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Mr Wiley

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
OFFICE OF SYNTHETIC LIQUID FUEL
LOUISIANA, MISSOURI

TOM Reel No. 132, Item No. 1

1130

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Oct. 15, 1947

Dec. 12, 1936

DUST REMOVAL

by Dr. Geister

Note: Only figure 8 in the text could be conveniently reproduced.

There was to be observed in 1936 a particularly strong interest in the subject of dust * resulting from an increasing production of dust from a large amount of low cost raw materials, the firing of pulverized coal, an increasing thruput of driers, mills, feeders, etc., This dust could not be satisfactorily or economically settled with the present development of the dust removal technique. It becomes very important to get an idea of the available dust removal means and I have tried to discuss in my report presented on Dec. 3, 1936 the dust removal installations at our works, the most recent information in literature, and on the minutes of the very important meetings of the sections of this society and of the union of the large boiler operators, in which I had occasion to participate.

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* Jan. 1936 elaboration of directions at the meeting of society of dust technique in Berlin.

* Jan. 1936 full day meeting of the union of owners of large boilers with the economic group for production of electricity in Dermanstad: the sole point of discussion was "overcoming the fly ash".

* Feb. 1936 "directions for dust removal (V.D.I. edition).

* April 1936 the first copy of the new quarterly magazine "Staub" has been published (ed.) Knapp, Halle/Saale publisher: "The Dust Removal Section of the union of German technical societies".

* April 1936 directions for determination and composition of dust based on their grain size and speed of settling, published by the V.D.I. edition.

* May 1936 the first of series of communications of the section of the dust technique connected with the V. D. I. meeting in Dermanstad.

The dust removal equipment today can be subdivided on the basis of physical properties used into:

1. Gravity separators
2. Centrifugal separators
3. Electrostatic separators
4. Moleculer and frictional force separators

The first three forces mentioned here should be made to operate in such a way that the dust particles would leave the stream of gas in which they are suspended at the proper place and as rapidly as possible, while the filters operating on molecular and frictional forces depend on leaving the particles in the carrier gas, but preventing their motion with it.

While the force of gravity is not large, it is always freely available, and must therefore be considered first as the cheapest, if it can be made effective. The force of gravity imparts to any mass, including our dusts, an acceleration according to the classical laws of acceleration; nevertheless dusts differ from other solid bodies, in that their free fall is very rapidly braked by the viscosity of the carrier gases. In cases of greater acceleration the uniform fall is designated in case of dust as the "velocity of the migrational motion". The magnitude of the migrational velocity must be established first before arriving at the adequate dust removal.

Explanation based on forces	Migrational velocity of the grains of dust with the carrier gas.		Conclusions
		Depending on	
Gravity Separators	$W = \frac{2}{9} \frac{\gamma_1 - \gamma_2}{\eta} r^2$	1. the equivalent dust particles radius r 2. the specific gravity of the dust γ_1 3. viscosity of the gas η 4. (specific gravity of the gas γ_2)	W is reduced with a sq. of r, necessitating very large dimensions of the structure for finer dusts in gravity dust separators.
Centrifugal Separators	$W = \frac{2}{9} \times \frac{r^2}{g} \times \frac{\gamma_1}{\eta} \times \frac{u^2}{R}$	1. volume velocity u 2. the equivalent radius of the dust particle r 3. the curvature of the path R 4. specific gravity of dust γ_1 5. viscosity of the gas η	high volume velocity and sharp curvature favor dust removal in centrifugal separators.
Electrostatic Separators	$W = \frac{10^6 \times E \times e}{9 \times \pi \times \eta}$	1. field potential E 2. the elementary chargee 3. the viscosity of gas η	grain size and specific gravity have no effect; all dust particles therefore practically equal; settling is low.
Frictional Separators	the effect increases with resistance	1. Molecular forces 2. frictional forces	narrow long and twisted channels increase the activity; that is small pores, thick and irregularly constructed filters.

The table above summarizes the formula connecting the velocity, the factors it depends on and the conclusions one may draw from these formulas. The factors "specific gravity" and "viscosity" are in general known. The equivalent radius of the dust particle on the other hand must first be determined.

For particles over 60 μ the grain size are determined with screens, if smaller than 60 μ by air flotation. Air flotation permit the estimation of sizes only down to 5 μ and the still finer dusts must be analyzed by elutriation. Drs. Krause and Zell have developed a method for estimating the particle in application to color printing sizes between 20 μ and 0.5 μ *. The results of all measurements

* Current number of this magazine -- index at the end.

furnish the characteristics of the particles and we distinguish between uniform particles, sifted particles, unsifted particles and air separated. The residue, thruput and size distribution curves in figure 2 are cited as examples.

A method of determining whether gravity or centrifugal separators can give the proper degree of dust removal for a given composition of dust has been given by Schulte 2/ in the V.D.I. referendum and is shown in the bottom line of figure 1. There is at present no computations known for dust of different shape and different specific gravities. For these dusts the curve of equal precipitation derived from the determination of dust is used to replace the characteristic particle size curves 3/.

It is well known that the dust carried by air currents is re-deposited in certain parts. There is a dust drift in such places similar to snow drifts. Naturally, an understanding of the underlying laws of these phenomena could lead to decisions on suitable dust separators. Dr. Sell 4/ has derived the principal formula on the motion of dust particles in air stream and their deposition, occasionally in the presence of baffles, and confirmed them experimentally. Using hydronamics and aerodynamics he first investigated different baffles, on the side facing towards the air inlet, because that side alone affects deposition of dust. India ink droplets of about 50 μ diameter were used as dust, and they were blown against different baffles at a velocity of 9.2m/sec. Figure 3 illustrates the first baffle, a cylinder. The paths of the dust passing tangentially over the baffle are called the limiting paths, and were drawn later. A relative degree of dust removal is obtained from the proportion of the distance of the parallel part of the limiting paths to the diameter of the baffle. It proved to be equal to 0.60 in figure 3 where a cylinder was used, 0.75 in figure 4 representing a plate, 0.82 with the baffle shown in figure 5.

The last shown baffle arrangement has therefore the highest relative degree of dust precipitation, and its resistance to flow was reduced by stream-lining it as shown in figure 6 and 7.

In the second part of his investigation Dr. Sell studied the deposition of dust on oiled metallic filters, which have gradually replaced, since 1916, the formerly generally used cotton filters because of the scarcity of textiles. As in several other cases, "Ersatz", improvements, such as metal filters have become the standard type on the market. This type of construction is always characterized by specially formed sheets or by fillers, which give frequent changes in direction to the stream of gas: the particles of dust are removed from the streams by collision with the oiled deflecting surfaces, on which they become fastened. All producers of power are familiar with these filters, which must be occasionally renewed by hand. They are also made as endless bands for use with large volumes of

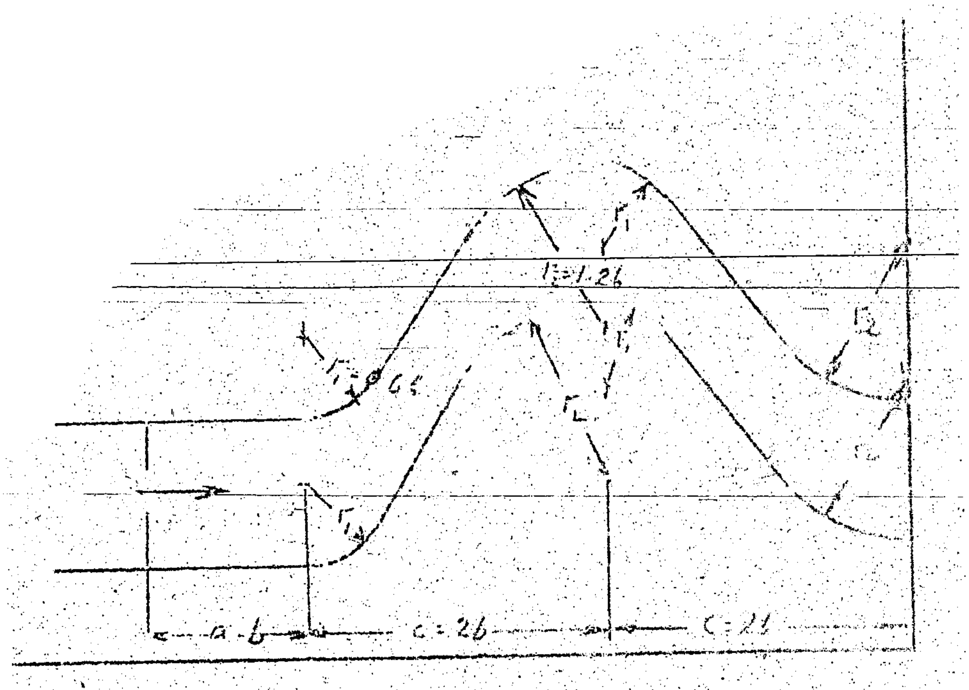

Figure 8. Shapes and sizes of the channel

gases, which must be continuously purified and humidified.

Dr. Sell's studies were intended to determine the forms of deflecting sheets which offer a low resistance to flow with a high degree of dust removal, and he found that in shapes represented in figure 8, in which the channel is first reduced like in an orifice, and then widened out, the resistance is ten to fifteen times smaller than in the case when the radii r_1 and r_2 are of equal size. The reversal of the direction of the flow increased the resistance by 25%. In the original paper are three photographs showing the development of the proper shape of the channel, but they could not be reproduced.

An understanding of the velocity of travel of dust and the behavior of dust in different fields of flow permits us today to evaluate the principal dust removers. Figure 12 summarizes the dry and wet gravity dust removers. The simplest dry gravity dust remover has formerly been a settling chamber. It fulfills the requirements when the time of fall of the dust is equal to or smaller than the time of residence of gas. The time of fall is small in case of a minimum length of the fall, the time of stay becomes large in a large cross section for the gas thruput. Both requirements are satisfied in the Heinicke construction system. The path of fall is made small by the roof-shaped construction. The dust particles precipitate in the pockets to the right and to the left. The erections and operations are cheap, but the space requirements are large and the gas velocity must not exceed 1-2m/sec.

The type Bartl operates with equally low gas velocities, but with more condensed dimensions. Breaking down the stream of the gas and repeatedly reflecting it, while simultaneously making use of pockets, a dust removal similar to that shown in figure 8 with metal filters is obtained. In the Filtrex system deflection almost reach the limit of possibilities. A spherical form produces uniform gas velocities even after the flow has reached a definite amounts of gas. About 3-4% of the gas goes with the dust into a separator connected in series with the former and the residual gas from it is returned to the main stream. Such a division of the gas stream into a principal stream freed from dust and a side stream containing dust can also be found in other systems. It offers the advantage of keeping the separators connected in series of a small size.

As a general rule, dry gravity separators can be used for coarse and medium fine dusts. Wetting them with water permits also the catching of fine dusts. The bottom line of figure 12 shows three systems, namely the Babcock wet dust separator with sprinklers, Van Tongeren dust chamber with moistened metallic surfaces, and the Finow dust remover similar to that represented by figure 8. The Finow dust remover is the most remarkable by consuming the least water of any of the wet dust removers shown here as well as others.

The wet dust removers removed almost 100% of the dust, and their use seemed therefore to be indicated. However many of the dusts are either ruined by water, or may be but difficulty recovered, and even with valueless dusts getting rid of the sludge and of the slime may represent a more difficult problem than the dust removal itself. Dust removers were therefore preferentially used dry, and since this is only possible to a limited extent with gravity separators, they were in most cases replaced with centrifugal precipitation.

The formula for the velocity of travel in centrifugal separators (figure 1) shows that the volume velocity of the gas must be at the maximum and the radius of curvature of the gas path must be kept at a minimum. These two requirements were not always met in the older separators. Thus, as late as 1931 a table of measures of cyclones, was published in technical paper, in which as the inlet cross section was increased all the other dimensions were also increased, and the conditions regulating good centrifugal separation were met the poorer the larger the volume of gas. If any dust is separated in them it is chiefly due to gravity and not to the centrifugal force. This is an installation built with a large consumption of material and still not properly operating. A water supply pipe on top supplied a spray to a poorly working separator. A frequently plugged outlet was one of its additional drawbacks.

Such failures are impossible if proper attention be paid to the laws of deposition of dust. Some of the fly ash centrifugal separators which are most in use are shown in figure 15.

Judging from outward appearance, the Hartmann separator has the usual cyclone shape, but in this system the two principal requirements of a centrifugal separator built in accordance with our newest knowledge are satisfied. The radius of curvature remains small even with large amounts of gas, and the angular velocity is in all cases so great that only centrifugal force acts, and no longer the gravity, so that the Hartmann dust remover may be used either in a vertical or a horizontal position. Because of the necessary high gas velocity the resulting resistance amounts to 3.15-3.95 inches of water, but on the other hand the Hartmann separators work with a very good degree of total dust removal, with the particle of dust as small as 5 μ.

The Van Tongeren centrifugal dust remover works with a lower resistance but with a separation of particles down to only 20 μ. In this system the dust carrying side stream is also used with sharp deflections.

The Lurgi multiklon system also pays strict attention to the requirements of the centrifugal dust removers, even when handling large volumes of gas. Large volumes of gas cannot be passed through cyclones with small radii of curvature, and the total gas stream is so much subdivided into smaller streams until each individual stream meets the requirements of cyclones. This measure is so systematically followed that even as many as 100 cyclones have been combined into one multiklon.

We may point out in this connection centrifugal separators which do not appear to meet the correct requirements at first sight, but in which the low grade of dust removal is overcome by the method of their use; I have in mind the air separators of our mills. We know that the thruput of each mill is increased when the ground material is separated from the material to be ground as rapidly as possible. The most common form for it is that of air separation as shown in figure 15 on a Raymond mill. The air separation is based on the fact that only such particles are entrained from the dust mixture which can be carried by an upward rising air stream; the rate of deposition of these particles is less than the velocity of the air (where the deposition velocity is equal to the migrational velocity in figure 1). However the continuous air flotation of the ground material is entirely successful in increasing thruput only when the finished products are actually deposited in the centrifugal separator connected in series, because otherwise they will be returned into the mill by the circulating air current, and this will lower the thruput. The thruput was actually increased by 50% in one mill by improving the deposition.

Moistening with water is used in the centrifugal separators just as in gravity separators whenever the proportion of the smallest particle sizes is very great and difficult to be measured, as is particularly the case with fly ash. Figure 15 shows the Pfleiderer separator installed by our company in the high pressure boilers in Oppau and Leuna for the deposition of fly ash; where the stream of gas is broken down like in the metallic filters and the particles of dust are thrown out from the gas path by deflections of the flow, and remain stuck in any moistened spot.

In the Frey system the dust containing gases enter the separator from above, pass through water sprays and reach a many-bladed fan which throws the dust out upon the moistened walls.

In the Babcock system, figure 16, space is saved by using blowers as separators, but the turbulence is objectionable for dust separation.

What has been previously said about air separation in mills applies also to pure air flotation; that is to equipment which is principally used for the separation of grits and flour. Here again the danger exists of having the fine powder carried over with the air blasts and reaching the grits. Hildebrandt meets this danger by the addition of a centrifugal separator and obtains a practically grit free product.

The very fine and valuable dusts which cannot economically be obtained by centrifugal force, and which may not be wet with oil or water are separated in layer filters. Three kinds of layer filters are used in the dust removal technique; textiles, filtering materials in piles and sieves, and filter stones. Cotton comes primarily into consideration as a textile because it retains the finest dust not only because of its shape, but also because of its natural oil coating. The effect of heat upon cotton is naturally an objection, as well as action of different chemicals, [illegible] combustibility. The system of Beth is the most important; the [illegible] is subdivided as in the multiklon and is led to the individual [illegible] connected in parallel. The dust remains on the filters in a [illegible] prevented from further travel; it must therefore be removed from time to time to prevent the resistance to gas flow from becoming too high. The cleaning of the [illegible] filters is done by [illegible].

The Rudiger filter consists of a pile of material wet with water. It is used with fine [illegible] and obtains a high degree of dust removal with a small water consumption ([illegible]). The water in addition to moistening also cleans the filter.

Another filter through piled material and which also is self cleaning but without wetting is the travelling layer-filter already known for some time. Wetting of such filters frequently resulted in gumming up. Dr. [illegible] of the I. G. Höchst has [illegible] "vibrating gas cleaner", 8/ in which a pile of leather dust [illegible] is completely cleaned by vibrations for three minutes.

The above [illegible] is a brief summary of the modern most frequently used dust separators based on [illegible] centrifugal force and filtration. The electrostatic precipitator is the [illegible] of the dust removing processes. When the volume of gas to be treated is not large, it is considerably more expensive than the previously described processes, it requires considerable space, because in them gas velocities [illegible] of 1-4m/sec. may not be exceeded nor is it entirely suitable for any kind of dust, but it exceeds all others in perfection of separation, because the particle size and the specific gravity of the dust have no effect, so that the finest [illegible] such as cigarette smoke can be retained. It would take us too far to discuss in any detail the construction system and the operations of the electrostatic dust remover. The electrical precipitations have been reviewed in the [illegible] report [illegible] explained by two Lurgi dust and arsenic dust separators from the [illegible].

The rest of the article is devoted to the description of some installations in Leuna with photographs which are not clear enough to be reproduced. There is also a table of comparison of operations of different dust removers which is not readable. The author summarized his ideas by saying the dust removal technique had greatly progressed in recent years. Whoever is in need of a dust separation has first to know the distribution of particle sizes of the dust, their weight, the amount of dust per nm^3 of gas and the velocity of propagation of dust using the formulas in figure 1.

References:

1) Dr. Krause u. Dr. Zell: Laboratoriumsbericht der Alizarin-Abteilung vom 16.7.1936 Nr. 1964.

2) Dr. Schultes: Gesichtspunkte für die Auswahl eines zweckmäßigen Entstaubungsverfahrens. VDI-Hauptversammlung Darmstadt, Fachvorträge VDI-Verlag, Berlin.

3) Richtlinien für die Bestimmung der Zusammensetzung von Stauben nach Korngröße und Fallgeschwindigkeit, herausgegeben vom Fachausschuß für Staubtechnik beim VDK, 1936, VDI-Verlag, Berlin.

4) Dr. Sell: Staubabscheidung an einfachen Körpern und in Luftfiltern. Forschungsheft 347, VDI-Verlag, Berlin, Ausgabe B, Band 2, 1931.

5) Richtlinien für Leistungsversuche an Entstaubern, herausgegeben vom Fachausschuß für Staubtechnik [illegible], [illegible] Berlin, 1936.

6) Staub, Veröffentlichungen der Staubbekämpfungsstelle beim Verband der Deutschen gewerblichen Berufsgenossenschaft und [illegible] über das Schrifttum, Heft 1, April 1936, Verlag Knapp, Halle (Saale), 1936.

7) Dr. Fiesel: Fortschritte in der Entwicklung von elektrischen Entstaubungsanlagen und Verwertung feinkörniger Abfallstoffe. VDI-Hauptversammlung Darmstadt, Fachvorträge, VDI-Verlag.

8) Dr. Gollner: Neuer [illegible] Fliehkraft-Staubabscheider, Berg- und Hüttenmännische Zeitschrift "Glückauf", 1933, Nr. 18, [illegible].

9) Nagel: Zur Frage der Güte von Fliehkraft-Entstaubern. Archiv für Wärmewirtschaft und Dampfkesselwesen 17 (1936) S. [illegible].

10) Heldau: Der Industrie[illegible], VDI-Verlag, Berlin, 1936.

11) Prockat: Forderungen und Fortschritte auf dem Gebiet der technischen Staubbekämpfung. Die chemische Fabrik (1936) [illegible].

12) Bericht Nr. 99 der Versuchsgruppe Werk Lu: Hildebrandt-Sichter.

13) Deutsch: Elektrische Gasreinigung. Zeitschrift für technische Physik 6 (1925) 9-423.

14) Deutsch: Elektrische Fällung metallhaltigen Staubes aus Industriegasen. Metall und Erz 24 (1927) 25-356.

15) Weyl: Elektrische Entteerung von Generator - und Koksofangas. Stahl und Eisen 1926, Heft 52.

16) Eiring: Die elektrische Gasreinigung unter besonderer Berücksichtigung der Elektro-Entteerung in Gaswerken und Kokereien. Das Gas - und Wasserfach, 1934, Nr. 8.

17) Dr. Heymann: Die Entwicklung der elektrischen Gasreinigung. Montanische Rundschau 22 (1935) 10.

18) Dr. Kiesskalt: Verfahrenstechnik, Beiheft VDI Nr. 1, 1936, VDI-Verlag.