

advise against this method, for the reason that the mesh becomes distorted and weakened at the point of contact of the cross wires.

Metallic filter cloth is being used more each year as a liner for centrifugal filters.

Industrial Filter Media

By Arthur Wright

FILTRATION ENGINEERS, INC., 253 BROADWAY, NEW YORK, N. Y.

Industrial filtration involves the separation of a comparatively large amount of solids from a small volume of liquid. The rate of flow of liquid through the filter medium is low; hence woven fabrics through which only a small flow is obtainable are used most successfully. Fabrics of high resistance to flow of water through them have for years constituted the typical filter cloth for industrial filtration. To-day cotton duck represents one limit, the dense, and unbleached muslin the other limit, open.

Filter fabrics can be divided into two main classes: those used for neutral or noncorrosive liquors, and those for corrosive liquors. The latter are mainly special media of wool, metal, asbestos, stone, etc. For noncorrosive liquors cotton is the material used almost without exception.

COTTON FILTER CLOTHS

WEAVES—Cotton filter cloth fabrics are made up in duck or plain, twill, and chain weaves. Plain weave has the square or right-angle appearance of all ducking and is woven by the filling or weft passing over one warp and under the next, known as "over one under one." Twill has the diagonal lines so characteristic of its weave, and is made by weaving "over two and under two," with the next filling splitting the warp members. Chain, or as it is also known, broken twill, has a herringbone appearance and is woven with one filling going over two and under two, the next reversing this order, the third being a true twill sequence, and the next repeating the above cycle again. For each weave there is considerable modification, depending on the weights of yarn used and the number per inch. Muslins and drills are trade names for very light duck and twill weaves.

The nomenclature of the various weaves should be better standardized. At present a duck is known by a number (as 00) or by the weight per unit measure (10 oz.). Twill and chain weaves are designated by the number of warp and filling members per inch, as for instance No. 2232, where there are 22 warp members per inch and 32 fillings. There is ambiguity here, for the twills woven of different yarns under the same number of members must weigh differently. A combination of weight per unit and designation of the number of warp and filling members would do much to clarify this.

USE OF MUSLIN—The commercial use of unbleached muslin and other comparatively frail filter cloths marks a distinct advance in the subject of filter media, and represents the application of a principle long understood but impractical until the advent of our modern filters.

Filtration through fabrics should be surface filtration where in all the particles filtered out of the liquor accumulate on the surface of the medium, as distinct from bed filtration where in some of the solids are caught through the depth of the filter bed, as in sand or charcoal filters. A thin fabric has not sufficient depth to hold solids within it, whereas thick media will often hold back solids that penetrate the surface. Proof of this is furnished when the surface of a heavy twill or duck cloth will often be quite clean, while the cloth is almost impervious on account of particles lodged within the cloth.

When bag filters, gravity or suction filters, and filter presses were the only agencies at hand, strength of the fabric was the primal specification for all cloths. In bag filters, strength is required lest the weight of the liquor inside the bag burst it, and in tank filters unloading by shoveling out the cake requires a cloth of substantial strength. In filter presses the strength required is not so much due to the pressure of filtration as to the squeezing effect at the gasket joint between the abutting plates and frames. Too much emphasis has often been put on this point. The absolute pressure on the cloth between the plates is not excessive save where the cloth is laid in a wrinkled condition and the pressure has to be increased to stop leakage at such places. To correct carelessness in laying the cloths, strong fabrics were required. For a time, manufacturers of this type of filter were too much engrossed in their schemes of drainage, washing methods, accuracy of machined surfaces, etc., and overlooked the cutting edge of the gasket surfaces. Only a strong cloth would not be cut through by these sharp edges. A rounded edge overcomes this and eliminates the breakage at this point.

FACTORS IN SELECTION OF CLOTH—It is obvious that the yarn used in the cloth is the determining factor in structural strength. It is also important that the cloth be dense enough to make a tight gasket joint when the press is made up. These factors have determined for the most part the specifications of the filter cloth used in filter presses.

Other factors, especially in our modern filters, affect the selection of the best filter medium. The filter cloth is fixed to the drainage member either as a sewn bag, or a wired sheet, or a clamped covering. This precludes quick changes. In consequence a cloth must have an economical life or the attendant expense of replacing the medium will make the entire filter operation excessively costly. Also, in modern filters the discharge of the cake should be without hand labor. This means automatic or semi-automatic discharging methods, the efficiency of which is largely dependent upon the filter cloth used.

PROPERTIES AFFECTING DISCHARGE OF CAKE

The discharge of the cake from the filter cloth can generally be accepted as a simple matter so long as the deposited cake is entirely on the surface of the cloth. Even with the most freely filtering liquors containing granular solids in suspension, some fine solids penetrate the surface and enmesh in the interior of the cloth. Automatic means of discharge are practically worthless in cleaning the cloth from these solids. Such a condition is fatal to modern type filters, and in some industries where it is almost impossible to prevent solids penetrating the surface of the cloth, as, for instance, raw cane-sugar manufacture, plate and frame filters are still supreme. In these filters the cloth can be changed after each operation. Naturally if the cloth is open or so thin as to prevent the fine particles from collecting within the fabric, discharge of the cake from the surface cleans the cloth.

SMOOTHNESS OF SURFACE—Experience has proved, especially in the case of sluicing discharge, that the surface of the cloth must be smooth for the best results. A duck weave has proved a better cloth than a twill weave of admittedly better porosity.

POROSITY—A new filter cloth held up against the light may show open pores, and yet become positively dense when wetted or in operation for a few runs. In this case the reverse current cannot permeate well and tends to belly out the cloth without lifting the cake away from the cloth. Some operators have had but little better success in discharging when trying out open cloths. A too porous cloth lets the reverse current through too readily, so that it discharges small patches of cake and lets the incoming air

pass out through these openings without penetrating the rest of the surface. There is a definite porosity for any particular material being handled, and this can be determined definitely only by actual test.

NAP—The nap or hairy surface of the yarn is of almost equal importance. The nap in the yarn exercises an effect similar to that of the hair in wall plaster. The nap is the loose ends of the cotton and is, of course, greatest in the short staple stock. Egyptian cotton and domestic long staple make cloths of immensely better discharging quality. The costs of these are probably sufficiently high to warrant the proper singeing of the nap from cloths made of short staple. Singeing is generally only surface action, but it is held that with thin fabrics the singeing flame can be regulated to work through the entire fabric. Mercerization of cotton cloths will also reduce the nap but it is not comparable, as a manufacturing process, to the simpler and more easily controlled singeing.

A cloth of only slightly heavier weave than unbleached muslin is used in Sweetland filters for clarifying cane sugar refinery liquors. It has a smooth surface and a high capacity for the flow of liquid through it, and its thinness precludes the possibility of solids lodging within it: hence automatic discharge from it is easily made. There is no gainsaying that it will not stand hard usage. However, any cloth capable of 8 wks.' life under 24 hrs. per day operation must be admitted to be a practical medium.

SELECTION OF DRAINAGE MEMBERS

There are means of protecting a cloth so as to increase its life, but none is more effective than adequate support in the drainage member. A screen of 5 mesh per inch or greater should have a protector for light cloths. This can be a lighter or finer mesh screen, or it is cheaper and easier to envelop the drainage member in an open weave burlap. The latter cushions the filter medium against the drainage member and in addition to increasing the life of the cloth it will often be found to add somewhat to its capacity.

Every filter cloth is affected by the kind of drainage under it. Efforts to give the maximum drainage have resulted in excessive drainage in some cases. The foreign presses used in the breweries for sweetening off the mash are examples. The drainage member here is made up of 0.125 in. by 1 in. steel flats spaced at 0.75 in. centers and set edgewise to the cloth. Only a heavy woven fabric can safely bridge these spaces even under a low head of 5 lbs. per sq. in. This drainage member, requiring a heavy filter medium, unnecessarily complicates the operation of these filters. Albuminoidal material lodges in the cloths so that they must be removed after each run, whereas a thin weave could be cleaned *in situ*. If we take the flow from the outlet of a filter element even when the filtrate is flowing fast and distribute it across the entire area of the element, it is evident that the flow through a square inch is hardly faster than in drops at a time. So long as the space for the flow to the outlet does not set up an appreciable back pressure, it is sufficient. In an experiment made some years ago on a free-filtering calcium sulfate slurry, two leaves were connected to a common header and tested under the same suction pressure, with all operating factors maintained constant. One leaf had a drainage member made of wooden slats, the other, using the same-sized collecting frame, had one layer only of a thin burlap. The burlap leaf lagged at first, but in less than 0.5 hr. the cake on both leaves was the same. A large chemical plant recently discarded iron screen drainage members and substituted five layers of burlap and obtained a higher rate of flow. Naturally with a soft drainage of this nature thin cloths can be substituted for the old heavy cloths with marked success.

REQUIREMENTS OF A FILTER CLOTH

We no longer give primal consideration to the rate of filtration for any cloths. With few exceptions the resistance of the depositing cake to the flow of filtrate is many times that of even dense cotton ducking, so that the initial resistance of the filter cloth is trivial in comparison. This is not true of paper pulp filtration, where only a small suction is employed and where the pulp is free-filtering. The filtering rate of the cloth will be found to be of moment only when its resistance increases with recurring operation due to poor cleaning of the previous loading.

Formerly the first consideration of a filter cloth was its clarifying properties. To-day this is quite secondary. Most operators are realizing that the true filter medium is a layer or film of the solids which are being filtered out of the liquor. Of course, with this in mind, provision must be made for the cloudy filtrate obtained at the start of filtration. If extremely open weaves are eliminated, the amount of cloudy filtrate is not excessive for refiltration, and clear filtrate should be obtained shortly after starting up. When it is indispensable that only clear liquid be obtained, as in the case of cane sugar sirups in refineries, pre-coating the cloths with an inert, free-filtering solid automatically provides the filtering layer.

A novel and uncommon observance of a principle commonly known to all of us came to notice recently. Animal and vegetable fibers used in the manufacture of the ordinary filter fabric are absorbent. In a plate and frame installation handling a mildly caustic liquor the plant superintendent noticed that his cloth failed more quickly in the gasket portion than in the filtering area. The wash water penetrated through the filtering area but failed to wash out the soluble between the abutting gasket surfaces. He made this part of the cloth nonabsorbent by painting it with a tar base paint, thus materially increasing the life of the filter cloth with no noticeable expense.

ALLOWANCE FOR SHRINKAGE OR STRETCH

The consideration of shrinkage and stretch of filter cloths is of vital importance. Every cotton yarn shrinks when wetted, and the amount varies, depending upon the physical constants of weaving, that is, the tension under which the cloth is woven, the density of the threads, and the number of intersections. Duck and chain cloths shrink much more than twill weaves. Stretch is the reverse of shrinkage and is due to mechanical pressure, usually that of reversed compressed air in discharging. Twill weaves give much more than any others and make trouble in pressure leaf filters especially. These points must be taken care of by the local user by providing extra material for liquors in which the cloth shrinks and by making up the leaves as tightly as possible where stretching is to be encountered.

MEDIA FOR CORROSIVE MATERIALS

So far we have considered the material being filtered noncorrosive to the medium. Alkalies and acids are, of course, hard on vegetable and animal fiber. Some salts like aluminium sulfate have a contracting action, and unstable salts, such as some of the ammonium salts, give trouble. The degree of the deleterious effect depends upon the concentration of the liquor and the temperature. Actual test is the best means of determining whether a cotton, wool, metal, or stone medium is required.

For weak caustics like milk of lime, cotton can be used economically. But wherever cottons are used with even the weakest alkalies, precautions should always be taken that the caustic does not concentrate. Letting a filter stand several days so that the cloth becomes dry before the filter is again put into operation is manifestly poor practice, as the

drying of the cloth concentrates such caustic as is present. Wool is the poorest material to use on caustics of any strength. This should be remembered where a cake filtered from an acid liquor, in which wool is a very good medium, is washed with a caustic.

Strictly speaking, the world's best acid filter medium is silica, or other inert compounds as carborundum, alundum, etc. Filtros, a porous fused silica, is typical of this class of material. Mechanically these media do not lend themselves as well to the types of industrial filters most widely used. They are sometimes faulty on account of their lack of uniform porosity and the possibility of solids penetrating the surface, never to be removed.

METALLIC CLOTHS

One of the factors of safety provided in this weave is that any imperfection due to faulty workmanship can be reduced by rolling the cloth between heavy cylinders, thus closing up the imperfection. Much criticism has been leveled at this rolling, on account of the injury to the wires. If the metal is soft enough the rolling has only a small, if any, deleterious effect. If heavier wires of improperly annealed material are used it is quite evident that rolling is a poor expedient.

The improvements in twill weave instead of square weave, strength proportioned to the warp members, monel metal for iron, etc., are later-day improvements making the cloth a better medium. The wire cloth company who turned out the first commercial cloth later perfected a weave from the old Dutch cloth of commerce which has proved to offer some striking advantages. Much heavier wire can be used and the smooth finish of its surface as well as the evenness of its weave are some of its commending features.

In some liquors the metal is slowly attacked so that its life is definite. For such work there can be no discussion as to the kind of metallic cloth to use. The wire of maximum cross-section is desired and the cloth using it should consequently be selected.

CLEANING OF FILTER CLOTHS

The filter medium often becomes fouled as a result of incrustation, either from handling supersaturated solutions or from precipitation caused by lowering the pressure of the liquor. In order that the porosity shall be maintained sufficiently to obtain production, the cloth must be cleaned with an agent that will dissolve the incrustation. This is particularly true of metallic filter cloth used on caustic liquor containing calcium compounds as precipitates. The use of an acid, such as hydrochloric, to remove these incrustations is, of course, fraught with danger to the cloth. In most instances the incrustation is unnecessary. Calcium carbonate will often deposit because the liquor contains bicarbonate. If the temperature had been raised and held at the boiling point the bicarbonate would have broken down to normal carbonate. This is very evident in beet sugar manufacture. There is a safety provision for even these liquors as they are generally handled. In closed outlet filters all that is required is that there shall be a back pressure on the medium above the actual point of precipitation. In practice this back pressure can take the form of a pipe delivering the filtrate to an outlet some feet above the filter. In a magnesia plant the scale that formed on the vertical pipe required a change of a section of the pipe each week. This, however, was a great improvement on having the filter cloth plugged up with this deposit. Of course, this remedy is not applicable to suction filters. In this case pretreatment is the only outlet, and where this is not feasible a different type of machine is probably the solution for successful handling of this material.

Fundamental Laws of Filtration with Suggestions Regarding Research Work

By D. R. Sperry

119 McKee St., BATAVIA, ILL.

[The material covered by the first part of this paper will be found in *Chemical and Metallurgical Engineering*, 15 (1916), 198.]

The fundamental law of filtration developed in this article is:

$$\frac{dQ}{dT} = \frac{P}{\frac{R\%Q}{K} + R_m} \quad (1)$$

The discharge formula under constant rate of flow conditions may be derived from (1) as follows:

$$\text{If } \frac{dQ}{dT} = \text{constant} = M$$

$$P = \frac{R\%QM}{K} + R_m M$$

$$\text{or if } \frac{2K}{R\%} = W$$

$$P = \frac{2QM}{W} + R_m M \text{ and } Q = \frac{PW}{2M} - \frac{WR_m}{2}$$

where Q = flow of liquid; P = pressure; T = time; K = rate of deposition; R = resistance; $\%$ = per cent of solids; R_m = resistance of filter base.

Using the terms W for $\frac{2K}{R\%}$ and N for $\frac{KR_m}{R\%}$, the equation for discharge under constant pressure conditions, developed in the original article, may be expressed as

$$Q = \sqrt{WPT + N^2} - N.$$

SUGGESTIONS AS TO RESEARCH

It should be borne in mind that these expressions are for rigid solids. There should be an investigation as to the effect of pressure upon nonrigid solids. It will of course change both K and R , and to a certain extent R_m .

A table should be made showing the value of K for different substances, and a careful record made of size and shape of the suspended particles, etc.

A table should be made showing the value of R for different substances with full data regarding particles, etc.

An investigation should be made of filter cloths. The value of R_m should be found for various weaves and weights of cloth. Measurements should be made of the strength of various cloths, their coefficient of shrinkage, their ability to stand acids and alkalies, their ability to wear under ordinary treatment, leakage at beginning of runs, etc.

The effect of viscosity upon the fundamental laws should be studied, along with the effect of change in temperature.

The effect of sedimentation should be studied in so far as it influences filtration.

The effect of various filter-base supports should be studied.

The effect of consolidation of adjacent cake formations should be studied, and the effect upon the time-discharge curves.

The effect caused by the addition of different alloys to various mixtures should be investigated.

A study should be made of filter paper and a table made similar to that made for cloths.

Filter bases not made of cloth or paper should be studied.

The effect of feeding filters with different kinds and sizes of pumps should be investigated.

The Feeding of Filters

By J. F. Springer

618 WEST 136TH ST., NEW YORK, N. Y.

Feeding may be defined as consisting of the transmission under pressure of the unfiltered liquor from a point where it is received from storage to the inlet aperture of the filter.