PERFORATED DRUM

The former class has found but limited application in the commercial world outside of the sugar industry and the drying of crystals, etc. There is some doubt of the propriety of characterizing centrifugals used in these instances as filters, for while the cake which forms in the periphery of the drum is probably more or less of a filtering medium, the function of the machine is more essentially that of a centrifugal extractor of the type used in laundries, for drying clothes. However, similarly constructed machines have been used rather extensively in an experimental way.

The serious drawback to this class of filters is the fact that the action of the centrifugal force constantly tends more firmly to pack the residue that has accumulated on the filter base, quickly rendering the mass impervious. We have here a vicious circle. The greater the force, the more densely the residue becomes packed against the periphery, and the more densely it is packed, the greater is the amount of centrifugal force necessary to force the liquid through. Furthermore, a filter of this class has no particular advantage over a standard type of plate press, and differs from it only in that the pressure is derived from centrifugal force instead of from gravity or a pump, both of which have a pronounced advantage over centrifugal force from the standpoint of expense and convenience.

IMPERFORATE DRUM

Centrifugal filters of the second class lend themselves to the application of an important novel principle. The force developed may be utilized not only to supply the pressure required to force the liquid through the filter, but, of far greater importance still, also to prevent the accumulation of residue on the paper. The surface of the filter medium remains clean and the filter is in substantially the same condition at the conclusion of a run as at the beginning.

On first thought it would seem that this novel principle might best be utilized by employing the filter medium as a tube in the center of the bowl, the passage of the liquid being from the outside towards the center and the residue being deposited on the outer side of the filter, from whence it would be most easily dislodged by the centrifugal force. Experiments, however, have given negative results. It is impracticable to dress this type of filter properly with filter paper, and the centrifugal force tends to open up the paper. In the most approved construction, the filter base is held horizontally, or in the same plane in which the drum revolves. The liquid to be treated is forced by the hydrostatic pressure due to centrifugal force to pass up (or down) through the filter paper, leaving the sediment on its surface. The flow of liquid through the paper is at right angles to the direction of the centrifugal force, and as soon as an appreciable amount of residue has accumulated the centrifugal force dislodges it and deposits it in the periphery of the drum.

ADVANTAGES—Liquids carrying a slimy sediment, or one made up of particles that tend to "shingle over" or seal the paper, may be filtered as easily as ordinary liquids. Since the filter does not lose its efficiency, the filter area may be very small; many gallons may be filtered through a few square inches of surface. In the filtration of expensive liquids, such as pharmaceutical preparations, physiological serums, high-priced varnishes and lacquers, etc., this factor presents an important advantage, since the loss due to absorption by the filter medium is materially reduced. Incidentally, this type of filter permits the utilization of the principle of centrifugal clarification, for the liquid is automatically subjected to clarification *before* it reaches the filter paper. The gross impurities are thrown out by centrifugal force; the filter paper has only to remove the lighter flock or cloud.

DISADVANTAGES—The limit as to size is low. The largest drum that has been found commercially practicable thus far is about 10 in. in diameter by about 8 in. high, fitted with twenty filter plates 7 in. in diameter. This drum is operated at 6000 r. p. m. It has a dirt or sediment-holding capacity of between 110 and 125 cu. in. Such a machine will filter from 10 to 200 gal. per hr., depending upon the density of the filter paper and the viscosity of the liquid.

High-speed centrifugals call for a high degree of mechanical excellence. An unusual degree of care is necessary in their manufacture, which makes the price relatively high. While the operator need not necessarily be a skilled mechanic, he should have a higher degree of intelligence than a plate press operator. That centrifugals of this type are thoroughly practicable from a mechanical standpoint is demonstrated by the fact that thousands are in operation in plants where the care they receive is far below what would be given them in the ordinary type of industrial institutions.

DISCUSSION OF CENTRIFUGAL DRAINING

By T. A. Bryson

TOLHURST MACHINE WORKS, TROY, N. Y.

Filtration in centrifugal machines is accomplished by the application of centrifugal force to remove liquids from solids. The action may be compared with that of a gravity filter in which the separation of solids and liquids is brought about by the force of gravity. Aside from the modifications in apparatus used, the difference in the two methods is largely in the amount of separating force employed. In the gravity filter or drain table the force is of a fixed magnitude; in the centrifugal filter the separating force may be made, within practical limits, of any desired amount.

In analyzing the force producing draining, let us consider a stone whirled rapidly upon a string. The centrifugal force so generated will be evidenced by tension in the string.

If W is the weight in pounds of the stone, R the length in feet of the string, and N the number of revolutions per minute, the centrifugal force (C_F) will be

$$C_F = \frac{W R N^2}{2932}$$

If there were no whirling and the stone were merely suspended by the string, the tension due to gravity would be W .

The ratio of the tension caused by centrifugal force to that caused by gravity is therefore

$$\frac{C_F}{W} = C_R = \frac{R N^2}{2932}$$

in which we may call C_R the centrifugal ratio.

By referring to the centrifugal ratio we do not have to be concerned about the weight of any particular body of solid or liquid. Whatever its weight, W , may be, the centrifugal force acting upon it will be $W C_R$; or the force acting upon a unit volume of liquid will be $w s C_R$; where w equals the unit weight of water and s the specific gravity of the liquid.

Applying this to the centrifugal basket in which the solids are retained, we have at any point in the load at a distance R' from the axis of rotation, the centrifugal ratio:

$$C_R = \frac{R' N^2}{2932}$$

It follows that the draining force varies directly as the distance from the axis and as the square of the revolutions. For any given speed the force is entirely dependent upon the distance from the center and the variation of the draining effort lies within the limits of the inner and outer surface of the load as determined by the width of the basket ring.

FIG. 1

Usual practice is to make R_1 , the inner radius of the basket ring, about $0.7 R_2$. If R_1 is made less than this, the interior surface of the load has too great a reduction of draining effect, the load is more difficult to reach in discharging the basket, and with finely divided materials there is more danger of clogging due to the thickness of the wall. We therefore measure the effectiveness of the machine by reference to the relation of the centrifugal force to that of gravity.

The above chart shows this relation with various basket diameters and speeds. The values given are for the periphery of the basket, and the average force acting on the charge would be somewhat less, probably in the neighborhood of 85 per cent of the values given.

FACTORS AFFECTING DRAINAGE

The dryness which may be obtained in a centrifugal depends upon several factors.

Assuming a coarse granular or crystalline material without a great excess of liquid, the moisture in the mass to be treated is in contact with particles of solid. The liquid clings to particles with a tenacity dependent upon the surface tension and the area of contact. It is drawn from the particle with a force equal to the weight of the liquid multiplied by the centrifugal ratio. The

weight of the liquid depends obviously upon its specific gravity and its volume, which latter is governed by the interstices between the particles of solids. The maximum dryness is obtained when sufficient liquid has been removed to leave a film of liquid so thin that the centrifugal force developed by its weight is too small to break down the surface tension. Until this condition of equilibrium exists, there will be an unbalanced force tending to move the liquid toward the periphery. The time required for the liquid to find its way out depends upon its viscosity and the size of the openings in the mass of solids, through which it must pass.

We may then sum up the factors affecting the draining as follows:

REMOVING FORCE:

- 1—Centrifugal ratio
- 2—Specific gravity of liquid
- 3—Volume of liquid

RESTRAINING FORCE:

- 4—Surface tension
- 5—Area of contact of liquid and solid

RESISTANCE TO MOTION:

- 6—Viscosity
- 7—Size of openings in the mass

Factors 3, 5, and 7 are all governed by the size of the solid particles. The more finely divided particles will present a greater surface area for a given volume of liquid and the smaller channels for the passage of the liquid will further restrict its flow.

It is therefore to be expected that the more finely divided materials will require a longer time to drain and more moisture will be retained when equilibrium is reached.

It is obvious that the physical characteristics of any wet material may vary between wide limits and from hour to hour during production. For this reason it does not seem that any great hope is offered in presenting the factors governing draining in mathematical form.

Even the effect of centrifugal force may not be expressed as a continuous function, for experiments have shown that with many materials there is a maximum centrifugal force above which it is not advisable to go. This is especially noticeable with finely divided materials which may often be handled more satisfactorily at comparatively low speeds, particularly during the earlier stages of dewatering.

If a charge of finely divided material is quickly subjected to high centrifugal force there is a tendency for the cake to be spun up on the basket side sheet in an almost impervious wall. The outer layers—those nearest to the basket sheet—seem to be so densely compacted that the passage of the liquid from the interior is prevented or greatly retarded.

When there is a sufficiently large percentage of liquid in the charge, free liquid will collect on the inner surface of the cake.

The conditions are now more similar to those obtaining in a filter press. The wet material is quite fluid and the machine is invariably charged while running. As the cake builds up in thickness, the resistance increases due both to the longer distance the liquid must travel and to the increased squeezing action at the periphery occasioned by the hydrostatic head within.

If the speed of the machine is maintained low, not only during charging, but for some time thereafter, until the major portion of the liquid is removed, the total time required for the operation will probably be shortened.

When the solid particles are slimy or soft, it is possible that the high centrifugal force actually deforms them and the free area between the particles is closed up. With very fine solids, which are not soft, it is possible that there may be a question of the arrangement of the particles under the influence of centrifugal force.

It is claimed that particles collecting on a gravity filter under the comparatively low force of gravity, arrange themselves in cubical piling. This gives the maximum volume of voids between the particles and therefore the greatest cross-sectional area for the passage of liquid. It is probably true that under reasonably low centrifugal force the same condition obtains. When the centrifugal force is very high at the time of charging, it is conceivable that the particles might be driven into hexagonal piling which is the most stable arrangement, but it would make the exit area for the liquid a minimum.

It has been shown in practice with these fine materials that if the majority of liquid is removed at a low speed and the cake sufficiently dewatered to reduce its fluidity, the basket may then be brought to full speed, causing a noticeable increase in volume of effluent and much less tendency for the cake to become impervious. This would seem to indicate that the deleterious effect of high centrifugal force at the beginning of the operation is due more to the arrangement of the particles than to the closing of the openings by actual deformation.

By maintaining the particles in cubical piling until the fluidity of the cake is reduced to the point where they are less liable to rearrangement, a larger draining area is maintained.

In any case it is advisable to use the lowest speed that will give satisfactory results. This means less strain on the machine and, where corrosion of the basket may have weakened it, greater

FIG. 2

safety. In this connection: never speed a machine beyond the manufacturer's rating. The centrifugal force and consequently the strain upon the basket increases as the square of the speed. Frequent inspection of the basket is advisable, especially if corrosive materials are handled.

Fig. 2 illustrates a typical draining curve which in this case is plotted from tests on sodium fluosilicate. After the machine had been run for a given time a sample of the cake was taken by pushing a thin-walled tube through the cake and withdrawing a plug of solids. This method avoided errors in sampling if there were any difference in dryness between the inner and outer surfaces of the wall. The per cent moisture is computed on the basis of extracted material (moisture plus dry solid equals 100).

Fig. 3 shows a washing curve in which the volume of wash water is plotted against specific gravity of effluent.

COMPENSATION FOR UNBALANCED LOADING

The most important factor from the design standpoint is that of unbalanced loading of the basket.

Good practice demands that in charging the basket, the material be as evenly distributed as possible. Much effort has been made to construct machines which will automatically adjust

FIG. 3

themselves to unbalanced loads, with the result that the compensating devices employed have become the distinguishing features of the several types of machines.

Suppose a basket were loaded so that 20 lbs. more weight were placed on one side than the other and that the machine were speeded to develop 500 lbs. centrifugal force per lb. of load. The force produced by the excess weight would be $20 \times 500 = 10,000$ lbs. This force would tend to pull the basket and spindle away from the center and would act in a constantly changing direction

like the pull of a stone whirled on a string. To resist such a force would require excessively heavy construction, and would cause severe vibration in the machine, in addition to the great waste of power in bearing friction.

If, however, the spindle were allowed perfect freedom, the rotation would take place about the center of gravity of the loaded basket. In other words, the basket would automatically revolve about the point in respect to which the load were balanced. This would cause a gyrating or whipping motion of the spindle.

This self-balancing characteristic of rotating bodies is taken advantage of by the builders. In practice, perfect freedom cannot be allowed, as it is necessary to provide restraint sufficient to prevent excessive gyration and to counteract certain disturbing forces which are common to high speed rotors.

Practically all centrifugals are equipped with bearings which allow gyration to a greater or less degree. In one type the bearing box is mounted in a rubber cushion or is controlled by steel springs. Another method is to mount the bearing boxes rigidly in the case, which is itself allowed to sway under the influence of the unbalanced load, the inertia of the case being sufficient to permit only a slight oscillation. A third type depends upon the action of gravity to control the motion of a sliding step bearing.

MAINTENANCE

Centrifugals should be substantially supported; preferably on a concrete foundation. The feet or base of the machine should have a good even bearing and the anchor bolts should be kept tight to prevent rocking. Poor installations are the most frequent causes of unsteady running. When machines are set on wooden upper floors, it is well to place them over or near a girder and to tie together the beams underneath so that the load will be distributed; in this way preventing the floor from yielding in spots and causing vibration.

As in all high-speed machinery, lubrication is of prime importance. For machines designed for oil lubrication, a fairly heavy engine oil has been found to give the best results. For the thrust bearing, particularly in the large machines where the load supported is heavy, a thin oil will be forced from between the bearing surfaces. As a general rule, the heaviest engine oil which will not gum and clog the oil channels or ducts should be used. Oiling should be done regularly. A thorough inspection and refilling of oil cups at the beginning of each day or each shift is an excellent practice.

Where there is a question of the use of centrifugals, probably the only satisfactory procedure is to let the centrifugal builder make tests of the material to be handled, from which he can predict fairly closely what may be expected under operating conditions.

[In this discussion, Mr. Bryson showed a large number of slides illustrating compensating and discharging equipment, and the application of the centrifugal filter in various industries.]

Pulp or Filter Mass Filters

By E. E. Finch

THE KARL KIEFFER MACHINE CO., CINCINNATI, OHIO

Pulp filters, as they are commonly called, are filters in which a mass of cellulose is formed in filtering layers as the filtering medium. They are used for filtration purposes to clarify the product, but we should not confuse the fact that clarification and filtration are not always the same.

One of the first filters of this type introduced into this country consisted of a series of plates, vertically arranged, and in these plates was compressed a form of mass or pulp as the filtering medium. Measured from the standard of today, the filter of course was very crude and unsatisfactory. Rubber gaskets were used, a procedure which would not be tolerated at this time.

A little later on another type of German filter was imported, which consisted simply of a large brass or copper cylinder in the center of which was a perforated pipe. The mass was packed loosely into the cylinder around the pipe, the product entered at the side, filtered through the mass and escaped through the perforated center cylinder.

The development of the large pulp filters began about 1900. Manufacturers were working along different lines, under different patents, and various types were built. It was soon proved, however, that the type that must be used was one that would permit of high pressure, but that would at the same time prevent the possibility of imperfect filtration. It was seen that the filter itself should be made of either copper and tin or of special bronze, and that the filtering material must be of the highest quality and most carefully selected and prepared. It was found necessary that great care be used in the construction of the filter itself. Only the highest grade of pure copper could come in contact with the product and in most of these filters the copper was coated with a heavy coating of pure block tin.

Another very important point, and one that exists at this date, is the question of the filter mass or filtering medium. The success of any filter very largely depends upon the preparation and care of the filter mass. Too much emphasis cannot be placed upon this one point.

In the handling of the great variety of products, such as fruit juices, tonics, elixirs, perfumes, and also various food commodities, in which the odor or flavor may be seriously affected, the selection of the filtering material is of prime importance. Various fibrous products have been used, such as wood fiber, linen fiber, cotton fiber, asbestos, and infusorial earths. Wood fiber should never be used, because it is coarse and flat and lacks resiliency. Linen fiber is not to be considered. Asbestos, if properly treated, may be used sparingly at times and has some advantages. Infusorial earths may be used occasionally for certain commodities, but there is always the danger of such materials affecting the flavor and aroma of the product handled.

The best filtering medium is a pure cotton mass. It has great resiliency, and by the use of either short or long fiber, a filtering layer may be produced to suit the operating conditions. It may be used repeatedly without any ill effects, provided it is properly washed so that the fibers are not balled or knotted.

PREPARATION OF FILTER MASS

The filter mass is first dissolved into a soft mass, without balls or knots, and then formed into what is commonly termed a filter cell. In small filters this is usually a single cell. In large filters a layer consists of a double cell. This cell usually is a layer of mass from one-fourth to two inches in thickness.

The layer or double cell is usually formed in a hydraulic press, before placing in the filter, and thus can be carefully examined by the operator. The pressure used on the hydraulic press varies from 20 to 50 lbs., according to the product that is to be handled. These layers are superimposed, one above the other, in the filter. Between the layers is placed a coarse-mesh screen which acts as the inlet conductor. In the interior of the layer of mass are two fine-mesh screens with rib centers which act as outlet conductors for the filtered product. If the layers are not properly formed and in the process of filtration considerable sediment collects on the filter plates, the pressure of the pump increases, and there is the possibility of this pressure breaking through the layer of pulp and into the outlet, allowing the unfiltered liquid to pass through.

To overcome this, the mass around the center outlet is compressed to three times that of the rest of the layer, or, in other words, is compressed to bone hardness. The coarse-