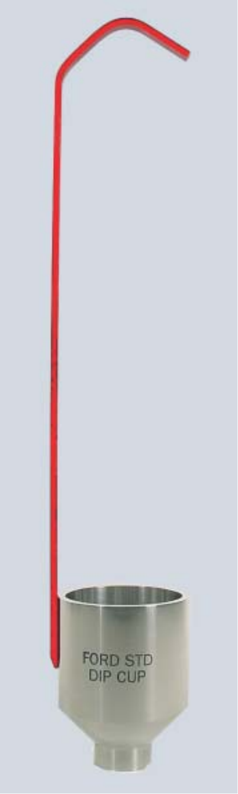
Quick, Easy, Accurate, Meaningful:

What a Viscosity Measurement Should Be

There are a variety of ways to measure the viscosity of architectural paints: Efflux cups, Krebs Viscometer with paddle spindle, Rotational Viscometer with disk spindle or cone/plate. All have their advantages and disadvantages. The best measurement procedure ultimately will be one that provides a reliable, pass/fail method that lab technicians and plant personnel can do quickly and easily. This article will briefly summarize the viscosity test methods used by industry (which, in many cases, are all required) and provide information on a proposed two-point test that may give a clear pass/fail QC measurement.

In a busy QC lab, or out on the production floor in a manufacturing plant, a quick and easy measurement is usually desirable. However, like most things that are quick and easy, that may be all you get — not enough detail, only a 'go'/'no go' number. A goal for the meaningful viscosity measurement of paint is to get data that not only tells you if the paint is "ok", but also qualifies how the paint will perform during application, i.e., a test that is not too time consuming or overwhelming.

Figure 1/Ford Dip Cup provided by Paul N. Gardner Company, Inc.



Rheogram testing (shear rate ramps) does provide useful information about the fluid's shear dependence. But, by now, we all have come to the realization that paints are, by design, shear thinning. That is, the more they are worked, the thinner they get, as indicated by decreasing viscosity values. But there is also a time dependency with these fluids; they tend to rebuild their viscosity, but not always to their original viscosity value, when the shearing action stops. This recovery is a desired characteristic to help with continued minimal flow and leveling when the paint brush stops applying the paint. Both rheological characteristics are important. A single test that can provide a handle on this range of desired information may be the best measurement technique.

Measurement Capabilities and Limitations

The following is an overview of the capabilities and limitations of some typical paint lab viscosity measurements.

Efflux Cups

Figure 1 depicts a Ford Dip Cup, and the following points are characteristic of Efflux cups in general.

·Quick and easy to set up and run.

·Potential variability between viscosity readings because temperature isn't controlled.

·Measurements are subjective based on the operator's perception of start and stop time.

·No information about rheological properties means no real comparison to performance criteria of the paint.

·Can be time consuming to clean.

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Krebs Viscometer

A Krebs viscometer is shown in Figure 2. The limitations and capabilities of this measurement technique are noted below.

·Similar advantages and disadvantages to the Efflux cups. Older-model Krebs viscometers require you to perform calculations.

·Temperature control during the measurement is extremely difficult and, with digital instruments, impractical.

·No rheological properties can be determined because of the unique paddle spindle, Krebs unit of measure, and single speed, so the measured value has little to say about the performance criteria of the paint.

Controlled-Rate Viscometers: Disk Spindles

A disk spindle is shown in Figure 3. Capabilities and limitations are indicated as follows.

·Relatively easy to set up and run.

·Sample volume is comparatively large (at least 400 mL beaker).

·Temperature control can be accomplished, but rarely is done.

·Clean up can be time consuming.

·Obtain only "assumed" information about rheological behavior of the paint, because – even though the speed can be varied – information can't be directly compared to application and performance criteria.

·Shear rate can't be quantified in the universal term of reciprocal seconds (sec $^{-1}$).

·High shear rates, brushing for example, cannot be attained in the 10,000 sec $^{-1}$ to 13,000 sec $^{-1}$ region.

Proposed Two-Point Test

So what can be advocated that won't require a lengthy test time, difficult set up and use, manual calculations, but also provide good temperature control, easy robust use and minimal clean up? A possible test method would be a two-step shear measurement utilizing shear rates that differ significantly, typically more than an order of magnitude.

A recent innovation in the industry is the modification of the ICI Cone/Plate Viscometer to have variable-speed drive and integrated temperature control built into the sample plate (Figure 4). This type of instrument measures over a broad range of shear rates to include the high shear rate (10,000 sec $^{-1}$) characteristic of applying paint.

Figure 2/Brookfield KU-2 Viscometer for measuring viscosity in Krebs Units.

Figure 3/Brookfield DV-II+ Pro Rotational Viscometer for measuring viscosity of samples in a beaker with standard spindles.

Figure 4/Brookfield CAP2000+ Cone/Plate Viscometer for measuring viscosity using quick, two-point test method.

Figure 5/Quick, two-point viscosity test on two different paint samples utilizing two shear rates.

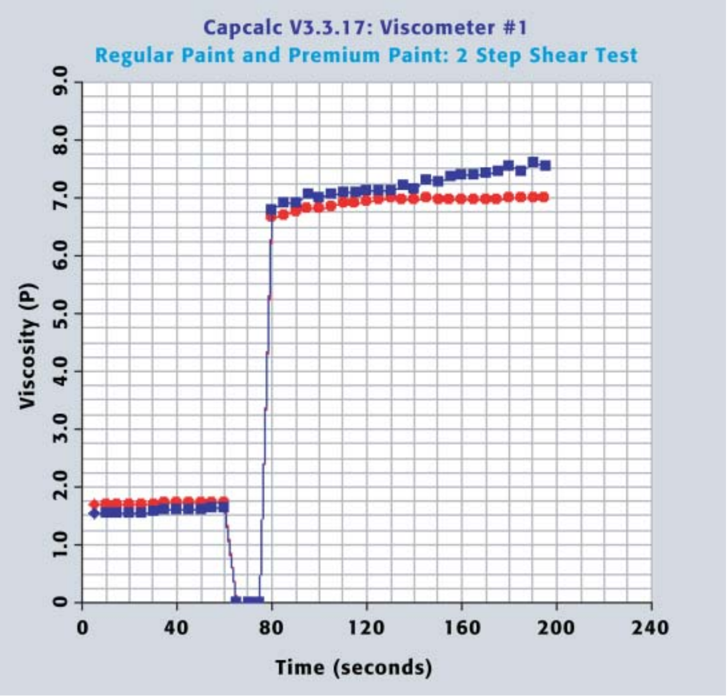

Figure 5 is a graph showing viscosity information on two blue paint samples. One is a satin-finish acrylic latex paint, and the other is a premium eggshell finish. Both are commercially available paints and are manufactured by the same company. The paints were tested using a Brookfield CAP2000+L Cone/Plate Viscometer running at two different shear rates and a wait time at each speed before the data is recorded.

What can be seen is that both paints appear to have a similar initial viscosity value when being sheared at 12,000 sec^{-1}. The difference in the premium paint versus the regular paint is that the premium paint seems to be increasing in viscosity over time at the lower shear rate of 667 sec^{-1}, while the regular paint seems to level out. It isn't necessarily the difference in viscosity between the paints at the end of an elapsed time of 120 seconds of low shear that is the only revealing piece of information. It is the rate of the increase in measured viscosity that may be useful to the paint tester. If the paint measured too high of a viscosity too quickly, perhaps the paint had been under-mixed, volatiles had come off during preparation, or the premix condition wasn't correct. Another possibility is that running at 12,000 sec^{-1} "erases" any thixotropy issues, and the fluid recovers too quickly. If the paint measures too thin (too low in viscosity), perhaps the fluid was unevenly mixed and not representative of a homogenous paint. These are not definitive answers by any means, but illustrate the kinds of questions and interpretations that can be raised while making a simple measurement.

This two-shear step with wait-time method is an indicative measure of a paint's "true" performance: it simulates how the paint is being applied with a paint brush and then tests at a relatively lower shear to see how the viscosity of the paint recovers from being sheared. The inclusion of a wait-time interval of 15 seconds is mostly pragmatic: it provides enough time for an operator using the viscometer to input the next lower shear rate. Remember, the goal was to find a method that would provide viscosity information and be easy for the operator to perform.

Cone/Plate Viscometer

Here then, is an overview of a variable-shear cone/plate viscometer and the features that make it a good choice for measurements of paints by multiple operators over multiple shifts.

- Easy to set up and operate.
- Very simple, quick measurement method.
- Better potential reproducibility between operators because variables are controlled:
  - Temperature: built-in temperature control through a Pelletier Plate;
  - No operator interpretation of readings; viscosity is always calculated and displayed;
  - Built in timers with hold times for testing;
- Overall test time is shorter due to low sample volume (<1mL), so time spent waiting for the sample to be conditioned at a target temperature is minimized.
- Low sample volume means clean up is very quick and easy; high-polish carbide plate lets the operator know when the measuring surface is clean; the cone can be cleaned on the viscometer.
- Rheological properties of viscosity versus shear can be evaluated; variable-shear-rate capability from 10 sec^{-1} to 12,000 sec^{-1} is sufficiently broad for most applications.

When considering the options for testing paint viscosity, a cone/plate viscometer is a suitable choice to replace other test methods for use in the QA and production environments. The two-shear test method with wait time provides a template for understanding the paint viscosity analysis in a way that is not cumbersome or overwhelming, but still is revealing. ⊕

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