from the coal transfer chutes has been sucked. This motor needs 415volts, 50c/s 3 phase A.C power supply to run the blower. V belts are used for power transmission from motor to blower. The motor runs at 1435rpm. This motor is attached to the blower.

The blower in the coal extraction system is driven by the motor through V belts. The blower in MTPS of axial inflow and radial outflow type. It has a straight blade along with shaft and Plummer block with its bearing. The blower is rotating at the speed of 1435rpm. The capacity of the blower is 3600m3/hr.The blower has created negative pressure in the suction side and positive pressure in the delivery side. The coal emanated in the coal transfer chutes has been extracted through the suction mouth pieces and the air coal mixtures travelled through the duct and enter into cyclone separator.

The ducts from the suction point are connected to the barrel pipe which is placed inside the conical shell. The bottom of the shell is attached to the hopper and the top end of the shell is attached to the inlet of the blower duct. Cyclonic separation is a method of removing particulates from an air,without the use of filters. Rotational effects and gravity are used to separate mixers of air coal mixtures. The method can also be used to separate fine coal particles. These coal particles are collected at the hoppers. Then the coal particles which are collected at the hopper are removed by using rotary air lock feeder.

The rotary air lock feeder is used to arrest the entire of atmospheric air into the hopper inside and easily disposed of coal particle from the hopper.The feeder is connected through gear motor. The gearbox is used to reduce the motor speed. A rotary blade is used to cut the coal particles from hopper to discharge chute.Then the filtered air is sent out to the atmosphere through chimney from the blower. Chimney is attached to the outlet of the blower and nozzle is fitted at the top of the chimney. Nozzle increases the velocity of the cleaned air from the blower and allows to the atmosphere.

Ambient air quality and suspended particulates matter in MTPS

Air pollutants are introduced in the atmosphere from varying sources that alters the composition of the atmosphere and upset the biotic environment[8]. The concentration of air pollutants depends not only on the quantities that are expelled from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions[9]. The air pollution concentration varies spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is getting adversely affected[10].

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In Mettur thermal power station primary fuel is coal. The requirement of coal per day 14000tons. The coal transported through railway wagons has been unloaded in wagon Tripler. From the wagon Tripler coals transmitted to various conveyor through transfer chute. During the coal unloading activity, enormous coal has been extracted from the coal transfer chute, which in turn polluted the entire coal handling area. Hence the working area in this coal handling plant becomes coally which in turn harmful to personnel working in this area[26][27]. Hence it is necessary to control the pollution level in this area. In line with condition stipulated by the pollution control board.
The air pollution in the Mettur thermal power station i n coal handling plant 1 is shown below.

SL.NO	CONVEYOR 1	CONVEYOR 2
SPM	19mg/m^3	5mg/m^3

Table 3.1 Pollution at conveyors

Problem identification

In Mettur thermal power station 140000tons of coal has been handled per day with the help of wagon Tripler. As per pollution control ACT 1981 the coal level in coal handling area should be 0.2mg/m3 inside the plant. But pollution is more in the plant. The coal extraction systems available in the plant are not more effective in controlling the pollution. The above reading of the latest ambient air quality clearly exhibits the pollution level in MTPS. Hence, to tide over the problem, it is necessary to go for effective coal control measures in MTPS.

Experimental testing

Pulse jet bag filter

In online bag filter, bags are cleaned row by row, eve n while the coal laden gas is filtered concurrently. The sequence of cleaning is controlled automatically by a sequence controller [24]. This operates the assem bly of solenoid and pulse valves which direct the a ir flow into the manifolds. The holes are jig drilled fo r perfect alignment with the venture centre for achievi ng maximum cleaning efficiency[11].

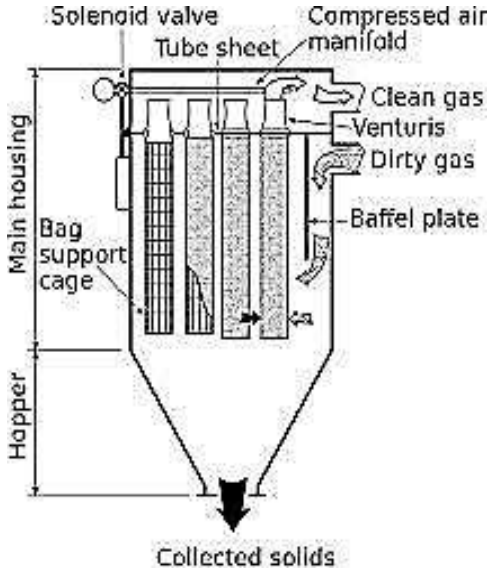

Fig 5.2Arrangement of Filters

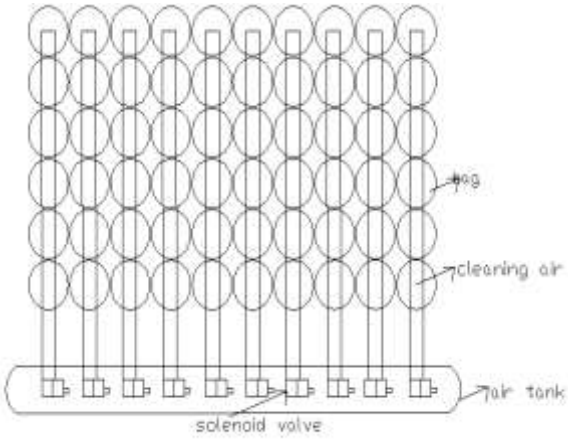

Fig 5.1 Section view of Pulse Jetbag Filter

Fig 5.3 Schematic Entire View of Filter Bag and associated components

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Bag filter data sheet

BAG FILTER DATA		
SI.NO	**DESCRIPTION**	**COAL HANDLING SYSTEM**
1	System No	Coal extraction system
2	Location-building	Wagon Tripler
3	**INLET AIR**	
	Quantity m^3/hr	36,000
	Temperature(^{0}c)	Below 100^{0}c
	Inlet coal load(g/cum)	10
4	**FILTER DATA**	
	Type of cleaning	Pulse jet
	Total filtering area(sq.m)	450m^2(approx)
	Air to cloth ratio(CUM/SQM/MIN)	Above 1.5
	Pressure drop across bag filter(pa)	125-150
	No of filter bags	60
5	**MATERIAL OF CONSTRUCTION**	**MS PLATE**
	Casing material & thickness	Ms-(with stiffer)
	Bag holding plate	Ms-5mm
	Hopper material & thickness	Ms-6mm
	Number of hopper	1
	Hopper valley angle	55^0-60^{0}c
	Overall dimension(L*B*H)in mm	To suit the existing space when the cyclone is fitted
	Fabric weight	500gms
	Max. admissible temp	120^{0}C
	Fabric dimension	Dia 160mm*3720(lg)mm
	Type of fastening	Snap belt
7	**BAG CLEANING MECHANISM**	
	Type	pulse jet cleaning
	Quantity of solenoid size	10
	Solenoid valve size	40 N.B
	Venture provided	M.S. PLATE
	No of venture	60
	Compressed air quantity(Nm^3/hr)for bag cleaning	67
	Compressed air pressure(kg/sq.cm.g)	5 to 6(mandatory at solenoid valve inlet)
8	**COAL DISPOSAL**	
	(Rotary air lock feeder)size	200dia or 200mm *200mm
	Rotary air lock motor rating (kw/rpm)	0.5/(24-25)rpm
	Rotary air lock feeder	1
	Rotary air lock drive arrangement	Coupled drive with geared motor
	Coal emission level at stack outlet	Limited to 50gm/Nm^3
	Coal disposal below rotary air lock feeder	Through existing chute/pipe to lorry loading

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Typical characteristics of bag materials

5.3 TYPICAL CHARACTERISTICS OF BAG MATERIALS:

FABRIC TYPE	MAX.TEMP POSSIBLE	FLEX ABRASION	MOISTURE	ACID	BASE	ORGANIC
POLYLPROPYLENE	90°C	GOOD	EXCEL	EXCEL	EXCEL	EXCEL
ACRYLIC	120°C	GOOD	GOOD	GOOD	GOOD	GOOD
POLYESTER	130°C	EXCEL	FAIR	FAIR	POOR	GOOD
NOMEX®	190°C	GOOD	POOR	POOR	FAIR	GOOD
FIBER GLASS	260°C	POOR	EXCEL	EXCEL*	EXCEL	EXCEL
PPS	180°C	GOOD	GOOD	GOOD	EXCEL	GOOD

*Except fluorine

Experimental arrangement of pulse jet bag filters

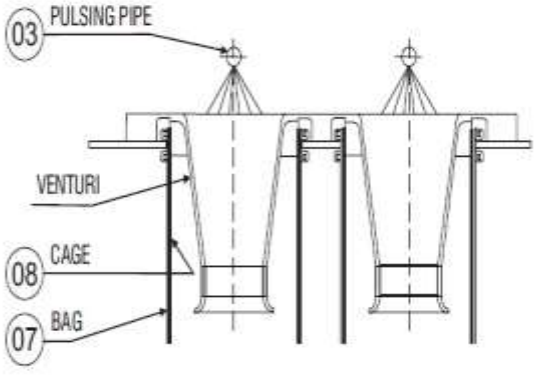
Bag/Cage/Venturi Arrangement:

Cages are wire frames placed inside pulse jet filter elements to provide support to the fabric as flexing occurs during filtration and cleaning cycles[12].Cages for long filter elements are made in sections which snap together for easier handling .Wear points on filter bags may develop at the horizontal supports .

Cage designs to reduce these points increase the number of vertical wires and reduce the horizontal supports. Protective coating on cages can extend the life of the cage and the bag. Coating such as vinyl, epoxy,zinc,and

Teflon may be used[13].

Snap Type Ring Bag



Solenoid Pulse Valve:

The pulse of compressed air is controlled by series of pulse solenoid valves that are placed on air reservoir .The diaphragm of the pulse valve is closed as the compressed air is trapped between diaphragm and solenoid valve

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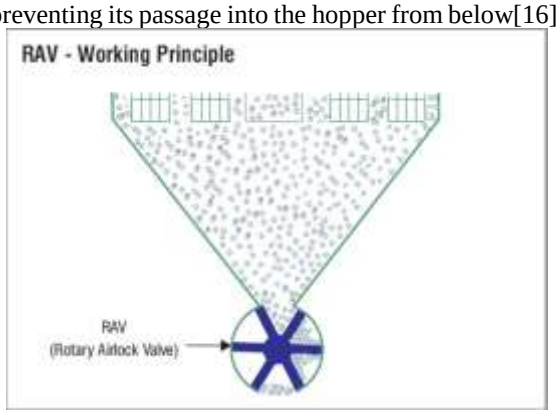
Orifice[14]. When the solenoid valve is energized through an input signal from the sequential controller, the trapped air flows from the top of the diaphragm through the orifice of the solenoid valve[15].
The inflowing compressed air lifts up the diaphragm and flows through the outlet of the pulse valve. Again, when the solenoid valve is de-energized, the air gets trapped, closing the diaphragm as a result of pressure equalization[25]. The next solenoid valve gets energized and the entire process is repeated sequentially in the cycle.

RAV(Rotary Airlock Valve)
The rotary air lock valve maintains an air seal preventing its passage into the hopper from below[16].



Experimental testing

It consist of a total 60 bags. These 60 bags are arranged in rows each consists of a 6 bags each. Each bag filter consists of cage inside the bags. The diameter of each bag is 160mm and 3720mm length. The distance between each bag is 10mm and the distance between each row is 170mm. Each row consists of a pipe which is used for cleaning of air. Each pipe consists of a solenoid valve the outlet is connected to the pipe which is attached to the bag and the inlet is attached to the reservoir. The Power supply is given to the solenoid valve by the timer. The bag filter is fabricated and covered with a 6mm MS steel plate and the exhaust air from the bag filter is sent out through the chimney.
In an online bag filter, the coal that is disc lodged from a row of bags may be picked up by the adjacent row of bags as the latter is under suction. The coal may remain is suspended condition- especially if it is light and / or fine - the reverse upward gas flow not allowing the coal to settle in the hopper[19]. This phenomenon is called fluidization of coal.The coal particles are sucked from the suction point and allowed to the bag filter. The air from the suction point is made to fall on the battle plate and then it is allowed to the bags[20]. This air goes to the bottom of the bag, then it comes out on the top of the bag, there all the coal particles are collected on the outer surface of the bag. Then the cleaned air is sent out through the chimney.

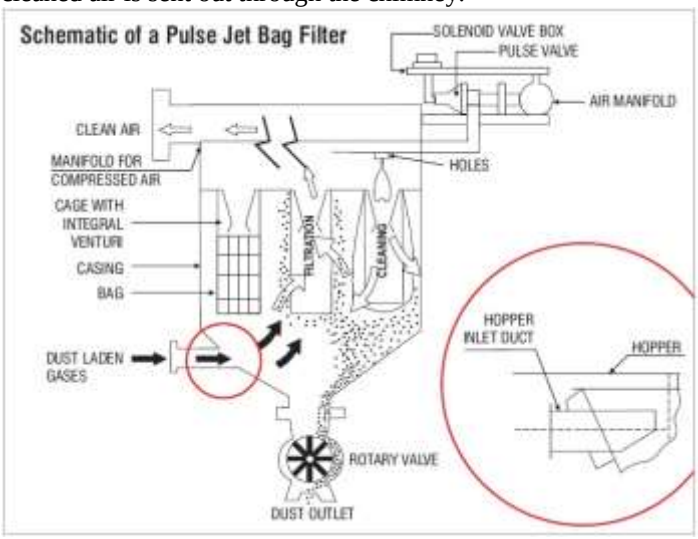


Fig 7.1 Mechanism and Schematic of Pulse Jetbag Filter

The latest technology of cleaning is high pressure cleaning with pulse jet bag filter, periodically a jet of high pressure air is blasted down the inside of the bag which is supported internally by wireframe. During the cleaning operation, the bag is collapsed on the frame because of the pressure of the gas being cleaned on the outside. When the bag is inflated, the coal cake is loosened and falls into the hopper below. The two important advantages of the method are, no moving parts is required and continuous cleaning is possible. It is not necessary to isolate an entire row or a compartment from services.

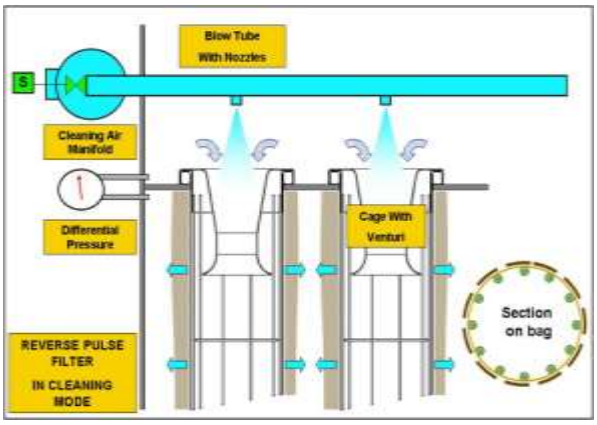


Fig 1.11 solenoid valve open

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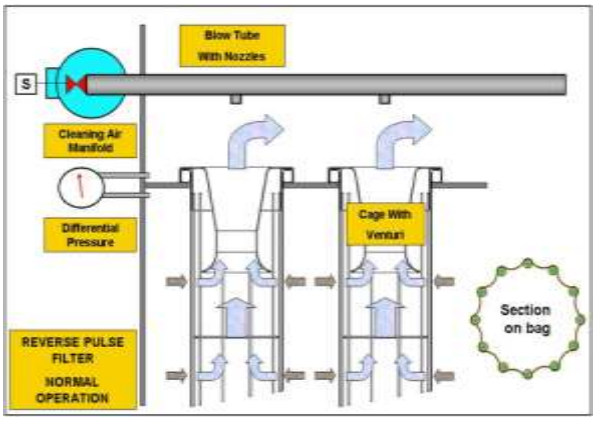

Fig 7.3 Solenoid Valve Closed

When the solenoid valve is open the coal particles are sucked through the suction point, whereas when the solenoid valve is closed, there is an admission of particles inside the bag filter.In an improved pulse jet, the only nozzle for passing compressed air above the bag is replaced by a venture on the top of the bag so that all the air pressure is used to create a pressure wave down the inside of the bag[17][18]. With this mechanism, even hydroscopic particles removed, but the disadvantage is due to high mechanical stress that can rupture the bags.

Pulse jet bag filters were designed to operate at higher air to cloth ratio than other cleaning styles while handling the same volume of airflow in a small physical shape. Generally requiring less housing, the pulse jet filters relies on filter bags that hang vertically and are firmly held in place by clamps, snap bands or hold downs.

When coal laden gas enters the system and comes in contact with the filters, the coal has collected on the outside surface. To clean the filters, a blast of compressed air is directed into the top opening of the filter. The air is supplied through a blowpipe which feed into ventures (to increase the velocity) located above each filter. As the filter flexes, the coal cake fractures and coal particles fall into the hopper below.

The cleaning frequency and cycle for the pulse jet system is critical for maximum efficiency and is set by an adjustable timer to ensure proper cleaning. Pulse jet cleaning requires no moving parts, cleans on demand.

Experimental results

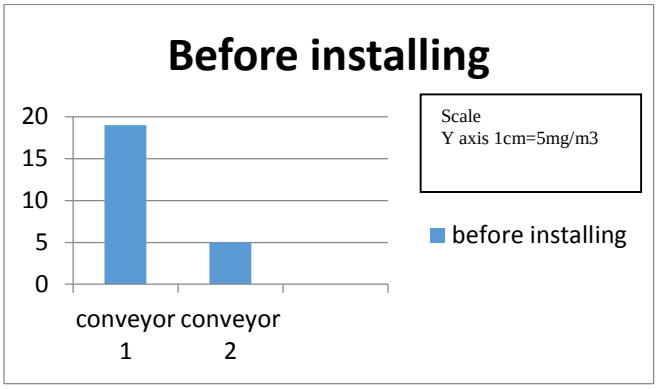

Fig 8.1 Pollution level in Conveyor 1&2 before installing

When the conveyor 1 at the MTPS which has air pollution of 19mg/m3 is tested with the pulse jet air bag filter.Coneyor 1 is tested by passing a air at extreme pressure through the nozzle top to the pulse jet bag.And finaly the amount of pollutants are measured using Gas analyzer which 2mg/m3.

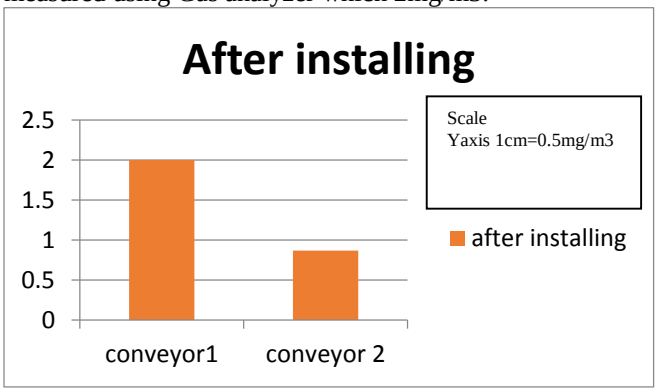

Fig 8.2 Pollution level in Conveyor 1&2 after installing

When the conveyor 2 at the MTPS which has air pollution of 5mg/m3 is tested with the pulse jet air bag filter.Coneyor 2 is tested by passing a air at extreme pressure through the nozzle top to the pulse jet bag.And finaly the amount of pollutants are measured using Gas analyzer which 0.8mg/m3.

Inference

In Mettur thermal power station the primary fuel for boilers are coals. The coal has handled to the turn of 14000 tons per day. During the coal handling activity, the coal dust emanated from the conveyor and transfer chutes. This emanated coal dust creating pollution in the entire coal handling plant, which in turn creating health hazards to the persons working in MTPS.

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Also the government of Tamilnadu has forth several stringent conditions regarding the pollution and enforced to a bid by norms. Hence it is absolutely needed of the hour to control the pollution level in MTPS.The coal extraction system in MTPS plays the major role in controlling coal dust. The available coal extraction system is of old design as which are all erected 25 years back. These dust extraction systems are of the old technology of cyclone separator, which has several disadvantages and the fine dust particles could be filtered or retained in the system. Hence the latest and efficient technology of bag filter will cater the requirement of MTPS considering the efficiency bar .It is observed from the various testing. That bag filter will be more efficient than the present method of dust separation called cyclone separator.

Also the bag filter has several advantages like less maintained, round the clock uninterrupted operation. It is well proved that the bag filter in the dust extraction system will provide the solution to the problems in MTPS. Hence it is concluded that introducing of bag filters in place of cyclone separator will be more powerful, efficient and pollution level in MTPS can be reduced to be barest minimum.If the proposed system installed 90% of particulate matters(Fig 8.1 & 8.2) are removed with minimal maintenance.

Reference

1. *ASHRAE " Method of testing air cleaning devices used in ventilation for removing particulate matter", American society of heating, ventilating and air conditioning engineers, New York, 1976,52-76.*
2. *Leith.D and M J Ellenbecker "Dust emission from a pulse jet fabric filter filtration and separation", July-august, 1983, pp.311-314.*
3. *Smith,W.B,,K.M.cushing and R.C carr "Measurements procedures and supporting research for fabric filters" Conference on fabric filter technology for coal fired power plants.CS-2238,electric power research institute,1981.*
4. *FAA Research 1989 – 2002. Human Factors in Aviation Maintenance and Inspection/ Strategic Program Plan, 1998.*
5. *Weakly A " Controlling dust without using bag houses", Coal Age Nov, 2000, pp24–26.*
6. *Cecala AB, Organiscak JA, Heitbrink WA, Zimmer JA, Fisher T, Gresh RE, Ashley JD " Reducing enclosed cab drill operator's respirable dust exposure at a surface coal operation using a retrofitted filtration and pressurization system". In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Exploration, Inc. Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003 pp. 31–36.*
7. *Listak JM, Reed WR " Water separator shows potential for reducing respirable dust generated on small-diameter rotary blasthole drills", Int J Min Reclam Environ 21(3): 2003, pp:160–172.*
8. *NIOSH " Work-related lung disease surveillance report, 2002", Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003111,2003.*
9. *Olson KS, Veith DL ," Fugitive dust control for haulage roads and tailing basins", Minneapolis, MN: U.S. Department of the Interior, Bureau of Mines, RI 9069,1987.*
10. *Organiscak JA, Page SJ ,"Field assessment of control techniques and long-term dust variability for surface coal mine rock drills and bulldozers", Int J Surf Min Reclam Env 13: 1999, pp165–172.*
11. *Page SJ "Respirable dust control on overburden drills at surface mines. In: Proceedings of the American Mining Congress Coal", Convention, 1991, pp. 523–539.*
12. *Quilliam JH ,"Sources and methods of control of dust. In: The ventilation of South African gold mines", Yeoville, Republic of South Africa: The Mine Ventilation Society of South Africa,1974.*
13. *Reed WR, Organiscak JA ,"Evaluation of dust exposure to truck drivers following the lead haul truck", In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and 2005, pg.75.*
14. *Reed WR, Organiscak JA, Page SJ,"New approach controls dust at the collector dump point", Eng Min J 205(7): 2004, 29–31.*
15. *Rodgers SJ, Rankin RL, Marshall MD ,"Improved dust control at chutes, dumps, transfer points, and crushers in noncoal mining operations", MSA Research Corp. U.S. Bureau of Mines contract No. H0230027. NTIS No. 1978, PP-297-422.*
16. *USBM ,"Technology news 286: Optimizing dust control on surface coal mine drills",*

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines,1987.

17. *USBM ,"Technology news 308: Impact of drill stem water separation on dust control for surface coal mines", Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines,1988*
18. *USBM ,"Technology news 447: Dust collector discharge shroud reduces dust exposure to drill operators at surface coal mines", Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines,1995.*
19. *U.S. Department of Health and Human Services,"Agency for Toxic Substances and Disease Registry (ATSDR)",Atlanta, Georgia,1993.*
20. *American Coal Ash Association," Annual Coal Combustion Product (CCP) Survey Report. 1996" Coal Combustion Product (CCP)- Production and Use (Short Tons). 2760 Eisenhower Avenue, Suite 304, Alexandria, VA 22314-4553,1996.*
21. *Boustead, I.; Hancock, G.F. ,"Handbook of Industrial Energy Analysis. New York: John Wiley & Sons", 1979, pp. 120–146.*
22. *Ecobalance, Inc. "Comparison of Coal Combustion Products (CCPs) Used as Structural Fill Material vs. Disposal in a Landfill Using the Life Cycle Assessment Framework. Prepared for the American Coal Ash Association", 2760 Eisenhower Avenue, Suite 304, Alexandria, VA 22314-4553,September,1997.*
23. *Finlayson-Pitts, B.J; Pitts, J.N., Jr. "Atmospheric Chemistry: Fundamentals and Experimental Techniques", New York: John Wiley & Sons, Inc,1986.*
24. *Moran, M.J, "Availability Analysis - A Guide to Efficient Energy Use", Corrected Edition.American Society of Mechanical Engineers Press. New York,1989.*
25. *SRI International,"Chemical Economics Handbook. Limestone", 214.1000A,1996.*
26. *"Ullmann's Encyclopedia of Industrial Chemistry", Fifth Edition. Weinheim (Federal Republic of Germany): VCH,1985.*
27. *Explorations, Inc. Vol. 318. Littleton, CO: "Society for Mining, Metallurgy, and Exploration", Inc., 1986, pp. 147–153.*