USING DYNE TEST MARKER PENS TO MEASURE SUBSTRATE SURFACE ENERGY

This sheet describes how Dyne test marker pens can be used to measure the surface energy of films and other non-absorbent substrates. This method parallels ASTM Std. D2578[1], which covers the testing of polyethylene (PE) and polypropylene (PP) films via the application of formamide/ethyl Cellosolve* solutions. The fluids used in Dyne test marker pens are based on those specified in ASTM D2578; the critical difference between this test and the ASTM technique is the manner in which the fluids are applied to the test sample.

In general, the ability of a substrate to anchor inks, coatings, or adhesives is directly related to its surface energy. If the substrate surface energy does not significantly exceed the surface tension of the fluid which is to cover it, wetting will be impeded and a poor bond will result. Clearly, surface energy must be assessed before printing, coating, or laminating is attempted.

The unit of measurement of Surface Energy is Dyne/cm^2; this can also be expressed in mN/m. Dyne = Unit of force equal to the force that imparts an acceleration of 1cm/sec/sec to a mass of 1 gram. 1 Dyne = 0.00001 Newtons.

Typical Surface Energy of Base Material	
PTFE	<20 mN/m(Dyne)
Silicone	<20 mN/m(Dyne)
PP	30 mN/m(Dyne)
PE	32 mN/m(Dyne)
PS	34 mN/m(Dyne)
PC	34 mN/m(Dyne)
ABS	34 mN/m(Dyne)

Required Surface Energy for Adhesion With:	
UV ink	48 – 56 mN/m(Dyne)
Waterbased ink	50 – 56 mN/m(Dyne)
Coatings	46 – 52 mN/m(Dyne)
UV adhesive	44 – 50 mN/m(Dyne)
Water-based adhesive	48 – 56 mN/m(Dyne)

Dyne test marker pens perform well on most non-absorbent materials. It is critical that the test fluid does not alter the surface properties of the substrate. For example, if the test fluid permeates a fibre substrate (e.g. paper) and causes swelling, results will indicate unrealistically easy wetting. A chemical reaction between the test fluid and the substrate invalidates results altogether.

To ensure repeatability of this test, material preparation and test technique must be standardized. ASTM Std. D618[2] documents suggested conditioning methods. Unfortunately, this standard is untenable for treated film testing; conditioning times range from 24 to 96 hours. Such rigorous controls may be of value for R & D, but for normal QC testing, much shorter conditioning times should be used. Standardization of ambient, substrate, and test solution temperature is critical, as is inspection methodology. Have one trainer instruct all testers to minimize variability. Relative humidity should not be excessive; higher RH tends to increase data variability. Finally, the elapsed time between extrusion or coating to test (or from test to printing, etc.) must be controlled.

Surface energy is critically important to many converting operations. Unfortunately, it is not the sole determinant of product suitability. Other factors, such as surface topography, coating rheology, and chemical incompatibility, must also be considered. This is why broad-based communications with vendors and customers is so important. But at least by systematically measuring substrate surface energy, you will have a sound starting point from which to resolve other problems which may arise.

IMPORTANT SAFETY NOTICE: The fluids contained in Dyne test marker pens are considered hazardous materials. Avoid contact with skin. Use with adequate ventilation. Avoid contact with eyes. Pregnant women should not perform this test. For further information, refer to product SDS.

For the results of this test to be meaningful, the following four points are absolutely essential and must be followed.

1. Do not touch or in any way contaminate the surface to be tested. Dirty surfaces lose their wettability.
2. Do not use contaminated or outdated DYNE test marker pens.
3. Never retest the same location on a sample; move along the sample, or pull a new one.
4. Store and use DYNE test marker pens at room temperature.

Materials/Equipment required

- Dyne test marker pens
- Subject material
- Clean, level test area
- Thermometer and hygrometer

Method

1. Pull test sample. Be sure to pull a good specimen; surface aberrations cause poor results. For extruded film, one entire web cross-section should suffice. Do not touch the surface.
2. Place the sample on a clean, level surface. If required, fix the edges to avoid curling or other deformation.
3. Record ambient temperature and relative humidity. If sample temperature differs from ambient, allow it to stabilize.
4. Test at least three points across the sample; ¼, ½ and ¾ across the film section. It is good practice to test the outer edges as well. For non-film materials, test locations must be determined in-house.
5. Determination of Wetting
   a. Choose a Dyne test marker pen of a dyne level you believe is slightly lower than that of the test sample.
   b. Press applicator tip firmly down on subject material until the tip is saturated with ink.
   c. Use a light touch to draw the pen across the test sample in two or three parallel passes. Disregard the first pass(es); to flush any contamination from the tip, and to ensure that the test fluid layer is thin enough for accurate measurement, evaluate only the last pass.
   d. If the last ink swath remains wetted out on the test sample for three seconds or more, repeat steps “b” and “c” with the next higher dyne level marker. If the last ink swath beads up, tears apart, or shrinks into a thin line within one second or less, repeat steps “b” and “c” with the next lower dyne level marker. If the ink swath holds for one to three seconds before losing its integrity, the dyne level of the marker closely matches that of the sample.

This is a relatively accurate surface energy measurement technique; used in standard 2 dyne/cm increments, Dyne test marker pens can generally produce results with a precision of ± 2.0 dynes/cm. Repeated use of DYNE test marker pens should enable testers to estimate surface energy to within ±1.0 dyne/cm.

To investigate discrepancies between obtained and expected results, a more precise measurement method should be considered; application of Dyne Testing surface tension test inks (per ASTM D2578-23) or by use of a drawdown rod is recommended. Alternatively, if results are suspect, replicate the test with a set of unused markers. This test has proven itself on a wide variety of substrates; it is, however, theoretically more prone to contamination than some other techniques. For this reason, even in the absence of unexpected results, you should establish a quality assurance plan which calls for regular audits during the phase-in stage of Dyne test marker pen use. The effect of all changeovers from one substrate to another should be monitored especially closely. Slip and other additives tend to bloom to the surface of extruded sheets and films; transferring surface-active additives from one material to another can have a profound effect on surface energy measurement. In general, once you demonstrate that a switch from substrate A to substrate B has no effect, it is relatively safe to assume that future changeovers from A to B will act similarly.

Surface energy is critically important to many converting operations. Unfortunately, it is not the sole determining factor in product suitability. Other factors, such as surface topography, coating rheology, chemical incompatibility etc. must also be considered. Correctly stored and used Dyne test pens will give you good indication of surface energy on many materials, however, you must always verify your results by sample production.

---

[1]Annual Book of ASTM Standards, Wetting Tension of Polyethylene and Polypropylene Films

[2]Annual Book of ASTM Standards, Conditioning Plastics and Insulating Materials for Testing

*ethyl Cellosolve is a registered trademark of Union Carbide Corp. for ethylene glycol monoethyl ether (2-ethoxyethanol)