Application Report

Application report:	AR304
Industry section:	packaging, printing, surface treatment, inks, bonding
Author:	Dr. Andrew Mellor (KRÜSS)
Date:	11/2026
Method:	Drop Shape Analyzer – DSA25 with Stood-up Drop® dosing unit
Keywords:	Digital Dyne®, test inks, dyne pens, PP, PE, receding contact angle, dewetting, quality control surface activation, plasma, corona, flame treatment

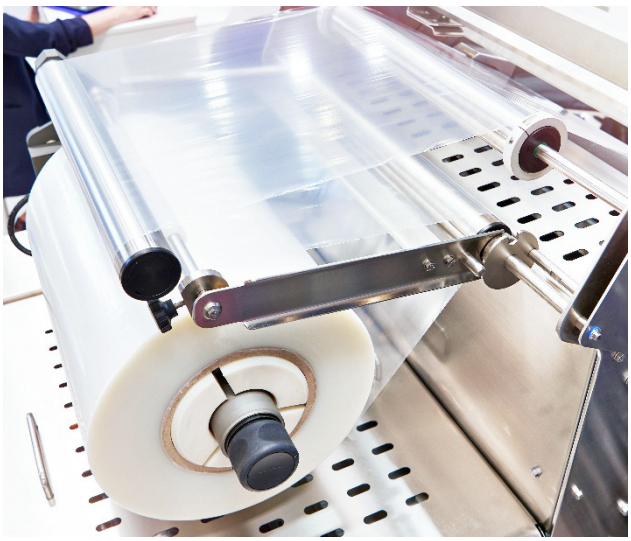




Building Digital Dyne®

Surface testing in the 21st century

For more than 70 years, dyne pens and test inks have been the industry standard for verifying surface treatment levels in production. Developed in the 1950s, dyne tests are a simple tool for assessing printability and ”surface readiness” with respect to bonding and coating of materials, and they have spread throughout many industries around the world. Despite their prevalence, dyne tests are associated with several significant challenges, most notably; subjective interpretation, inconsistent results, lack of digital traceability, and above all else toxicity. Until now, replacing dyne tests with modern alternatives has been limited, mostly due to the effort of introducing new parameters, workflows, and specifications into running systems, as well as concerns about meeting customer expectations. The Digital Dyne® is the first scientifically backed, modern alternative to dyne pens, offering a fast, easy, objective and non-toxic route to the same results, i.e. so-called Digital Dyne values which have been validated against real world dyne tests.



Background

Are pens & inks safe?

Traditionally, dyne pens and test inks in the range of 30 – 58 mN/m are formulated as a series of mixtures of two components, formamide and 2-ethoxyethanol (Ethyl Cellosolve), plus a colored dye. Indeed, both current dyne-testing norms (ASTM D2578, ISO 8296) directly specify these mixtures for determining ”wetting tension” of PE and PP films [1, 2]. In view of this, the widespread use of dyne tests raises significant concerns about occupational health in many lab and production environments. Both formamide and 2-ethoxyethanol are classified as *toxic to reproduction* (Cat. 1B). Both are readily adsorbed into the body via skin/airways. Both have shown evidence of causing developmental effects to

the unborn child, with 2-ethoxyethanol also having shown evidence of affecting fertility. In 2012 the European Chemicals Agency added formamide to its list of "Substances of Very High Concern" [3]. Despite this, an informal poll of 15 manufacturers across Europe revealed 80 % still use formamide-based test inks, while 58% test once or more every single day.

Non-toxic pen/ink alternatives do exist but have been poorly adopted due to two key setbacks; 1) results are inconsistent with existing tests, 2) they don't conform to international standards. The current ASTM D2578 and ISO 8296 standards were first published 60 and 40 years ago, respectively. Since then, attempts have been made to promote alternative methods, however, they generally fail to reliably reproduce expected dyne values and have been poorly adopted by industry.

Dyne pens don't test wettability

Consider the procedure for performing dyne tests (Fig. 1):

1) The ink is spread in a line across a surface.
2) The tester waits a fixed amount of time.
3) The tester assesses whether the line has retracted into individual drops or remains as a flat film.

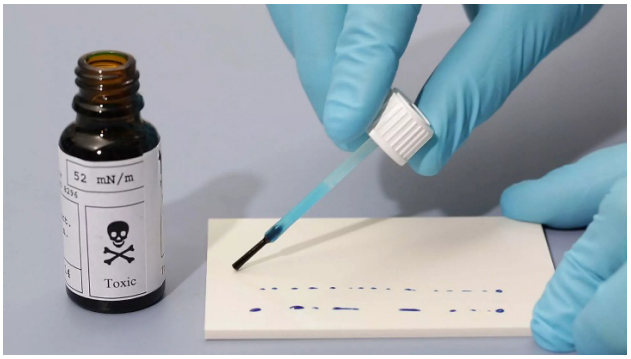


Fig. 1: Representative image of a dyne test being performed on PTFE using a 52 mN/m test ink.

A common misconception is that dyne tests assess surface *wettability*, however, in truth they rather assess surface "*dewettability*" (Fig. 2) [4]. The distinction between wettability and dewettability may seem subtle, but the two terms are not interchangeable, especially for activated surfaces (plasma, corona, flame, etc.).

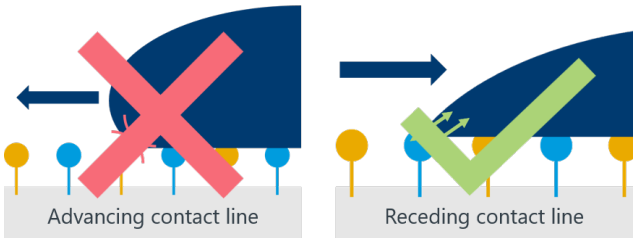


Fig. 2: Interaction between a water drop and surface during wetting (left) and dewetting (right).

This misconception has led to many failed attempts to correlate water contact angle (WCA) with dyne values, such as those of ASTM D5946 (1996) and ISO 15989 (2004). WCA tests are particularly appealing as an objective, non-toxic, quantitative alternative to dyne tests. Typically, WCA involves assessing a drop's shape after it has spread across a surface ("recently advanced" WCA) and therefore is a measure of *wettability* not *dewettability*. This in turn explains the observed unreliability of most conversions from WCA to dyne.

To examine *dewettability* via WCA, one must measure drops that have been dewetted from a surface ("recently receded" WCA). Techniques for generating such drops are well described in literature, but such methods tend to be considerably more complex and time-consuming than traditional WCA testing. Indeed, it has been noted that a typical advancing/receding test procedure can take on the order of 1–2 hours per sample [5, 6, 7]. To our knowledge, no attempt has been made to directly correlate recently receded WCA values with dyne values for PP and PE films.

The recently developed KRÜSS Stood-up Drop® overcomes the difficulty of generating recently receded drops by using a patented dosing system to deposit water drops such that they spontaneously dewet, or "stand up", from surfaces. This innovation reduces typical measurement times from hours to less than two seconds, while simultaneously allowing for fully automated, user independent testing.

In this report we seek to demonstrate the consistency between so called Digital Dyne measurements, using the KRÜSS Stood-up Drop, and traditional dyne values, as recorded by real-world operators in working environments.

Experimental section

Digital Dyne measurements

To collect Digital Dyne test results, a KRÜSS Stood-up Drop system was applied to record recently receded

contact angles of water drops deposited on PP and PE films. Each Digital Dyne result represents the average of two independent measurements, with a total of 2,244 individual measurements being recorded. Each Digital Dyne value was reported as an exact quantity rounded to 1 decimal place.

Dyne test evaluation

In this study, dyne tests were carried out by multiple real-world operators, using established dyne test practices from different production sites. All operators were well experienced with dyne testing. As per standard practice, dyne tests were carried out using a series of test inks based on formamide and 2-ethoxyethanol in the range of 30 to 58 mN/m, with steps of 2 mN/m between each. Results outside the given range were recorded as either < 32 or > 58 mN/m depending on which side of the scale they fell off. Both dyne pen and brush/bottle applicators were used. As each dyne test represents a pass/fail assessment with a 2 mN/m window, results were interpreted as intervals extending from the stated value to 2 mN/m above it. For example, a dyne result of 38 mN/m represents an expected dyne range of 38-40 mN/m for that sample.

For each sample in this study, dyne and Digital Dyne results were recorded by the same operator under the same conditions at roughly the same time.

Results and discussion

Real-world evaluation of the Digital Dyne

1,138 individual PP and PE film samples were produced and tested by three independent companies within the packaging industry. Measurements were collected over a period of 1-3 months under normal production conditions. To represent a broad range of industrial PP/PE films, various blends and orientations were included in the study, together with different surface activation methods.

Across all samples, lower receding contact angles were consistently associated with higher dyne-test values. Least-squares regression was used to establish a quantitative relationship between Stood-up Drop receding contact angles and dyne test results, enabling direct conversion between the two measurement scales (Fig. 3). The resulting correlation remained stable across companies, operators, polymer grades, and surface-treatment methods, demonstrating that the relationship is broadly applicable across industrial film-production environments.

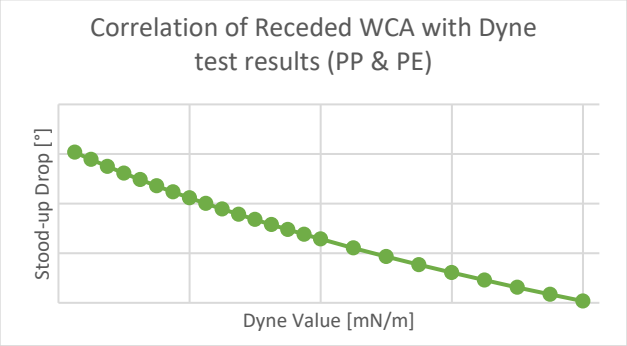
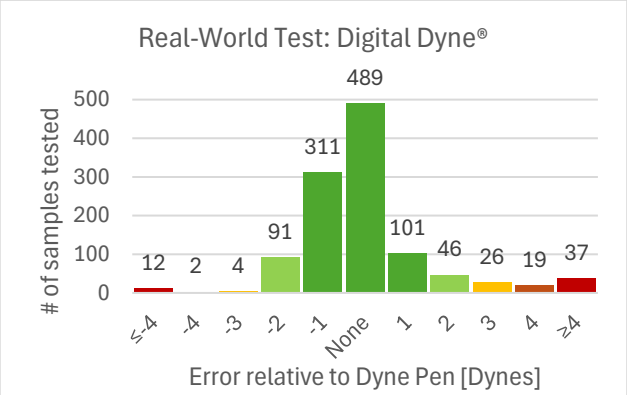


Fig. 3: Correlation between Stood-up Drop generated recently receded contact angle measurements and corresponding dyne test results for PP and PE films.

Agreement with Industrial Reference Results

Digital Dyne results showed excellent agreement with conventional dyne testing. While 43 % of measurements fell directly within the nominal dyne test range, agreement increased sharply to 79 % within ±1 mN/m and approximately 91 % within ±2 mN/m of the reported dyne value (Fig. 4).



Error (mN/m)	< ± 1 Dyne	± 2 Dyne	± 3 Dyne	> ± 4 Dyne
# of Tests	901	137	30	70
%	79 %	12 %	3 %	6 %

Fig. 4: Agreement between Digital Dyne and conventional dyne testing. The histogram shows the distribution of sample-level errors, while the accompanying table summarizes the percentage of measurements within defined error ranges.

Deviations from nominal dyne test values are consistent with the limitations of the test itself, which is heavily influenced by application technique, ambient conditions, contamination, and operator judgement. Industry reports place dyne test reproducibility around ±4 mN/m for production environments [8]. In other words, the uncertainty of the dyne test itself is most likely the biggest limiting

factor in this study. As such, Digital Dyne offers a route to significantly more reliable testing of polymer films in production.

The observed agreement between dyne tests and Digital Dyne values (>90 % within 1-2 mN/m) was considered within acceptable tolerance by all companies participating in this study.

Above & beyond dyne tests

Several samples produced Digital Dyne values below the lower limit of conventional dyne tests (32 mN/m). Corresponding dyne results for these materials were recorded as "<32 mN/m", demonstrating how Digital Dyne is able to correctly identify low-energy surfaces even beyond the limits of the dyne test. This highlights a practical advantage of providing a continuous measurement scale rather than relying on the fixed increments of conventional dyne tests.

Further evidence of the robustness of the Digital Dyne approach emerged during validation when one dataset was found to deviate systematically from the established correlation. Investigation revealed that all measurements in question originated from a single company using a single batch of test inks. That batch was subsequently retested and confirmed to be contaminated, which led to the erroneous results. Data from this batch were excluded from the final analysis and are not part of the full 1,138 sample data set. The fact that Digital Dyne was able to correctly identify false dyne results demonstrates the method does more than reproduce dyne tests; it may also detect questionable measurements that might otherwise remain unnoticed.

Summary

Digital Dyne® has been shown to robustly reproduce dyne tests for treated PP and PE films, thereby replacing subjective interpretation of toxic test liquids with an automated water-based measurement. Recently receded contact angles provide the key dewetting information required to simulate dyne tests accurately, while the KRÜSS Stood-up Drop® system enables measurements via a rapid one-click workflow. Validation across 1,138 real-world samples demonstrated excellent agreement with conventional dyne testing, with approximately 92 % of results falling within ±2 mN/m of the reported test ink value. This corresponds to a practical resolution of around 1-2 mN/m and confirms a robust relationship between objective contact angle measurements and established dyne tests. Digital Dyne provides a practical route to traceable, operator-independent testing without requiring changes to existing specifications. The method therefore offers a credible path for companies to transition away from dyne pens and test inks.

Literature

[1] ASTM International: ASTM D2578-23, Standard Test Method for Wetting Tension of Polyethylene and Polypropylene Films, 2023.

[2] International Organization for Standardization: ISO 8296:2003, Plastics - Film and sheeting - Determination of wetting tension, confirmed 2023.

[3] European Chemicals Agency: Support document for identification of formamide as a substance of very high concern because of its CMR properties.

[4] D. Diaz, A. Bhargava, F. Walz, A. Sharifi, S. Summaly, R. Berger, M. Kappl, H.-J. Butt, D. Lohse, T. Willers, V. Sanjay, D. Vollmer: Stood-up Drop to Determine Receding Contact Angles. In: Soft Matter, 2025. DOI: 10.1039/d5sm00985e.
→ Free access

[5] H.-J. Butt et al.: Contact angle hysteresis. Current Opinion in Colloid & Interface Science, 59, 2022, 101574.

[6] KRÜSS: Stood-up Drop - optical determination of the recently receded contact angle.
kruss-scientific.com/en/know-how/glossary/stood-up-drop

[7] T. Huhtamäki, X. Tian, J. T. Korhonen, and R. H. A. Ras: Surface-wetting characterization using contact-angle measurements. Nature Protocols, 13, 2018, 1521–1538.

[8] Vetaphone A/S: Guide to Dyne Testing and Surface Energy Measurement. Technical article, Vetaphone Knowledge Centre, accessed November 2026.

You can find many more interesting Application Reports on our website under
https://www.kruss-scientific.com/en/know-how/application-reports