Design Analysis of Variable Capacity Reverse Air Bag House

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***Abstract*— In a present day the many industries such as cement, asphalt, sugar, power plants, steel mills, pharmaceutical producers, food manufacturers, chemical producers and other industrial companies handles billion tones of dust each year and does a good job in keeping dust out of the atmosphere. Over the years, the allowable dust emissions from these industries have become lower and lower. Particulate Matter (PM) has impacts on climate and it also adversely affects the human health. Currently using process emission control device in Cement Plant include various types of Bag Houses, Bag Filters and Electro Static Precipitator (ESP).The cement sector has been rapidly growing at a rate over 8% and it is expected to grow further. In view of the growth rate it is expected that more & more cement plants would come up and the existing plants may expand their capacities through up gradation or modernization. Usage of more fly ash, slag is also increasing to create additional production capacity. In order to meet the increasing demand, most cement plants are making efforts to achieve higher production levels, at times by stretching the existing production facilities and by adding additional capacities. On the other hand, the environmental concerns in terms of emissions to atmosphere are also growing. Most cement plants have made considerable efforts in controlling the stack emissions using most efficient control systems like RABH bag filters and ESP, and these plants generally meet the environmental regulations for stack emissions. However, fugitive emissions from various sources in cement plants still remain an area of concern. There have been environmental regulations in terms of preventing/controlling fugitive emissions. Many cement plants though have taken initiatives in controlling fugitive emissions with varying degree of effectiveness.**

However in general more efforts are required in this area to satisfactorily control the fugitive emissions on sustainable basis. The Indian cement industry is at present going through rapid growth in production and simultaneously improving the de-dusting systems to meet lower emission levels. High cement demand forecasts dictated a very Raw Mill and Short Kiln outage for tie-in of the new collector. This article provides an over view of key issues and considerations that lead to successful installation and minimized loss of plant operating time. Typically Indian cement industries had predominantly used Electrostatic Precipitator (ESP) till about 1985. Now most of the new plants are opting for Bag House for cement Raw Mill and kiln de-dusting over ESP. Over the last few years, imported membrane type filter bags have become cheaper due to lower import duty and favorable exchange rate. At the same time, the steel prices have more than doubled. In today's situation, membrane filter bags offer lower Capital as well as lower operating cost compared to conventional filter bags. Detailed cost analysis and references for both Reverse Air Bag House and Pulse Jet and type of filter bags is described in details in this article. Anyone involved in the selection of de-dusting equipment for cement plant would find the article very useful.

***Index Terms*— Reverse Air Bag House, Fabric, Filter Bag, Rabh, Bag Spacing.**

I. INTRODUCTION

The design of an industrial Reverse Air Bag House involves consideration of many factors including space restriction, capacity, cleaning method, fabric construction, fiber, air-to-cloth ratio; and many construction details such as inlet location, hopper design, and dust discharge devices. Air pollution control agency personnel who review Reverse Air Bag House design plans should consider these factors during the review process. A given process might often dictate a RABH for particulate emission control. RABH was to be used in a high temperature application (500°F or 260°C), a reverse-air cleaning bag house with woven fiberglass bags might be chosen. This would prevent the need of exhaust gas cooling for the use of Nome felt bags, which are more expensive than fiber-glass bags. All design factors must be weighed carefully in choosing the most appropriate RABH design.

A RABH unit consists of number of isolated modules containing rows of fabric bags in the form of round in shape. Particle laden gas coming out from the raw mill enters into RABH from the inlet duct. The Particle laden gases enter into the modules through hoppers and passes (usually) along the surface of the bags then radially through the fabric. The dampers are stated at the hopper inlet throughout the quantity of air flowing through the hopper can be controlled. Particles are retained on the upstream face of the bags, and the cleaned gas stream is vented for the further use or to the atmosphere. The filter is operated cyclically, alternating between relatively long periods of filtering and short periods of cleaning. During cleaning, dust that has accumulated on the bags is removed from the fabric surface with the help of reverse air and deposited in a hopper for subsequent disposal. Fabric filters collect particles with sizes ranging from submicron to several hundred microns in diameter at efficiencies generally in excess of 99 or 99.9 percent. The layer of dust, or dust cake, collected on the fabric is primarily responsible for such high efficiency. The cake is a barrier with tortuous pores that trap particles as they travel through the cake. Gas temperatures up to about 500^0F, with surges to about 550^0F can be accommodated routinely in some configurations. Most of the energy used to operate the system appears as pressure drop across the bags and associated hardware and ducting. Typical values of system pressure drop range from about 5 to 20 inches of water. RABH are used where high-efficiency particle collection is required. Limitations are imposed by gas characteristics (temperature and corrosivity) and particle characteristics (primarily stickiness) that affect the fabric or its operation and that cannot be economically accommodated. Important process variables include particle characteristics, gas characteristics, and

Fabric properties. The most important design parameter is the air- or gas-to-cloth ratio (the amount of gas in ft^3/min that

penetrates one $ft^2$of fabric) and the usual operating parameter of interest is pressure drop across the filter system. Fabric filters are usually made of woven or (more commonly) needle punched felts sewn to the desired shape, mounted in a plenum with special hardware, and used across a wide range of dust concentrations. Cement manufacturing industries are one of the important sectors of the Indian economy. The sector has experienced phenomenal growth especially after the control regime from 1999 and due to greater thrust by Government on infrastructure development and spurt in housing construction sector, which has led to increased demand for cement.

II. OBJECTIVES

1. Important factors in good RABH design.
2. Estimate the cloth area needed for a given gas process flow rate.
3. Calculate the number of bags required in a RABH for a given process flow rate.
4. Calculate the gross air-to-cloth ratio, the net air-to-cloth ratio, and the net, net air-to-cloth ratio for a RABH design.

The first step in reviewing design criteria is determining the flow rate of the gas being filtered by the RABH, which is measured in cubic meters (cubic feet) per minute. The gas volume to be treated is set by the process exhaust, but the filtration velocity or air-to-cloth ratio is determined by the RABH vendor's design. The air-to-cloth ratio that is finally chosen depends on specific design features including fabric type, fibers used for the fabric, bag cleaning mechanism, and the total number of modules, to mention a few.

Physical and chemical properties of the dust: are extremely important for selecting the fabric hat will be used. These include size, type, shape, and density of dust, average and maximum concentrations, chemical and physical properties such as abrasiveness, explosiveness, electro-static charge, and agglomerating tendencies. For example, abrasive dusts will deteriorate fabrics such as cotton or glass very quickly. If the dust has an electrostatic charge, the fabric choice must be compatible to provide maximum particle collection yet still be able to be cleaned without damaging the bags.

Predicting the gas flow rate is essential for good RABH design. The average and maxi-mum flow rate, temperature, moisture content, chemical properties such as dew point, corrosiveness, and combustibility should be identified prior to the final design. If the RABH is going to be installed on an existing source, a stack test could be performed by the industrial facility to determine the process gas stream properties. If the RABH is being installed on a new source, data from a similar plant or operation may be used, but the RABH should be designed conservatively (large amount of bags, additional modules, etc.). Sometimes, heavy dust concentrations are handled by using a RABH in conjunction with a cyclone pre-cleaner, instead of building a larger RABH. Once the gas stream properties are known, the designer will be able to determine if the RABH will require extras such as shell insulation, special bag treatments, or corrosion-proof coatings on structural components.

Fabric construction design features are then chosen. The design must determine the woven or felt filters, filter thickness, fiber size, fiber density, filter treatments such as napping, resin and heat setting, and special coatings. Once dust and gas stream proper-ties have been determined, filter choice and special treatment of the filter can be properly made. For example, if the process exhaust from a coal-fired boiler is 400°F (204°C), with a fairly high sulfur oxide concentration, the best choice might be to go with woven glass bags that are coated with silicon graphite or other lubricating material such as Teflon. Along with choosing the filter type we have to select the appropriate fiber type. Fibers typically used include cotton, nylon, fiberglass, Teflon, Nomex, Ryton, etc. The design should include a fiber choice dictated by any gas stream properties that would limit the life of the bag.

Proper air-to-cloth (A/C) ratio: is the key parameter for proper design. As stated previously, reverse-air fabric filters have the lowest A/C ratios, then shakers, and pulse-jet bag houses the highest.

Bag cleaning methods: must be properly matched with the chosen bags. The cost of the bag, filter construction, and the normal operating pressure drop across the RABH help dictate which cleaning method is most appropriate. For example, if felted Nomex bags are chosen for gas stream conditions that are high in temperature and somewhat alkaline pulse-jet cleaning would most likely be used.

The ratio of filtering time to cleaning time: is the measure of the percent of time the filters are performing. This general, “rule-of-thumb” ratio should be at least 10:1 or greater. For example, if the bags need shaking for 2 minutes every 15 minutes they are on-line, the RABH should be enlarged to handle this heavy dust concentration from the process. If bags are cleaned too frequently, their life will be greatly reduced.

Cleaning and filtering stress: is very important to minimize bag failures. The amount of flexing and creasing to the fabric must be matched with the cleaning mechanism and the A/C ratio, reverse-air is the gentlest, shaking and pulse-jet place the most vigorous stress on the fabric. For example, it would probably not be advisable to use woven glass bags on a shaker bag-house. These bags would normally not last very long due to the great stress on them during the cleaning cycle. However, fiberglass bags are used on RABHs that use shake-and-deflate cleaning. Bag spacing is very important for good operation and ease of maintenance.

Bag spacing: affects the velocity at which the flue gas moves through the RABH modules. If bags are spaced too close together, the gas velocity would be high because there is very little area between the bags for the gas stream to pass through. Settling of dust particles during bag cleaning would become difficult at high velocities. Therefore, it is preferable to space bags far enough apart to minimize this potential problem but not so far apart as to increase the size of the RABH shell and associated costs. Bag-to-bag abrasion can occur at the bottom of the bags because the bags are attached to the bag hanging support only at their tops and tube sheet at bottom. Slight bows in the bag support cages or a slight warping in the tube sheet can cause bag-to-bag contact at the bottom of the bags. Finally, access for bag inspection and replacement is important. For example, in a Reverse-Air unit, sufficient space between bags should be used so that maintenance personnel can check each bag visually for holes. The bag can either be replaced or a cap can be placed on the tube sheet opening to seal off the bag until it is later changed. The bag layout should allow the bag maintenance technician to reach all the bags from the walkway. One measure of bag accessibility is called bag reach and is the maximum number

of rows from the nearest walkway. There is no single value for bag reach, but typical units have a value of 3 or 4.

MODULE design: should allow for proper cleaning of bags. The design should include an extra MODULE to allow for reserve capacity and inspection and maintenance of broken bags. Shaker and reverse-air cleaning RABHs that are used in continuous operation require an extra MODULE for cleaning bags while the other MODULEs are still on-line filtering.

RABH dampers (also called RABH valves) are important. Reverse-air bag-houses use inlet and outlet dampers for gas filtering and bag cleaning sequences. During the filtering mode, the MODULE's outlet gas damper and inlet dam per's both open. During the cleaning sequence, the outlet damper is closed to block the flow of gas through the MODULE. The reverse-air damper is then opened to allow the air for bag cleaning to enter the MODULE. Dampers are occasionally installed in by-pass ducts. By-pass ducts, which allow the gas stream to by-pass the RABH completely, are a means of preventing significant damage to the bags and/or RABH. Dampers in by-pass ducts are opened when the pressure drop across the RABH or the gas temperature becomes too high. However, many state regulatory agencies have out lowed the use of RABH by-pass ducts and dampers to prevent the release of unabated particulate emissions into the atmosphere.

Space and cost requirements are: also considered in the design. RABHs require a good deal of installation space, initial costs, and operating and maintenance costs can be high. Bag replacement per year can average between 25 and 50% of the original number installed, particularly if the unit is operated continuously and required to meet emission limits less than 0.010gr/dscf. This can be very expensive if the bags are made of Teflon which are approximately$100 for a 5-inch, 9-foot long bag, or Gore-Tex which are approximately $140 for a 6-inch, 12-foot long bag. The emission regulations in terms of grain-loading and opacity requirements will ultimately play an important role in the final design decisions. RABHs usually have a collection efficiency of greater than 99%. Many **emission regulations** (and permit limits) require that industrial facilities meet opacity limits of less than 10% for six minutes, thus requiring the RABH to operate continuously at optimum performance.

III. PRINCIPLE

The Reverse Air Bag House (RABH) is a custom-built filter designed for cleaning gases with typically high flow rates and high temperatures. RABH is in modular construction with four or more independent modules. The extra space created between the hoppers provides a large passageway between rows down the middle of the system. This passageway is divided into three sections horizontally to make the inlet plenum, outlet plenum, and the reverse-air plenum. This construction not only offers control on the velocity profiles, but also facilitates on-line maintenance. Each module can be isolated for inspection or maintenance by closing inlet, outlet and reverse air dampers, while other modules are still in operation. The poppet outlet and reverse air dampers operate vertically, thus ensuring optimum sealing. These are sized appropriately for the application, in order to keep inlet, outlet & reverse air velocities low. This reduces both wear and pressure drop. The units, being custom built and voluminous, are dispatched knocked down to structures and panels. Each module is provided with inlet manual damper to suit the inlet nozzle of the hopper. These are with out-boarding bearings to avoid abrasion and erosion as they are not exposed to dust laden gases. RABH use long, cylindrical bags (or tubes) made of woven or felted fabric as a filter medium. Thimbles facilitate uniform distribution of gas flow into the bags without impact on bags. The construction is such that bags will never slip-out as they are located using clamp or snap band arrangement. To ensure the

positioning of the thimble and bag, in terms of verticality, the assembly is normally carried out at site,(For applications where there is relatively low dust loading and gas temperatures are 250 °F or less, pleated, nonwoven cartridges are sometimes used as filtering media instead of bags.). The dust laden gas to be cleaned enters the common inlet plenum. A portion passes through each inlet damper into the hopper area below each module. The dust laden gas then passes through the tube sheet to the inside of each bag. Virtually all the gas-borne dust particles are separated, to meet the outlet emission levels required, as the gas passes through the bags. Clean gas enters the outlet plenum through the open outlet damper.

When sufficient pressure drop (delta P) occurs, the cleaning process begins. Cleaning can take place while the RABH is online (filtering) or is offline (in isolation). When the MODULE is clean, normal filtering resumes. Each module is periodically and automatically shut-down for a brief reverse-air cleaning cycle, as per the system logic built in, with the help of the automatic sequential controllers; the latter controls various cycles like the interval time, close time, reverse-air time and the settle time. Clean gas is drawn from the outlet plenum by the reverse-air fan into the reverse-air plenum during cleaning. During this process, the outlet damper is closed and the reverse-air damper is opened letting in the reverse air in a direction opposite to the normal dusty gas flows. This action slowly collapses the bags, breaking up the dust cake on the inner surfaces of the bags, thereby allowing the dust to get discharged to the hoppers. RABHs are very efficient particulate collectors because of the dust cake formed on the surface of the bags. In reverse-air RABHs, the bags are fastened onto a cell plate at the bottom of the RABH and suspended from an adjustable hanger frame at the top. Dirty gas flow normally enters the RABH and passes through the bag from the inside, and the dust collects on the inside of the bags. Reverse-air RABHs are MODULE allied to allow continuous operation. Before a cleaning cycle begins, filtration is stopped in the MODULE to be cleaned. Bags are cleaned by injecting clean air into the dust collector in a reverse direction, which pressurizes the MODULE. The pressure makes the bags collapse partially, causing the dust cake to crack and fall into the hopper below. At the end of the cleaning cycle, reverse airflow is discontinued, and the MODULE is returned to the main stream. The flow of the dirty gas helps maintain the shape of the bag. However, to prevent total collapse and fabric chafing during the cleaning cycle, rigid rings are sewn into the bags at intervals. Space requirements for a reverse-air RABH are comparable to those of a shaker RABH; however, maintenance needs are somewhat greater.

IV. FORMULA USED

Pressure Drop: The Pressure drop is the sum of the pressure drop across the filter housing and across the dust- ledden fabric.

$\Delta P = \Delta P_f + \Delta P_d = K_1 v + K_{2vw}$

Where,

v= the filtration velocity

K_1= the flow resistance of the clean fabric A_c

K_2=the specific resistance of dust deposit

W=the fabric dust areal density

Total Gross Cloth Area:

$$V_f = \frac{Q}{Ac} \text{ or } Ac = \frac{Q}{Vf}$$

Where:

A_C = cloth area, ft^2

Q = process exhaust rate, ft^3/min

V_f = filtration velocity, ft/min

Amount of fabric required per bag:

$$A_b = \pi dh$$

Where: A_b= area of bag, ft^2

$\pi = 3.14$

Number of bag required in bag house:

$$\text{Number of bags} = \frac{A_c}{A_b}$$

Net air to cloth ratio: $(A/C)_{net}$

$$= \frac{Q}{A_c\left(\frac{Total\ of\ modules - 1}{total\ of\ modules}\right)}$$

Calculate net, net air to cloth ratio: $(A/C)_{net}$=

$$\frac{(A/C)_{gross}}{\frac{[(total\ of\ modules)-2]}{total\ of\ modules}}$$

V. RESULT

The RABH operated at an average pressure drop of 80 to 150 mmwg pressure drop across filter bags with raw mill down (Direct mode). The airflow is high in the direct mode due to addition of dilution air for cooling. The individual MODULEs clean down to 30 - 50 mmwg pressure drop. The air to cloth ratio is about 10 - 20% above design. Several times, the RABH has recovered from a total loss of cleaning system failure, without any manual bag cleaning during the initial plant start-up. The plant capacity was further increased to 4500 TPD by water spray in the down comer duct. The MODULEs near the RA Fan are having higher air flow compared to other MODULEs and hence had higher wear and tear, requiring faster bag replacement. The modules were replaced with new bags under the running conditions if plant and can use the RABH with the different load and capacity demand.

VI. CONCLUSION

RABH offer up to 2-3 times the filter life over conventional polyester felt bags.

Particulate matter emission will reduce to 30mg/Nm3. Also size of the RABH will be reduced compared to other conventional bag house(woven or felt) system. This pleated bag is more efficient in capturing submicron dust particles .Longer filter life and better pulse cleaning due to surface loading technology is offered. This has lower energy consumption with better pulse cleaning and lowers operating pressure drop. Cleaner air, longer filters life, and greater cost savings.

1. RABH preferred technology over Electrostatic Precipitator for de-dusting of cement kiln in India.
2. In the present Indian conditions, the Reverse air RABH design seems to offer more economical solution over pulse-Jet RABH.
3.Good quality, PTFE Membrane filter bags provide lower capital and operating cost for reverse air RABH in a cement kiln compared to conventional fiberglass filter bags.
4. PTFE membrane laminated Fiberglass and composites of fiberglass fibers offers the best filter media option for pulse-jet RABH design.
5. The impact of lower import duty and exchange rate has lead to more cement plants switching to membrane filter bags in last one year compared to all previous years combined.

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