

PRACTICAL ASPECTS OF AIR POLLUTION CONTROL

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INTRODUCTION

Whilst it is normally relatively easy for the man in the street to detect air pollution — he can see it or smell it, occasionally taste it — and to demand that "something must be done", it is not so easy for works management on whom the onus lies to put things right, — to know what is the best thing to do. Usually management knows only too well that it has a problem, what it is less sure of is how to solve its problem in the most effective way at the lowest cost — and that means first time!

Unfortunately there are few areas of engineering in which the average works manager or engineer has less experience and therefore feels less competent than pollution control. The very terms used are often new to him and he tends to feel rather at the mercy of the specialist equipment manufacturers, not only in the choice of equipment for this particular application, but in the assessment of the problem itself in quantitative, rather than the qualitative, terms used by the general public. In fact pollution control is rarely so complex that the non-specialist technical manager cannot understand and contribute to the "strategy" — the basic overall plan — to be employed in the solution to his problem. Further, unless he does understand at least in a general way, the problems posed by his particular process it is doubtful whether a successful solution can be achieved unless, by chance, the company he employs has experience in exactly the same operation. Even in the finer details of the design of a control system the general engineer need not feel at a loss. The normal laws of engineering and the natural sciences apply to dust collection equipment like any other; the law of "statistics" which under a variety of names states that "anything that can happen, will, and at the worst possible time", should always be borne in mind, as should that basic tenet of economics summed up in the old North country saying "You get nothing for nothing and very little for sixpence".

A successful pollution control system is invariably the result of the closest co-operation between plant personnel and equipment manufacturers and in this paper it is hoped to present some general guide lines to the potential equipment user to assist his understanding of the problems facing the supplier, and help make certain that the system employed does work.

GENERAL STRATEGY OF POLLUTION CONTROL

1. Process Alteration

The most effective way of controlling pollution is not to produce the pollutant in the first place. This approach is so obvious that it is often completely overlooked and yet process alterations or the substitution of materials to eliminate difficult or dangerous emissions can provide major cost benefits compared to the alternative of "tacking on" a filter to an existing plant.

As an example; a company in the United Kingdom produced small quantities — of the order of 1 ton/month — of cadmium copper for the manufacture of electrical fittings; the cadmium addition hardens the copper without reducing its conductivity too much. Because of cadmium's boiling point (767°C) and the high melting point of copper (1083°C) production of the alloy invariably gives rise to heavy fumes of cadmium oxide which is a considerable health hazard, and the company had been in the habit of making the alloy in an electric furnace, on night shift, once a week. When the pollution control authorities demanded that something be done to reduce the emission to atmosphere to an acceptable level, the actual cost of producing this small amount of alloy was examined for the first time; as a result the section was closed down and billets bought from an outside source at a considerable saving in cost. Clearly this second company has had to install dust collection equipment but it specialises in the field of alloy production and can afford the necessary equipment since its melting shop is fully utilised on a three shift basis. Other companies, mainly on the European continent who formerly manufactured cadmium copper for electrical power transmission in railway and

trolley bus systems have switched to the use of hard-drawn copper or alternative alloys such as chromium copper which, while probably not quite as good as the cadmium containing alloy, are reasonably satisfactory and avoid the health hazard during melting and casting operations.

Many examples are available of process changes brought about almost entirely to avoid pollution problems. Until about ten years ago the rotary furnace was by far the most common piece of equipment for the production of aluminium alloys from scrap materials. To clean and refine the alloy and to assist in heat transfer the furnace bath was always covered by a thick layer of molten flux, containing essentially sodium chloride with additions of other alkali chlorides and fluorides to increase its fluidity and activity. Unfortunately this flux produced a heavy emission of fine salt particles — together with some gaseous pollutants which will be discussed in a later section — and when the humidity was high these particles nucleated mist formation so that it was by no means uncommon for the area around the smelter to be fog bound whilst the rest of the countryside had nothing worse than grey or cloudy days. Since many of the works were in industrial towns and close to major roads this pollution problem did not go unnoticed. The collection of such a chemically active, and very fine material presented considerable technical and financial problems and the alternative approach of using electric furnaces — which require no flux — or reverberatory furnaces which use very little, has been taken up by many companies though it is extremely doubtful whether either of these furnaces produces metal of the quality of that smelted in rotary furnaces.

Those connected with the chemical industry will have seen the swing away from the mercury cell for the production of chlorine over the past few years whilst in the copper field the classic reverberatory/converter route to copper production from sulphide concentrates has been virtually killed in the U.S.A. by pollution control regulations.

2. Collection Systems

Whilst it is possible in some industries to add a filter on to an existing process, and several companies specialise in the manufacture of

scrubbers and bag filters for various wood-working unit operations, slag crushing etc., for bigger plant and essentially for the metallurgical and chemical industries, a complete collection system is called for if the pollution problem is to be solved satisfactorily. This system is made up of three parts - the three "C's" as they are often called - containment, conveying and collection; all three are important and mutually interdependent but probably the first is the most important because of its effect on the size and the economics of the whole control process. Unfortunately it is also, in general the most neglected.

(a) Containment

The object in containment design is firstly to prevent the pollutants entering the shop atmosphere, and the aim must always be to keep the concentration of gaseous and particulate pollutants below the accepted threshold level values, and secondly to reduce the ingress of clean air to a minimum; the second point is of particular importance from the economic aspect since collection equipment is sized and priced according to the volume handled, the concentration of the pollutant usually being of less concern. The only way to achieve really satisfactory containment is to bring the system as close to the source of the pollutant as possible, and this entails either enclosing the particular piece of equipment giving rise to the problem or attaching small high velocity ducts to it. When complete access to the plant is required while it is working - for example pickling or galvanizing baths - the slot type of collection operating at velocities of about 600 metres/minute has proved successful over bath widths of about a metre and "ring" type collectors have been used for many years in pit furnaces in foundries, though maintenance costs can be high if the temperature is excessive. "Boxing in" a furnace with an enclosing hood need not make that furnace unworkable though the instinct of the labour force is usually to insist that it does. Total 360° access to a furnace or crusher is rarely required, except perhaps during maintenance and rebuilding, and only the plant staff with their knowledge of the process can decide on the design which combines sufficient access to the equipment for it to be

operated efficiently with good pollution control. Some testwork is useful here and this need not be elaborate or expensive; a few tins or bricks positioned around the apparatus can be used to define the true working area and fix the size of the necessary access areas. Using these simple techniques one company in the United Kingdom replaced inefficient "swing" hoods on its furnace platform with box structures, built on to the furnace shell and tilting with it, which not only gave much improved fume containment but reduced the volume of gas handled to less than one third of its former figure.

(b) Conveying

Conveying presents less difficult problems to the general engineer, since he is usually more familiar with the handling and movement of gases, than with the finer points of containment and collection. However, even in this area simple mistakes can be made and it is normally safer to operate at velocities which are a little high rather than too low, so that the particulate matter remains in suspension and is all carried to the collector. In some cases where dust is the final product and not a nuisance, such as the zinc oxide industry, some settlement in the ductwork is encouraged and material of gradually diminishing particle size is collected from hoppers along the length of the ductwork, but, in pollution control, settlement should be avoided since it is at best a nuisance and can often be a major hazard. At one of the major copper smelters in Zambia a portion of the main converter balloon flue collapsed due to the weight of solids deposited in it - fortunately without hurting anyone. In other instances settlement of materials like zinc chloride has led to rapid corrosion of the ductwork, while at one plant deposits of fine dust acted as an insulator and caused the gas temperature at the filter to rise to a level at which the bags caught fire.

(c) Collection

Collection equipment, be it a cyclone, scrubber, fabric filter or precipitator, is the final and the expensive part of the whole

pollution control system but it still can, and should, be judged by potential purchasers like any other piece of engineering hardware — on its suitability for the purpose, capital and running costs, maintenance requirements and so on.

So far as "suitability" is concerned the first point to be noted is that no single piece of equipment is the universal panacea in spite of the claims of some manufacturers. If the emission consists of particulate matter then the approximate particle size and its chemical composition is the first factor to be considered in deciding on the type of equipment required; the composition and temperature of the carrier gas is of almost equal importance but usually the dust burden is of less concern, which is as well since the measurement of dust burdens inside ducts and stacks with reasonable accuracy is difficult and requires specialised equipment and techniques. Complete particle size analysis is (in the author's opinion) only rarely called for in pollution control work; it is nice to have information and photomicrographs on the size and the shape of the material you wish to collect, but so far as the choice of collection equipment is concerned, particulate matter falls into groups — smokes and fumes, dusts and grits — and the first choice of collection equipment is made according to these rough sizings. For the collection of smokes and fumes, only fabric filters, electrostatic precipitators or high powered scrubbers can give the required collection efficiency to improve markedly the appearance of a stack discharge; cyclones, settlement chambers and most washers of the low energy type are a waste of money except as preconditioners or protective devices for the main plant. As the particle size increases from, say, the less than 2 micrometres of the fumes, we come into size ranges where various other types of scrubbers using less power can be used successfully, and for the coarser dusts and grits the dry or wet cyclone type collector comes into its own. In the limited space available in this paper only the problems associated with some of the equipment suitable for smoke and fume arrestment will be discussed.

(i) Bag filters

The fabric or bag filter is capable of very high collection efficiencies on even fine fumes, it collects dry which can be an advantage and it is relatively simple to operate and understand. It has however, certain inherent drawbacks and it is important that these are understood by the purchaser and the working process examined really carefully to see that the filter and process can be mated successfully. Probably the biggest drawback of the bag filter is its very limited temperature range. Since cloth is used as the collection medium an upper limit is imposed above which the fabric is damaged — not necessarily by catching fire, though this possibility must always be borne in mind and catered for, but by a gradual loss of strength and flexibility. From the old cotton and woolen bags which could stand temperature of only about 70 - 80°C, we have progressed through nylon and terylene to glass and synthetics such as Nomex and PTFE which can tolerate temperatures well above 200°C, but besides this upper limit the fabric has a lower limit. This is the dew point, below which the bags become damp and blind and, in the presence of acid or alkali, will rot, so that the structure corrodes. Since acid gases such as SO₂ and SO₃, and hydrochloric acid in the effluent have a marked effect in raising the dew point the temperature range in which the plant can be operated successfully is narrow even using the more exotic fabrics and it is important therefore that the presence of these gases be reported to the filter designer and steps taken to avoid their harmful effects. In this connection the average composition and temperature of the gases is not enough and the necessity for the plant operator's really knowing his process cannot be overemphasized — and that means what actually goes on, not what is supposed to go on, and on the night shift too! As an example a company operating electric furnaces and melting brass scrap for the production of extrusion billets decided to install

filters of some sort. Since the emission contained mainly zinc oxide, whose average particle size is about 1 micrometer, together with smoke from oily contamination of the scrap, fabric filters were chosen as being the most likely to give a collection efficiency of +99% and companies were asked to tender for a single installation to handle the combined emission from eight furnaces plus an oil fired furnace which operated for a few hours only on Sunday nights. The combined emission was about 1 500 nm³/min and the average temperature said to be about 100 - 150°C since (it was stated) the furnaces, which melted and cast one or two tons of brass in an hour's cycle were always "staggered", so that cool air entering the system while a furnace was pouring, tempered the hotter gases collected from above the furnaces actually melting. A bag filter was installed and was a disaster as might have been expected since none of the "facts" given to the designer was correct - the list of inaccuracies is long but at least some are worth listing since they illustrate the dangers of not studying the process:

- (a) Far from the furnaces being staggered it was the practice of the work force always to leave the furnaces ready for pouring at the change of shift - three times a day. The furnaces were therefore poured within a matter of minutes of each other and, more important, charged together and the temperature in the common duct therefore rose rapidly to very high figures indeed - too hot for the filter to take without an elaborate cooling system in the circuit.

- (b) While the "average" emission from all of the furnaces consisted of a mixture of zinc oxide and carbon (from the burning and distillation of oil), at different stages in the melting cycle each furnace produced mainly smoke, then essentially zinc oxide and finally, during pouring, a blend of the two. Depending on the amount

and type of oil in the charge, the amount of oily carbon and oil vapour passing to the filter varied considerably and intermittent blinding of the bags due to the oil was always a problem.

- (c) Part of the charge to the furnaces consisted of bagged swarf and since the bags were relatively costly the operators were instructed to empty them onto the floor and shovel the swarf into the bath. In fact the more common practice was to empty directly into the furnaces when the bags often ignited and glowing pieces of hessian and paper were drawn into the ductwork by the strong draught. The gas velocity in the duct to the filter was about 1 300 metres/min and the bag filter was only some 70 metres from the furnaces so that there was little time for burning material to lose temperature before reaching the bags. Several bag fires were undoubtedly caused by such carryover and, though the incidence of fires was reduced by installing a multiple cyclone before the filter, the whole system had to be redesigned and a complete de-oiling plant installed to clean up the swarf in the charge before the emission problem was solved.

All of these problems could have been avoided by better co-operation between the supplier and work's management and both were culpable in this case, but at the very least, the equipment supplier should be able to rely on a full and accurate process description from the potential customer.

(ii) Wet collectors

The term wet collectors is used here rather than scrubbers because some of the problems to which the scrubber is heir apply also to the wet electrostatic precipitator. The two will, however, be discussed separately.

In some ways even the term "collectors" is a misnomer since unlike the dry collectors, which remove particulate matter from the air and deposit it in a hopper of some sort, the wet "collector" transfers the pollution problem from the air to water and solid matter has to be precipitated and/or filtered from the liquid phase: this is not always easy and sophisticated and expensive equipment is often called for. For those who have worked with fabric filters, the major, sometimes the overriding, attraction of wet collectors is that they do not catch fire and since the gases have to be cooled in any case, the volume of gas to be handled can be kept to a minimum. This is just as well, since most high efficiency scrubbers operate with a considerable pressure drop, and their running cost is therefore high, whilst precipitators are expensive in capital cost.

If wet collectors are free from the fire hazard then corrosion is their major problem and materials of construction should be chosen with the greatest care to suit the process, bearing in mind that the particulates as well as some of the carrier gases can often go into solution. A thorough understanding of the process is therefore called for, and this is more important than pilot work which rarely lasts long enough to show up corrosion hazards.

For example — at a company in Birmingham, producing secondary aluminium ingots in rotary furnaces the management decided, on advice from consultants, that a wet electrostatic precipitator was the answer to their pressing problems of salt emission. Test work was carried out for several weeks to establish the design parameters and a plant erected to handle the fume; in less than a month it was punctured due to corrosion of the main structure and eventually it had to be removed, under guarantee, at considerable loss to both parties. The pilot plant which was undamaged was made of mild steel, the full scale unit of a variety of stainless steel. Since the particulate matter to be collected consisted of soluble chloride plus fluoride, and

the carrier gas contained considerable amounts of SO_2 and SO_3 (from combustion of heavy oils) plus hydrochloric acid - from flux breakdown - and free chlorine (degassing), the likelihood of anything but the most exotic of metals being able to stand up to the acid "cocktail" which was circulated in that plant was obviously remote. For scrubbers non-metals resistant to corrosion should be used wherever possible for this type of application and similarly acid proof tiling, wood or concrete might be substituted for steel in the casing of wet precipitators.

Since most high efficiency scrubbers collecting fumes and smokes achieve this efficiency by operating at very high pressure drops their power requirement and the running cost is considerable. In order to keep these power costs to a minimum high efficiency fans are often used, and since these can cause trouble, the potential buyer should view their installation with some considerable reservation. At a secondary aluminium smelter near Leeds, just such a fan was installed behind a wet scrubber operating at a pressure drop of about 50 cm W.G. The scrubber itself worked fairly well though it was dirty and messy, but the stack resonated to some "harmonic" of the fan to such an extent that people living in a terrace about a quarter of a mile away from the works, and across a lake, were unable to sleep, and had an injunction served, and the works finally closed down. At another plant it proved impossible to keep the fan impeller in balance due to dust deposition behind the blades and on one occasion the impeller actually broke loose, wrecking the fan's concrete mounting block and careering through the works! The mechanism proposed for this out of balance was that water particles containing specks of dust coming into the fan from the scrubber, were caught on the back of the fan blades where the water evaporated the dust deposited and gradually built up into a hard cake.

Disposal of the effluent from wet collectors merits a

paper of its own, but again a thorough study of the process can show most of the problem areas before the plant is built. Soluble material will have to be precipitated to a level at which the final discharge meets the various water effluent regulations for example; oil will have to be removed and that is not always easy, but occasionally even after great care in design, a new and unexpected problem emerges. A company in the Midlands of England decided to install a rotary dryer to de-oil swarf and bought a venturi scrubber to collect the smoke produced; this it did quite successfully, but the vigorous action of the venturi on the mixture of fine oily carbon and oil vapour resulted in the production of a stiff, almost dry, black foam which floated on the top of the settling tanks and blew with the wind over all the washing and windows in the neighbourhood.

Clearly you cannot win them all, but with care and attention you can win most of them!