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White Paper [Ref. WP20171005]

Test Data Evaluation for a Rotary Drum Vacuum Filter

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Abstract

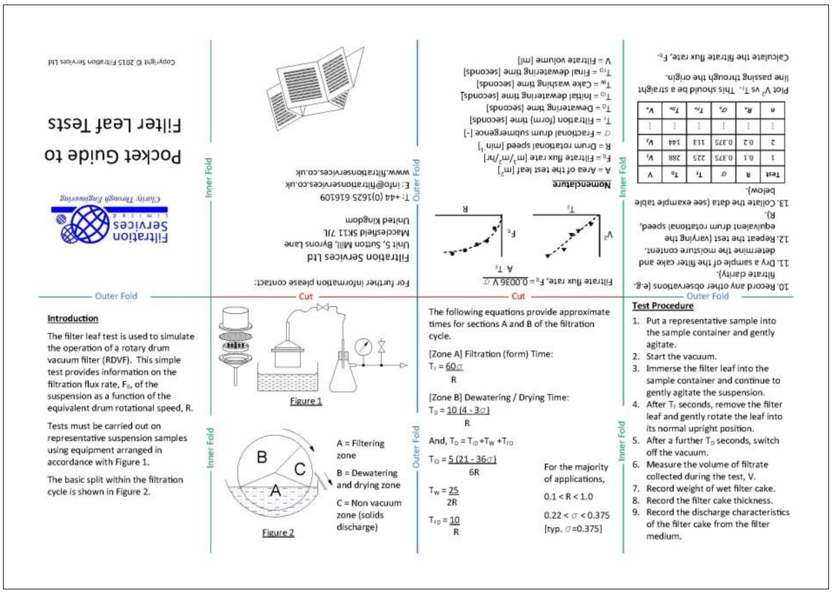
The purpose of this *White Paper* is to explain the methodology to evaluate test data for a rotary drum vacuum filter (RDVF).

Whilst it might be possible to make a reasonable first guess at the type and size of filter required for a particular duty based on process data, particle size distribution and concentration analysis, in reality the only way to understand the filtration characteristics of a suspension is by test work. For a rotary drum vacuum filter, this test work is carried out on an inverted filter leaf which mimics the operating cycle of the drum.

Test data generated by an inverted filter leaf needs to be evaluated in a way which compliments the RDVF and this *White Paper* has been set out to explain the procedure.

Figure 1. A filter leaf used for evaluating the filtration characteristics of a suspension.

An explanation of the filter leaf test procedure is given in the Filtration Services' published document entitled *Pocket Guide to Filter Leaf Tests*.



<u>Figure 2. Pocket Guide to Filter Leaf Tests</u>

Discussion

The inverted filter leaf test is only applicable to rotary drum vacuum filters. For alternative filtration technologies, different methods are used to determine the filtration and separation characteristics of the suspension. This *White Paper* is specific to the inverted filter leaf.

The Inverted Filter Leaf:

The vast majority of rotary drum vacuum filters are classed as *bottom-feed* units. This means that the solid-liquid suspension is fed into a gently agitated trough beneath the filter drum. The trough agitator is used to prevent the solids from settling and to maintain the suspension in a homogeneous state.

The filter drum is partly immersed in the suspension and vacuum is applied. Filtration is done against gravity, and referred to as *gravity hindered*. The inverted filter leaf mimics this mode of operation.

Conversely, horizontal belt filters, rotary table vacuum filters and pan filters are all *gravity assisted*.

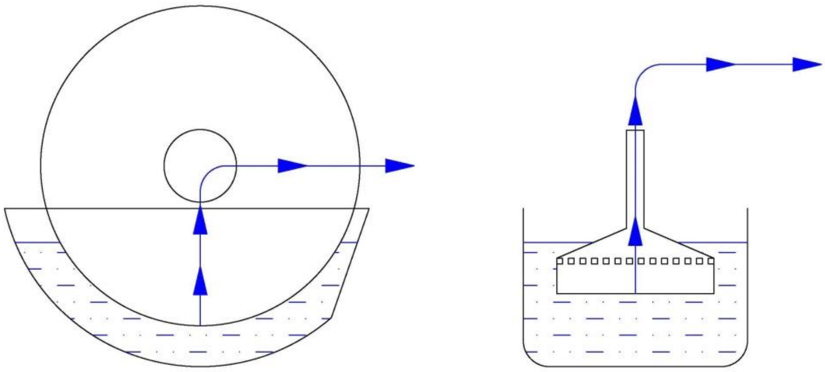
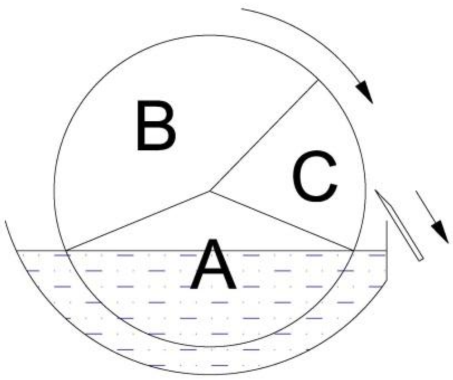


Figure 3. Illustration of an inverted test leaf mimicking a rotary drum vacuum filter.

The Filtration Cycle Timings:

In order to ensure that the inverted leaf test is as representative as possible to a rotary drum vacuum filter, it is important that the timings used for the leaf reflect the behaviour of the drum. The filtration cycle can be divided into three main time periods:-

- Filtration (or form) time, T_F
- Dewatering time, T_D
- Cake discharge time



Zone A: The filtration (or form) time is the time period where the filter cake is formed, i.e. when the drum panel is immersed in the filter trough.

Zone B: As the drum rotates, the applied vacuum dewaters the filter cake.

Zone C: This zone corresponds to a break in vacuum to release the filter cake from the drum surface.

Figure 4. RDVF operating zones

It is critical that all inverted filter leaf test work maintains the correct ratio of filtration (or form) and dewatering times otherwise the data will become unrepresentative. Information on the filtration (or form) and dewatering times are given in the *Pocket Guide to Filter Leaf Tests*.

For example:

$$T_F = \frac{60\sigma}{R}$$

And

$$T_D = \frac{10(4 - 3\sigma)}{R}$$

Where:

T_F	Filtration (or form) time	(s)
T_D	Dewatering time	(s)
σ	Fractional drum submergence	(-)
R	Drum rotational speed	(rpm)

The majority of rotary drum vacuum filters operate between 22% and 37.5% drum submergence, depending upon configuration. The standard drum submergence for Filtration Services' equipment is 37.5% (i.e. $\sigma = 0.375$).

The drum speed range is typically between 0.1 and 1.0 rpm (i.e. $0.1 \leq R \leq 1.0$).

For a fixed fractional drum submergence, σ, of 0.375:-

Drum speed R	Filtration (or form) time T_F	Dewatering time T_D
0.1	225	288
0.2	113	144
0.5	45	58
0.7	32	41
1.0	23	29

Collation of Data:

Using the inverted test leaf, filter the representative suspension sample and record the volume of filtrate, V (in millilitres). Ensure that the suspension sample has been agitated and utilise the inverted test leaf to maintain the solids in suspension.

Randomise the testing sequence to eliminate systematic errors. Record the filtration (or form) time and the filtrate volume, see below:

Filtration (or form) time T_F	Filtrate volume V
0	**0**
$T_{F(1)}$	$V_{(1)}$
$T_{F(2)}$	$V_{(2)}$
$T_{F(3)}$	$V_{(3)}$
$T_{F(4)}$	$V_{(4)}$
...	...
$T_{F(n)}$	$V_{(n)}$

It is reasonable to assume that the basic filtration theory model applies to rotary drum vacuum filters. This is because suspensions that form filter cakes which, for example, exhibit high levels of compressibility are unsuitable for use on rotary drum vacuum filters and is clearly evident when undertaking inverted leaf tests.

The basic filtration theory model assumes that there is a linear relationship between the square of the filtrate volume and the filtration (or form) time.

i.e. $V^2 \propto T_F$

So, a plot of V^2 vs T_F should produce a straight line. It is important to note that the straight line plot **must** pass through the origin. T_F=0; V=0; V^2=0.

The test data can then be approximated to a straight line passing through the origin in the format:

$y = mx$

Or, rather,

$V^2 = m.T_F$

Where,

$y \equiv V^2$

And,

$x \equiv T_F$

Once the slope of the line has been determined, it is possible to calculate the theoretical volume, *V'*, of filtrate for any filtration (or form) time.

$$V' = \sqrt[2]{m.T_F}$$

A consequence of knowing that the V^2 vs T_F is a straight line passing through the origin is that only one test data point is enough to generate a value for the gradient, *m*.

Data Analysis:

For the inverted filter leaf tests the following information is known or fixed at the outset:

Fixed parameters

- Filter leaf test area, *A* (m^2)
- Assumed fractional drum submergence, *σ (typ. 0.22 to 0.375)*
- Assumed drum rotational speed range, *R* (min^{-1})
    - Filtration (or form) time range, T_F *(secs)*

From the test work, the following data is obtained:

Measured values

- Filtrate volume, *V (ml)*

Additional test data might include the following:

- Wet filter cake weight, *w (grams)*
- Filter cake moisture content, *M (% by weight)*

The filtrate flux rate is a function of the filtrate volume per unit area, per unit time.

i.e.

$$F_R = f\left(\frac{V'}{A.T_F}\right)$$

The filtrate flux rate, F_R, (often expressed as $m^3/m^2/hr$) can be calculated from the following equation:

$$F_R = \frac{0.0036\, V'.\sigma}{A\,.T_F}$$

Or

$$F_R = 6 \times 10^{-5} \left(\frac{V'.R}{A}\right)$$

The flux rate can also be expressed in, for example, litres/m^2/hr or kg/m^2/hr. Furthermore, it is possible to express the flux rate for the feed suspension or the filter cake, or in whatever format suits the application. In this *White Paper* the format is assumed to be the filtrate flux rate.

A plot of F_R vs R gives the following profile:

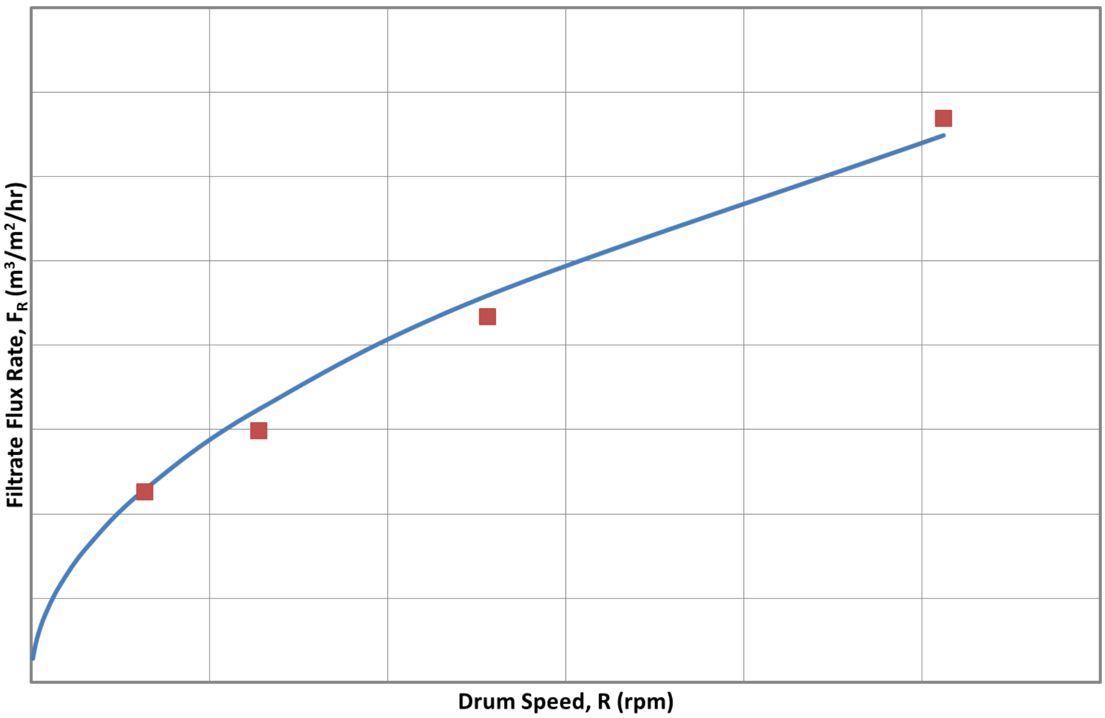


Figure 5. Filtrate Flux Rate, F_R, vs Drum Speed, R.

The filtrate flux profile illustrates that increasing the drum rotational speed will increase the filtrate flux rate. However, it should be noted that higher drum speeds also reduce the filtration (or form) time and generate thinner, and usually wetter, filter cakes. The inverted leaf test will give a clear indication on the quality of the filter cake and its ability to discharge from the filter medium.

The optimum drum speed for the application is a compromise based on maximising the filtrate flux rate, whilst maintaining a filter cake of adequate thickness and quality to be successfully and repeatedly discharged from the filter.

Summary

This *White Paper* demonstrates the basic principle of data evaluation for a rotary drum vacuum filter. It illustrates the importance of undertaking inverted leaf tests in order to generate filtration data which is representative of the system under investigation.

Flux rates, in conjunction with the mass balance, are used to calculate the required filtration area and basic operating parameters for a rotary drum vacuum filter.

Information on the suspensions' particle size distribution (PSD) and concentration **does not** contribute to the filtrate flux profile. PSD and concentration information is useful 'guidance' data only.

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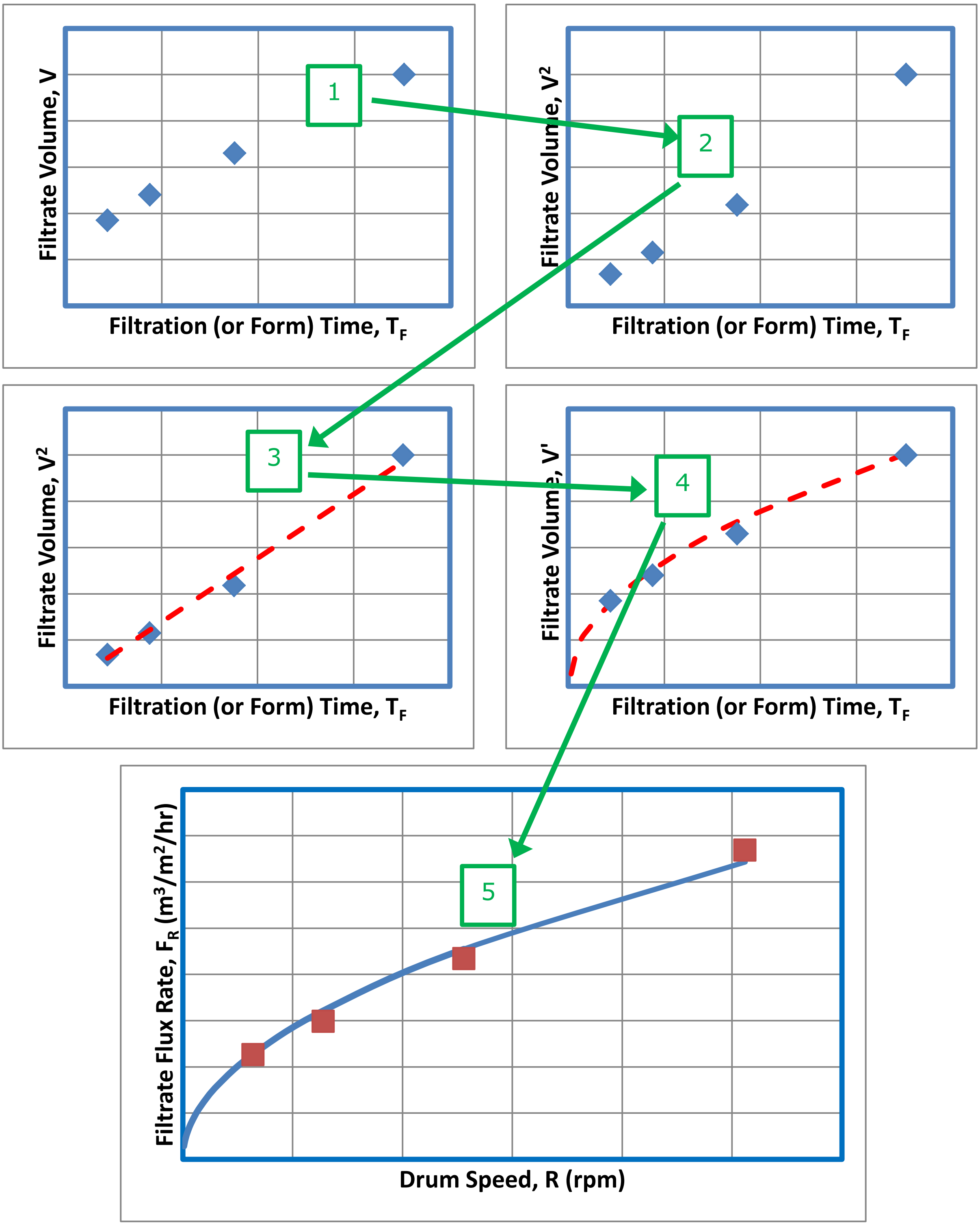
Filtrate Volume, V
Filtration (or Form) Time, T_F
1
Filtrate Volume, V^2
Filtration (or Form) Time, T_F
2
Filtrate Volume, V^2
Filtration (or Form) Time, T_F
3
Filtrate Volume, V'
Filtration (or Form) Time, T_F
4
Filtrate Flux Rate, F_R ($m^3/m^2/hr$)
Drum Speed, R (rpm)
5