Developments in Filtration

Papers presented at a Shirley Institute conference 1983

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BACKGROUND

Filtration and separation methods are used in almost every industry. With improving standards and high process costs there is increasing dependence on good reliable filtration methods. This publication is a collection of 12 papers presented by UK and overseas speakers, representing manufacturers of filtration equipment, makers of filter fabrics and research workers on a range of topics, reflecting the state of the art and science of filtration.

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REVIEW OF DUST CONTROL EQUIPMENT

D.T.Chambers and F.Cairns (Dust Control Equipment Ltd, Leicester)

In reviewing the art of dust control and the present state of that art, one must look at the major developments and advancements that have taken place primarily during the last 30 years. In the early 1950's dust filtration meant primarily intermittently cleaned woven fabric filters, and these filters together with the cyclones and wet collectors dominated the market up to the early 1960's. With all of these types of equipment the collection efficiency was easily predictable from grade efficiency curves, and as both flow and burden increased through any given collector so the inefficiency would increase.

The major step forward came about during the mid-60's with the introduction of reverse jet pulse filters which were continuously cleaned and which utilized on a wide scale for the first time nonwoven fabrics. Thus for the first time two distincly dissimilar fabric filters became available and broadly these may be classified as "nuisance" and "process" dust collectors.

The first type deals with applications where the dust produced is an unfortunate and unwanted by-product of some industrial process and the second involves the use of filtration equipment to collect the dust from some ongoing process where often the dust and the product are in fact the same thing. Nowadays when automation and 24-hour operation are often the order of the day, the requirements for equally rated process-dust collectors become greater. There are however certain aspects that are common to all filtration plants and broadly these may be classified as follows:

1. The plant provided must have an adequate area of effective filtration media relative to the dust type that it is handling. The selection of the correct filtration area (and hence the filtration velocity) is more critical as the ongoing effectiveness of the separation and filtration process depends on it. Particle size, shape, and chemical characteristics must all be taken into careful consideration as must the anticipated dust burden to the filter.

2. Whether the plant be a continually rated or an intermittent device, an efficient and automatic filter-cleaning mechanism must be built in.

3. By definition a dust collector collects waste or process product; consequently the unit selected must have suitable disposal equipment that will not cause a secondary dust hazard.

4. The unit selected must have sensible and convenient access for maintenance and service purposes, and on larger filters it is preferable that this access should be from the clean side of the filter element.

Filter selection procedure

Where isolated or scattered areas of localized emission are to be dealt with within the factory, self-contained dust collectors fitted with in-built fans, filters, and collection bins can offer excellent and economical service. Such units, usually with an exhaust capacity of up to 5,000m^3/hour each, can be sited adjacent to the piece of plant or machinery they serve, require only a small amount of ductwork between the unit and machine, can be interlocked with the machine so that it is impossible to run either without the other being in operation, and can be moved en-bloc with the machine for factory replanning. For many "nuisance" dust materials the normal filter employed is a good quality natural cotton, usually of a weight of around 250 g/m^2, with a filtration velocity in the order of 1.5 m/min. If, however, there is evidence of moisture or corrosive chemicals in the gas stream then it would be wise to consider using a woven polypropylene, nylon, or polyester material which nowadays can offer filtration efficiencies equivalent to that of a woven natural yarn. With units of this type considerable heat losses would occur if it were always necessary to discharge the cleaned air from the filter out to atmosphere as a security measure. Consequently care taken at the design application stage, in the selection of the filter media and overall size of filter relative to the gas volume, will ensure ongoing effectiveness. If the material is particularly fine or if there is an element of toxicity about it then it may be necessary to backup the cleaned air from the primary filter with a secondary filter of the static type. In any event, where air from a unit dust collector is to be returned back to the work zone, the plant should be designed such that the quantity of dust in the discharged air is below one-tenth of the MAC (maximum allowable concentration). It should be noted that this philosophy of returning the air back to the workroom should be discouraged from single module filters that handle more than 4-5,000 m^3/hour. This is for two reasons: first, should a filter fail, the scale of the resultant problem could be untenable and, secondly, with air volumes in excess of this value draught problems could be encountered within the factory area and there is a resultant return air re-distribution problem.

It had been the practice for many years with larger installations to adapt this type of intermittent unit to large plant usage, still using mechanical rapping gear energized at the end of the work period or shift. Although this type of filter is capable of giving reasonable service it can only do so on an intermittent basis because the cleaning has to be done under no-flow conditions, and this means interrupting the exhaust air at some predetermined interval. In an attempt to overcome this inherent design defect, compartmentalized filters were produced where each cell of the filter can be isolated by mechanical valve gear to allow cleaning of that particular cell under no-flow conditions. Although this tends to stabilize to some degree the pressure drop the increase in maintenance due to the complexity of this type of plant becomes excessive and uneconomic. As a result, the reverse jet filter has been produced to provide continuous cleaning, resulting in stable filter pressure drops and continuous volume flow. Generally this is achieved by injecting small quantities of high-energy gas, usually compressed air, into each filter pad or bag in turn. This is done on a recycling basis such that the whole filter unit may be cleaned down every 60-100 sec, and this results in constant pressure drop and constant throughput of air; this ability to stabilize the back pressure also enables the continuously cleaned collector to operate on high dust concentrations without the pre-separation devices required by intermittently cleaned shaken designs. With this type of reverse jet cleaning, improved filter materials such as synthetic needle felts can be used, generally felts of around 650 g/m^2. With material of this type it is really incorrect to talk of filtration efficiencies relative to particle size, etc. as the degree of filtration is such that it is more correct to describe inefficiency as penetration, and it should be remembered that with a nonwoven fabric inefficiency is not proportional to increased load or flow.

The heartof any fabric dust collector is, in fact, the filter fabric, and we are faced today with a multiplicity of suppliers and types of filter materials. Most reputable filter cloth manufacturers will provide for the user a full media specification which includes weight, thickness, permeability, strength, specific gravity, pore size, temperature limitations, as well as fibre information and (probably most important) details of surface finishes available. However, of much more importance to the dust control engineer are its properties and reactions to various elements of any proposed application; to this end a media specification given in absolute terms must be converted relative to its application usage and information must be provided with regard to chemical resistance, resistance to oxidizing agents, resistance to abrasion, flammability, applications to avoid, and applications most suitable.

With the introduction of nonwoven fabrics came the first attempts to lower the surface-retention properties in order to improve the dust cake release. This was originally done by singeing or heat-treating one side of the material but it has broadened into a more exact science over the years. Now surface finishes which include oleophobic, hydrophobic, eggshell and glazed are now all readily available and, if correctly utilized, assist in improving the dust cake release. One of the prime benefits in achieving this is a reduction in the quantity of high-energy gas required to clean the filter. Thus, better surface release equals less compressed air equals energy and cost saving. There has been a considerable development also in raising the upper temperature limitation of fabric filters and gradually we are moving into glass, metal, and ceramic fibres to permit exposure to higher and higher temperatures. This is particularly important on many hot gas processes because historically some cooling system has had to be used to bring down the gas temperature to around 200°C. If, therefore, the limitation can be increased, less cooling air and thus less total volume are required which again reduces both plant and operational costs. There is also an important consideration in that hotter air may be recirculated into a process system, thus showing in many cases an important saving in fuel. The result again is energy conservation and cost savings.

The major filter cloth manufacturers and the major filter cloth users usually now incorporate a quality-control system whereby material is checked at the places of both production and usage on similar testing apparatus. This dual testing has resulted in a considerable upgrading of specification and even now it is not unusual for many thousands of yards per year to be returned to the cloth manufacturer having fallen at the second test fence.

Most filter units are of metallic construction and easily earthed. However, the filter cloth and the collected dust are generally not good conductors of electricity and can therefore in a short time accumulate an electrical charge. Hence it is necessary to increase the electrical conductivity of the dust cake and the filter media, thus enabling the electrical charge to leak away to earth; otherwise a dangerous potential can arise.

Epitropic fibres (polyester fibres with a conductive carbon-impregnated outer surface) can form the basic constituents of a specialized needlefelt which can provide a level of resistance below 1×10^8 ohms. This is in conformity with the British Standard definition of an antistatic material. In general epitropic polyester felts have the same heat, chemical, and other properties as standard polyester. In addition to epitropic filter media it is also necessary to earth the filter unit completely to avoid the risk of a static charge discharging in the form of a spark. This is particularly important where the dust is of the type that could constitute an explosion risk. To ensure that there is a path of conductivity between individual filter pads the only foolproof way is to manufacture the seal frame, through or upon which the filter bags are mounted, from stainless steel. Copper braid earthing straps should be then fitted from the seal frame down through the main case of the filter unit finishing with a brass earthing boss which may then be wired externally from the filter down to earth. It should also be noted that the relative electrical charges on the dust and filter media will have an important effect on the attraction/reputation of the dust relative to the filter media which in turn can increase of decrease both filtration and filtration cleaning efficiency.

Talk of fire risk leads naturally to that of explosion and explosion-prevention protection, and it is true that a wide range of dusts are capable of producing an explosion: for example, carbonaceous dusts, plastics, fertilizers, pharmaceuticals, fuels, chemicals, foodstuffs and certain metals can, providing they are in a sufficiently fine state, all constitute a certain risk. Defining that risk is much more difficult. However by its very nature a dust collector usually contains clouds of finely divided particles in suspension. If these particles are of a material known to be combustible, then explosion-relief equipment must be provided.

Dust explosion may be defined as the combustion of a dust cloud resulting in a rapid expansion of gases due mainly to the heat developed during combustion. If this rapid expansion is restricted, for example with a dust collector, then the ongoing expansion would result in a build-up of pressure within that casing and cause an explosion. Within any given situation there are three pre-requisites for a dust explosion:

1. A combustible dust.
2. Air or another oxidant.
3. A source of ignition

There are many factors that may influence both the cause and the severity of a dust explosion - the degree of the source of ignition, the particle size and concentration, the normal operating turbulence within the dust collector, moisture, and finally the position of the vent unit - these all have their part to play in the safe release of an explosive pressure.

Basically there are four methods of either overcoming or preventing the destructive effects of an explosion:

1. By inerting, using an inert gas.
2. By suppression, whereby a suppressant under pressure is released into the explosion area within a very short time, probably 10 milliseconds, of the commencement of the explosive pressure rise.
3. By explosion containment whereby the vessel is designed to withstand the maximum pressure that could be generated. It is true to say that it is usually not viable commercially to build a dust collector to this standard.
4. By the most common method, namely an explosion relief panel.

It was considered for many years that a lightweight explosion relief door, usually held by over-centre catches or springs, was perhaps the best type of relief panel. However, a series of tests carried out in conjunction with the Fire Research Station at the Building Research Establishment showed that there was considerable increase in relief pressure due to the inertia of the door and this in turn could be exacerbated by the corrosion and freezing between the door, casing, and the restraint surfaces. The use of a hinged door is also suggested as unsatisfactory because if the door distorts or is removed from its anchorage it can block the vent duct from the building with serious consequences. Consequently a bursting membrane or panel is now considered the most satisfactory and safe technique provided, of course, that the characteristics both of the membrane and of its effect relative to a particular design of filter casing are known. It is probably true to say that the only really safe procedure is to test a specific design of filter with actual explosive tests.

Extensive test work has been carried out into explosion relief venting on fabric filters over the last 3-4 years, and the results of this work should not be ignored. This test work has clearly shown that the strength of a standard dust collector should be increased to withstand the rapid pressure rises that can occur. The dramatic power of dust explosions cannot be over-estimated and it is strongly recommended that advice is taken from knowledgeable sources on specific matters relative to this subject. Providing sensible precautions are taken, the risk can be minimized and, despite much apparent international theoretical argument at the moment, sufficient practical technology does exist such that severe hazards can be sensibly avoided.

The risk of fire and explosion can also be minimized by removing from the risk zone the elements of electrical control that most reverse jet fabric filters have hitherto required. This usually includes electrical printed circuit boards used in conjunction with solenoid and diaphragm valves to give the microsecond pulse time required. More recent developments, however, have brought about the design and production of a pneumatically operated controller for use in places where there is a fire or explosion risk. This controller, which is basically a rotary exhaust valve operated by a ratchet and pawl driven by a diaphragm cylinder, is now available in both a size and cost range that makes it notonly practically acceptable but commercially attractive.

It is also fair to comment that many users of reverse jet filters have become increasingly concerned about the compressed air requirement for their equipment. It is also equally true to say that most filter manufacturers in the design and specification of their compressed air requirements tend to err on the generous side to ensure the best possible performance from their filter. Modern electronic circuitry has made possible the introduction of a variable pressure-activated controller that is specifically designed to reduce the consumption of compressed air necessary for filter cleaning whilst maintaining proper filter performance. Basically the controller is activated by a pressure switch which is governed by the pressure differential between the clean and dirty sides of the filter compartment. This pressure switch has a variable setting to suit the particular application and the compressed air supply can be interrupted if the pressure drop is being held constant by a reduction either in the gas flow or in the product burden. The more sophisticated of these controllers also contain a device such that once activated they will complete at least one circle of operation before de-energizing. This electronic nicety ensures that for a plant that has an intermittent duty element the same two or three sections of the filter are not being cleaned repeatedly whilst the end of the line elements might be ignored.

The introduction of this type of equipment has specifically come about owing to a desire on filter manufacture to reduce the running costs of any industrial plant, and plants so far installed report good savings of compressed air and hence considerable monetary savings.

The actual design of a dust filter and the geometric layout are of considerable importance and more and more attention has been paid latterly to the size and shape of filter elements relative to their housing and associated cleaning mechanism. Gone are the days when a manufacturer would produce a filter range with one standardized set of cleaning mechanisms that would be suitable for a 3 ft long sock, a 6 ft, 10 ft, or 12 ft or whatever the particular project demanded. The size and proportion of the filter element are critical relative to the cleaning function. In this regard note should also be taken of the position of the inlet and the resultant flow through a dust collector. The ideal format is that where the dust and gas enter the filter at the top such that as dust is cleaned from the filter bags it is swept down towards the hopper and discharge equipment, i.e. the removed dust is taken away from the element thus reducing re-entrainment.

Contrast this with a design, still unfortunately quite common, where the dust enters the unit below the bottom of the filter bags, and the flow of air is essentially bottom to top. This type of filter is usually cleaned from the top so as the dust is driven off the bags it falls into the rising dust/air path where unfortunately it is held in suspension. Test work has shown unequivocally that this latter design does not perform as well as the top inlet type.

HUYGLAS* FILTER FABRIC -

A NEW CONCEPT IN HOT GAS FILTRATION

* Huyglas is registered trade mark.

H. Preisinger (Huyck-Fez G.m.b.H. Gloggnitz, Austria)

With the popularity of coal combustion once again emerging as a source of energy, together with more stringent requirements placed on allowable particulate emissions into the atmosphere, more emphasis than ever is currently being placed on technology for the cleaning of hot gases.

The ability of fabric filters to maintain a relatively consistent level of filtering efficiency, regardless of wide variations in the physical properties of the particulate, has caused much recent emphasis to be placed on the development of textile products that will function effectively in high-temperature and sometimes chemically adverse environments.

Background

In recent years glass-fibre fabrics have achieved the highest level of overall success on fabric filters venting fossil-fueled installations. The application of woven glass-fibre fabrics to reverse air dust collectors has been widely accepted by coal burning electric utilities as an efficient means of controlling particulate emissions.

Due, however, to the relatively low level of filtering efficiency of woven glass fibre, together with the inherent susceptibility of glass fibres to flex fatigue, these systems are seldom designed to operate at filter ratios which exceed 2:1 and in virtually every case the bags must be taken out of service for cleaning. The resulting low-ratio collector is consequently physically large, requiring not only significantly more space, more metal and more fabric area but also more motors, fans and duct work than does its high-ratio counterpart, the pulse jet dust collector. The consequences are a sizable capital expenditure coupled with a relatively high degree of continuing maintenance. Wilst a utility in general may be better suited to deal with these items on a long-term basis, more and more industrial companies are less willing and/or able to do so.

The economic advantages of pulse jet dust collectors have long since proven themselves in the various process recovery industries; however, high-temperature applications for pulse jet collectors have in the past been limited due to the lack of availability of a high-temperature-resistant fabric capable of operating efficiently at the typically higher air-to-cloth ratios of pulse jet dust collectors.

Pulse jet dust collectors normally utilize felted fabrics owing to the ability of felts to handle more gas volume per unit area of cloth. Prior to 1978 fabrics consisting of 100% glass fibre were commercially available only in woven form. In order to improve the efficiency of these fabrics the natural progression was to investigate means of producing a glass fibre textile product of a denser, more efficient and physically durable nature for application on high-ratio pulse jet and reverse pulse type dust collectors. Attempts have been made at applying woven glass fabrics incorporating textured yarns to pulse jet dust collectors but with only limited success due to the still inefficient and fragile nature of woven glass fibre.

A 100% glass-fibre felt seemed to be the obvious answer. Attempts by several concerns had been made to develop a felted glass fabric utilizing existing technology for processing synthetic fibre felts. The problem, however, existed in that glass fibres do not behave on felting equipment as do synthetic fibres and only limited success had been achieved up until 1978 when Huyck Felt introduced Huyglass filter fabric, the first commercially available 100% glass-fibre felted fabric for application on pulse jet dust collectors.

Product description

As already pointed out Huyglas filter fabric is a 100% glass-fibre needle-felted fabric, designed specifically for high-temperature application on pulse jet and reverse pulse type dust collectors. The fabric is capable of continuous operation in temperature environments of up to 260°C (500°F), withstanding surges to 287°C (550°F).

The current weight of the fabric is 915 g/m^2 (27 oz/yd^2). It is significantly heavier than most of the commonly available woven glass fabrics and synthetic fibre felts which normally range in the area of 400 g/m^2 - 540 g/m^2 (14 to 16 oz/yd^2). The approach here was to design a glass fabric that was not only superior in filtering efficiency to other types of glass-fibre fabrics but which also possessed the durability in terms of tensile strength and flex resistance necessary to withstand the rigours to which a fabric is subjected in a pulse jet dust collector, particularly where on-line cleaning is utilized.

Huyglas filter fabric is unaffected by sulphur trioxide in the gaseous state as well as degradation from hydrolysis. Futhermore the fabric is resistant, although not totally impervious, to the gradual effects of long-term exposure to concentrated sulphuric acid conditions.

The fabric possesses excellent dimensional stability characteristics, exhibiting virtually no shrinkage or elongation even at the high end of its temperature range.

From the standpoint of efficiency, Huyglas filter fabric ranks among the most efficient high-ratio filter media currently available. The filtering surface of the fabric consists of individual Beta glass fibres which is not only the finest form of glass but also one of the finest textile fibres of any generic classification available. These fine Beta fibres are able to be formed into a relatively dense fabric surface. This precludes the penetration of a high degree of fine particles into the depth of the filtering medium but at the same time allows a relatively large amount of gas per unit area to pass through the fabric.

On a point of information, individual Beta fibres are nominally

0.25 denier which with glass yields a fibre diameter of approximately 3.8 microns. For the sake of illustration the human hair is typically 70 microns, making BETA fibre over 18 times finer.

Application

In discussing the application of Huyglas filter fabric to hot gas filtration, it is anticipated that various forms of fossil-fueled installations will be by far the most significant area of growth over the next 10 to 15 years. These installations will consist of converting and retrofitting existing stoker and pulverized coal-fired combustion systems together with new installations which will include more recently developed coal-firing technology such as fluidized bed combustion and combustion of various types of coal slurries.

Another area of developmental work that is presently under way is the utilization of micro-pulverized coal which is significantly finer in nature than conventional pulverized coal. As a means of comparison, conventional pulverized coal typically runs approximately 70% less than 74 microns (approx. 200 mesh) as compared to micro-coal of which 100% falls below 44 microns which is approx. equal to 325 mesh. From a combustion stand-point the major advantages of using a more finely pulverized coal are somewhat obvious in that it allows for more rapid and complete combustion, at the same time requiring less excess combustion air, resulting in more efficient overall utilization of fuel.

The point that I would like to make here is that as technological advances allow for more efficient methods of coal combustion, which in many cases tend to create a finer grade of ash, the job of the baghouse dust collector will become increasingly more difficult. This is where a dense filtering medium such as Huyglas filter fabric will play an even more important role in maintaining the desired opacity and emissions levels. Although most of this discussion has so far focussed on coal firing, the application of Huyglas filter fabric for the filtration of hot gases is by no means limited to this area. Non-fossil-fueled applications which have been implemented to date, among others, include cement clinker coolers, biomass boilers, dryers and calciners, metal oxide collection, carbon black, metal smelting, and waste incineration.

Even in areas where the application of lower-temperature fabrics may be marginally acceptable, Huyglas filter fabric can prove economical. An example of this is a cement clinker cooler. Although fabrics with lower temperature capabilities are applied and are performing adequately on many of these installations, as demand for cement increases more and more of these installations will be pressed for increased output.

As output on these systems increases, so does operating temperature. In a case such as this, Huyglas filter fabric will allow the system to be operated at a higher temperature with less activation of cooling water sprays and consequently less system-maintenance. Several cement producers are presently examining the possibility of applying pulse jet dust collectors to vent the kiln, an application which to date has been primarily reverse air.

In other areas where bleed-in air is necessary for cooling purposes, Huyglas filter fabric, by allowing operation at higher temperature, decreases the need for cooling air, consequently allowing the system to handle a smaller volume of air.

A more specific example of a non-coal-fired application is at a kaolin clay-processing plant located in the State of Georgia, U.S.A. The installation consists of a four-module pulse jet dust collector venting an oil-fired rotary kiln. A problem existed in that the original fabric being used was degraded by sulphur oxide formed from the gas stream leaving the kiln, causing the bags in the unit to be replaced approximately every 9 weeks.

Each of the four modules which were manifolded together contained 432 bags having a total system cloth area of 1860 m^2 (20,012 ft^2). The system is designed to handle 1980 m^3 (70,000 ACFM) of gas at 176 ^oC (350 ^oF) at a net air-to-cloth ratio of 4.66:1 (85 m^3/m^2/hour). The dust collector is cleaned off-line.

In an attempt to improve bag life, plant management acted on the recommendation of the baghouse manufacturer and installed a set of Huyglas filter fabric bags. The installation of the new bags was completed, and evaluation of the bags during the 22-week period that followed indicated totally satisfactory performance with no bag failures and no visible plume from the stack. Physical tests conducted on sample bags removed after 18 weeks showed that the fabric retained 100% of its original strength.

Despite the initial higher cost of the Huyglas filter fabric bags, the plant realized a net cost reduction of $44,000 during the initial 22-week evaluation period alone. This saving resulted from avoidance of the rebagging of the four filters in the 9th and 18th week and from reduced fan-power cost as the filter bags operated at a substantially lower average pressure differential of 50 mm W.G. (2" W.G.) as opposed to 130 mm W.G. (5" W.G.). The bags went on to function well for a period of slightly over 2 years before they were removed.

In summary, as we all know, there is no perfect filter medium and no fabric, including Huyglas filter fabric, is the universal solution to every dust collection problem. However, in the four years plus that Huyglas filter fabric has been on the market, and after more than 60 installations, some of which are presently in various stages of start-up,

Huyglas filter fabric has without question demonstrated its ability as a viable and effective alternative to high-ratio, high-temperature dust collection.