# Instrumental Dye Fastness Rating Performance, The UMIST Fastrate System

# Instrumental rating of dye fastness

David P. Oulton and Stephen Eckersley describe the Fastrate system, marketed by Shirley Developments Ltd.

The implementation of instrumental fastness rating has been made practical by the availability of accurate easy to use colorimeters, and the publication of agreed standards for converting colour differences into grey scale ratings.

This article describes the SDL/UMIST 'Fastrate' system, and its validation for sensitivity, reproducibility and conformance to carefully controlled visual rating.

## The system

Fastrate uses a 'stapler' action X-rite 918 colorimeter. This has a 3mm aperture and precise sample guides. It is thus easy to select and measure specific small areas for staining and loss of depth.

Proving trials over several hundred ratings at each level of staining, have shown that the instrument is stable and reproducible. Measurement to measurement, a typical Standard Deviation of 0.004 was found in a set of Tristimulus measurements, with a mean of Y = 7.0 over 20 readings.

The system uses computer control of measurements, and delivers fully documented testing reports. To aid lab productivity, and testing management, the system has full information storage and retrieval facilities for customer, fabric, test, and performance standard details. It also generates work sheets, and maintains files of current and completed jobs.

Fastrate can be used to manage, rate and generate reports on up to 50 jobs per day. These can involve up to 1000 individual ratings.

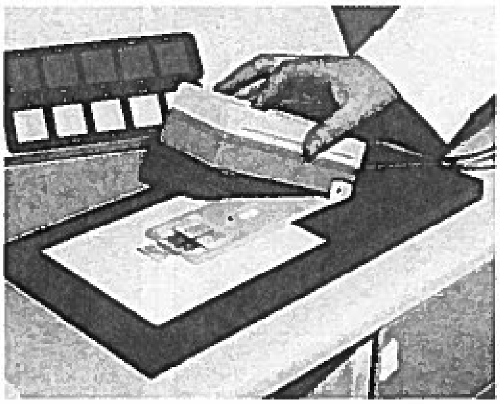
**Table 1.**
**Inter-lab averages (8 labs) against instrumental ratings**

| Shade | Change | Dry Rub | Wet Rub | Staining: Acetate | Cotton | Nylon | P-Ester | Acrylic | Wool |
|---|---|---|---|---|---|---|---|---|---|
| Red | | | | | | | | | |
| Visual | 4.6 | 4.4 | 3.0 | 3.2 | 4.3 | 3.8 | 4.3 | 4.5 | 4.5 |
| Instr. | 4.5 | 4.5 | 2.9 | 3.6 | 4.6 | 4.1 | 4.3 | 4.8 | 4.6 |
| Black | | | | | | | | | |
| Visual | 4.5 | 4.4 | 3.1 | 3.6 | 4.3 | 3.6 | 3.8 | 4.4 | 4.4 |
| Instr. | 4.5 | 4.6 | 3.0 | 3.3 | 4.6 | 3.7 | 4.0 | 4.7 | 4.6 |
| Brown | | | | | | | | | |
| Visual | 4.6 | 4.4 | 3.6 | 3.3 | 2.4 | 4.0 | 4.5 | 4.6 | 4.6 |
| Instr. | 5.0 | 4.7 | 3.1 | 2.8 | 1.8 | 4.5 | 4.7 | 4.6 | 4.7 |
| Navy | | | | | | | | | |
| Visual | 4.6 | 4.2 | 3.8 | 3.8 | 4.4 | 3.7 | 3.8 | 4.5 | 4.4 |
| Instr. | 4.5 | 4.2 | 3.9 | 3.5 | 4.6 | 3.8 | 4.3 | 4.7 | 4.6 |

Average deviation of instrumental grade from inter-lab mean < 0.23 of a grade.

**Table 2.**
**Visual ratings for 21 laboratories**

| Laboratory | Acetate | Cotton | Nylon | P-Ester | Acrylic | Wool |
|---|---|---|---|---|---|---|
| A | 3 | 4.5 | 2.5 | 4 | 4.5 | 4 |
| B | 2.5 | 4 | 2 | 4 | 4.5 | 3.5 |
| C | 2.5 | 4 | 1.5 | 3.5 | 4.5 | 3.5 |
| D | 2.5 | 3.5 | 2 | 3 | 4.5 | 3.5 |
| E | 2.5 | 4 | 2 | 4 | 4.5 | 3.5 |
| F | 3.5 | 4.5 | 2.5 | 4.5 | 5 | 4.5 |
| G | 3 | 4.5 | 2.5 | 4 | 4.5 | 4 |
| H | 3.5 | 4.5 | 2.5 | 4.5 | 5 | 4.5 |
| I | 3 | 4 | 2 | 4 | 4.5 | 4 |
| K | 3 | 4.5 | 2.5 | 4 | 5 | 4.5 |
| L | 4.5 | 2.5 | 4.5 | 4.5 | 4.5 | 4.5 |
| M | 3 | 4.5 | 2.5 | 4 | 4.5 | 4.5 |
| N | 2.5 | 4 | 2 | 3.5 | 4.5 | 4 |
| O | 3.5 | 4.5 | 2.5 | 4.5 | 4.5 | 4.5 |
| Q | 3 | 4 | 2 | 3.5 | 4.5 | 4 |
| R | 3 | 4 | 2.5 | 4 | 4.5 | 4 |
| S | 3.5 | 4.5 | 2.5 | 4 | 4.5 | 4 |
| T | 3 | 4.5 | 2.5 | 4 | 4.5 | 4 |
| V | 3 | 4.5 | 2.5 | 4 | 4.5 | 4 |
| W | 3 | 4.5 | 2.5 | 4.5 | 5 | 4 |
| X | 2.5 | 4.5 | 2 | 4 | 4.5 | 4 |
| Average | 2.95 | 4.29 | 2.29 | 3.98 | 4.60 | 4.02 |
| Std. Deviation | 0.68 | 0.92 | 0.54 | 0.89 | 0.96 | 0.88 |



*Close-up of the Fastrate system in use.*

## Performance

The following performance details have been found in the development and validation trials:-

1. Measurement to measurement reproducibility is better than +/– 0.1 of a grade.
2. System sensitivity is +/ – 0.05 of a grade.
3. Sensitivity to weave and fabric orientation effects (multi-fibre strip) is better than +/– 0.1 of a grade.
4. Sample texture effects can be averaged out to +/– 0.1 of a grade by multiple measurements.

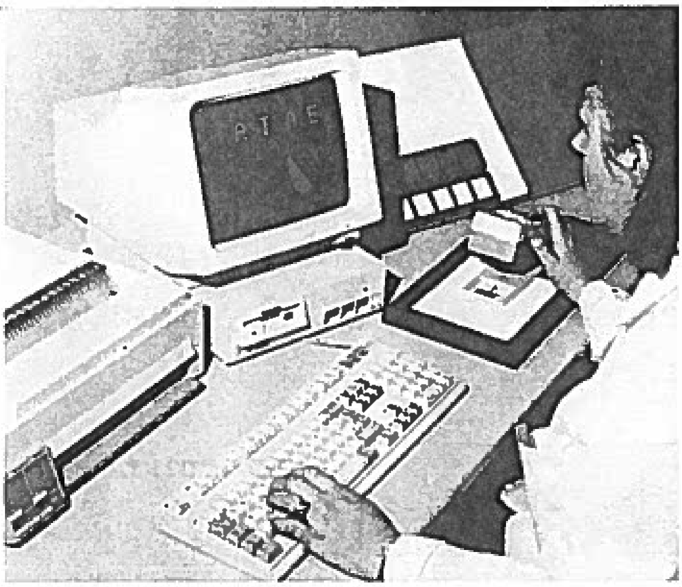
## Fastrate vs visual

Fastrate implements the equations published in BS1006.A04 and Draft ISO Standard ISO/DP105 A05. Details are available in Rigg's paper (1), which describes the trials on which the equations are based. These involved 350 rating samples, 27 to 40 assessors, and 9 U.K. laboratories. It also involved international inter-lab comparisons.

The equations transform, CIELAB Delta E colour difference values into loss of depth (L.O.D.) and staining on white (S.O.W.) grey scale ratings.

The Fastrate system has been subjected to extensive trials against visual rating. Visual rating is a subjective process and it is thus necessary to use multiple ratings of the same sample to arrive at a 'true' mean rating.

In the first trial (2) four different fabrics were sent to eight different laboratories for testing and rating. Table 1 shows the results and the instrumental ratings measured on the returned



*The Fastrate system comprises a compact arrangement of integrated components for easy desk-top operation.*

tested samples.

There is a wide spread in the visual ratings. This may reflect variation in the test procedures as well as in rating subjectively.

In a second larger trial (3) the same fabric was submitted to 21 laboratories for testing and rating. In this trial it was possible to do more detailed analysis of the results. Table 2 summarises the visual ratings, and Table 3 summarises the instrumental ratings measured on the returned test samples.

It is clear from the mean ratings that the Fastrate system closely reproduces the overall average ratings of the 21 laboratories. It is also clear that the uncertainty of rating indicated by the Standard Deviations is much smaller using the instrumental system.

The rating uncertainty contains three identifiable elements.

1. Rating subjectivity, due to visual comparison and viewing conditions.
2. Variation in severity of test, leading to higher and lower staining levels.
3. Evidence of systematic bias, in which certain labs rate more severely or leniently.

Colorimetric analysis shows that the overall stain varies significantly from lab to lab. The stain for Lab D was overall 0.45 of a grade heavier than the inter-lab average, while Lab H produced a stain 0.26 lighter.

Laboratories O and F were the only labs to rate significantly leniently overall, by 0.31 and 0.49 of a grade, against the inter-lab average, adjusted for relative staining level.

Three labs were consistently about 1/2 a grade severe, and eight, about 1/3 of a grade severe.

## Further analysis

It is interesting to apply correction factors to the visual grades for both severity, and test variability variations.

Table 4 shows the

**Table 3.**
**Instrumental ratings for samples from 21 laboratories**

| Laboratory | Acetate | Cotton | Nylon | P–Ester | Acrylic | Wool |
|---|---|---|---|---|---|---|
| A | 3.47 | 4.52 | 2.77 | 4.23 | 4.78 | 4.31 |
| B | 3.16 | 4.39 | 2.51 | 4.23 | 4.81 | 4.17 |
| C | 2.96 | 4.21 | 2.42 | 4.38 | 4.87 | 4.10 |
| D | 2.47 | 4.06 | 2.09 | 3.66 | 4.46 | 3.44 |
| E | 3.04 | 4.24 | 2.37 | 4.24 | 4.68 | 4.07 |
| F | 2.77 | 4.34 | 2.23 | 3.88 | 4.56 | 3.76 |
| G | 3.19 | 4.44 | 2.51 | 4.36 | 5.00 | 4.13 |
| H | 3.26 | 4.37 | 3.12 | 4.56 | 4.90 | 4.27 |
| I | 3.09 | 4.18 | 2.61 | 4.50 | 4.91 | 4.18 |
| K | 2.99 | 4.22 | 2.42 | 4.05 | 4.75 | 3.98 |
| L | 3.16 | 4.34 | 2.49 | 4.11 | 4.55 | 3.98 |
| M | 3.23 | 4.45 | 2.56 | 3.90 | 4.56 | 4.07 |
| N | 2.92 | 4.26 | 2.35 | 3.98 | 4.63 | 4.10 |
| O | 2.94 | 4.01 | 2.45 | 4.20 | 4.58 | 3.95 |
| Q | 3.36 | 4.31 | 2.70 | 4.26 | 4.89 | 3.80 |
| R | 3.31 | 4.39 | 2.59 | 4.25 | 4.74 | 4.18 |
| S | 3.06 | 4.41 | 2.66 | 4.37 | 4.82 | 4.05 |
| T | 3.01 | 4.31 | 2.61 | 4.14 | 4.66 | 3.77 |
| V | 3.19 | 4.34 | 2.65 | 4.22 | 4.70 | 4.37 |
| W | 3.05 | 4.37 | 2.56 | 4.25 | 4.75 | 4.09 |
| X | 3.22 | 4.37 | 2.56 | 4.25 | 4.75 | 4.09 |
| Average | 3.09 | 4.31 | 2.53 | 4.19 | 4.73 | 4.04 |
| Std. Deviation | 0.21 | 0.12 | 0.20 | 0.21 | 0.14 | 0.21 |

**Table 4.**
**Instrumental grades adjusted for test variability**

| Laboratory | Acetate | Cotton | Nylon | P–Ester | Acrylic | Wool |
|---|---|---|---|---|---|---|
| A | 3.27 | 4.32 | 2.57 | 4.03 | 4.58 | 4.11 |
| B | 3.10 | 4.33 | 2.45 | 4.17 | 4.75 | 4.11 |
| C | 2.95 | 4.20 | 2.41 | 4.37 | 4.91 | 4.09 |
| D | 2.92 | 4.51 | 2.54 | 4.11 | 4.91 | 3.89 |
| E | 3.08 | 4.28 | 2.41 | 4.28 | 4.72 | 4.11 |
| F | 3.00 | 4.57 | 2.46 | 4.11 | 4.79 | 3.99 |
| G | 3.07 | 4.32 | 2.39 | 4.24 | 4.88 | 4.01 |
| H | 3.00 | 4.11 | 2.86 | 4.30 | 4.64 | 4.01 |
| I | 2.99 | 4.08 | 2.51 | 4.40 | 4.81 | 4.08 |
| K | 3.07 | 4.30 | 2.50 | 4.13 | 4.83 | 4.06 |
| L | 3.20 | 4.38 | 2.53 | 4.15 | 4.59 | 4.02 |
| M | 3.25 | 4.47 | 2.58 | 3.92 | 4.58 | 4.09 |
| N | 3.03 | 4.37 | 2.46 | 4.09 | 4.74 | 4.21 |
| O | 3.07 | 4.14 | 2.58 | 4.33 | 4.71 | 4.08 |
| Q | 3.29 | 4.24 | 2.63 | 4.19 | 4.82 | 3.73 |
| R | 3.22 | 4.30 | 2.50 | 4.16 | 4.65 | 4.09 |
| S | 2.98 | 4.33 | 2.58 | 4.29 | 4.74 | 3.97 |
| T | 3.08 | 4.38 | 2.68 | 4.21 | 4.73 | 3.84 |
| V | 3.09 | 4.24 | 2.55 | 4.12 | 4.60 | 4.27 |
| W | 3.02 | 4.34 | 2.53 | 4.22 | 4.72 | 4.06 |
| X | 3.16 | 4.31 | 2.50 | 4.19 | 4.69 | 4.03 |
| Average | 3.09 | 4.31 | 2.53 | 4.19 | 4.73 | 4.04 |
| Std. Deviation | 0.10 | 0.12 | 0.10 | 0.11 | 0.10 | 0.12 |

**Table 5.**
**Corrected Visual Grades**

| Laboratory | Acetate | Cotton | Nylon | P–Ester | Acrylic | Wool |
|---|---|---|---|---|---|---|
| A | 3.26 | 4.76 | 2.76 | 4.26 | 4.76 | 4.26 |
| B | 2.96 | 4.46 | 2.46 | 4.46 | 4.96 | 3.96 |
| C | 3.07 | 4.57 | 2.07 | 4.07 | 5.07 | 4.07 |
| D | 2.70 | 3.70 | 2.20 | 3.20 | 4.70 | 3.70 |
| E | 2.86 | 4.36 | 2.36 | 4.36 | 4.86 | 3.86 |
| F | 3.01 | 4.01 | 2.01 | 4.01 | 4.51 | 4.01 |
| G | 3.19 | 4.69 | 2.69 | 4.19 | 4.69 | 4.19 |
| H | 3.50 | 4.50 | 2.50 | 4.50 | 5.00 | 4.50 |
| I | 3.33 | 4.33 | 2.33 | 4.33 | 4.83 | 4.33 |
| K | 2.90 | 4.40 | 2.40 | 3.90 | 4.90 | 3.90 |
| L | 2.86 | 4.36 | 2.36 | 4.36 | 4.36 | 4.36 |
| M | 2.96 | 4.46 | 2.46 | 3.96 | 4.46 | 4.46 |
| N | 2.79 | 4.29 | 2.29 | 3.79 | 4.79 | 4.29 |
| O | 3.19 | 4.19 | 2.19 | 4.19 | 4.19 | 4.19 |
| Q | 3.39 | 4.39 | 2.39 | 3.89 | 4.89 | 4.39 |
| R | 3.33 | 4.33 | 2.83 | 3.83 | 4.83 | 4.33 |
| S | 3.56 | 4.56 | 2.56 | 4.06 | 4.56 | 4.06 |
| T | 3.00 | 4.50 | 2.50 | 4.00 | 4.50 | 4.00 |
| V | 3.16 | 4.66 | 2.66 | 4.16 | 4.66 | 4.16 |
| W | 2.93 | 4.43 | 2.43 | 4.43 | 4.93 | 3.93 |
| X | 2.79 | 4.79 | 2.29 | 4.29 | 4.79 | 4.29 |
| Average | 3.08 | 4.42 | 2.42 | 4.11 | 4.72 | 4.15 |
| Std. Deviation | 0.24 | 0.24 | 0.21 | 0.29 | 0.22 | 0.21 |
| **Instrumental Gradings** | | | | | | |
| Average | 3.09 | 4.31 | 2.53 | 4.19 | 4.73 | 4.04 |
| Std. Deviation | 0.21 | 0.12 | 0.20 | 0.21 | 0.14 | 0.21 |
| **Instrumental gradings compensated for test variability** | | | | | | |
| Average | 3.09 | 4.31 | 2.53 | 4.19 | 4.73 | 4.04 |
| Std. Deviation | 0.10 | 0.12 | 0.10 | 0.11 | 0.10 | 0.12 |

instrumental ratings adjusted for test variability; Table 5 shows both corrections applied to the visual data. If this is done, Standard Deviations are much reduced; and Table 4 also compares compensated visual and instrumental ratings.

It is clear from these tables that the instrumental ratings reproduce the inter-lab mean ratings remarkably faithfully.

## Conclusions

The Fastrate system delivers easy to use accurate fastness ratings. It handles fastness lab management functions, and report generation, offering significant productivity gains.

The system is insensitive to orientation, weave, and texture effects, and it delivers ratings to at least +/ – 0.25 of a grade.

Gradings have been validated against visual ratings. The gradings show no lenience/severity bias, and agree with inter-lab mean ratings to +/– 0.1 of a grade.

Full objective dye fastness rating requires stain/loss of depth testing to be examined more closely for variability.

Instrumental rating has been shown to reduce the uncertainty of fastness assessment significantly.■

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3. 2nd report on the Instrumental Fastrate System.
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4. The development and validation of the Fastrate colorimetric fastness rating system.
David P. Oulton & Stephen Eckersley – submitted for publication March 1992.

# Controlling the environment

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temperature-sensitive environment, and it is possible, by using Satair equipment, to keep the temperature of textile factories down, through evaporative cooling," Mr. Wardman says.

Among Satair unit humidifiers used in the textile industry are:

The *W873 room humidifier*, for wall-mounting. It delivers a fine, non-wetting atomised mist at a variable rate of between 1.5 and 2.7 litres per hour (at 21 deg. C and 50% R.H.).

The *C8812 high-output, ceiling-suspended humidifier*. This unit has a capacity of 12 litres per hour, and is designed to emit a fine mist over critical process areas from its position in the ceiling or roof structure. The heart of the unit is a spinning disc atomiser, specially developed for energy-efficient operation.

Output of both these units is controlled via a room humidistat. An advanced feature is the washable air filter element, designed to be changed in seconds.

Satair *air washers* are designed to give humidity control to specified levels, with 'air scrubbing' to reduce airborne contaminants and improve the working environment. They are intended to provide 'the complete answer' to the highly-corrosive effect of air mixed with water, or the accumulation in water of airborne atmospheric contaminants.

## Air conditioning

A. & A. describe their full-scale Satair *humidification and air conditioning systems* as "the ultimate in development of the 'wet duct' principle. Again, the glass fibre construction is a major benefit, removing the need for regular maintenance and eventual complete replacement associated with metal-built systems.

The Satair system uses a patented 'pod' atomiser, which fills the duct with finely-atomised water particles from its stainless steel spinning disc. This method cools and humidifies the air, so that it is supplied to the mill environment at precisely the right temperature and moisture levels needed to maintain the chosen conditions. The driving motor is ventilated outside the duct.

The Satair system's air supply grilles are designed to eliminate water in non-aerosol form: evaporation occurs instantly the moistured air passes through the grilles, allowing the ducting to be safely located directly over machinery.

Savings on both capital and running costs and in energy consumption, are claimed for the Satair system. Its use of 'super-saturation' technology means it requires lower air volumes than conventional plant, making the whole system smaller and less expensive to run. Even for similar air volumes, the Satair pod atomiser uses less power than spray-type air washers or spray atomisers powered by compressed air.■

# Getting the breaks . . .

● From page 32

a complete unit in which the amplifier, signal processor and optics are all integrated within a sealed housing.

● *Type B detector*. This version is designed for flexibility, allowing the optics to be situated up to 3 metres from the electronics. This enables wider spacing of the optics, for detection of breaks in large balloons or traverses.

● *Nelson detectors* are among Dent's most recent developments. They use a newly-refined technique of reflective optoelectronics, suited to applications where space is very limited. For instance where yarns run parallel, Nelson units can detect on tracks spaced by as little as 10mm. There are two versions of the Nelson detector: one detects moving yarn, and can spot breaks in yarns from 10 dtex up to carpet yarns; the other detects yarn presence or absence along straight paths, working on yarns as fine as 5 dtex.

● *Compact detector*. This is a miniature unit only 10mm high, using the latest surface-mount technology to combine smaller size with higher operating sensitivity. Aimed at restricted-space applications, the Compact detector can handle yarns from 5 dtex to 5,000 dtex at speeds up to 8,000 metres per minute.

● *IQ100 Intelligent Detector*. This family of programmable yarn break detectors uses a microprocessor in each unit, enabling a wide range of parameters to be pre-programmed, either by Dent or the customer, catering for factors such as yarn frequency and delivery speed in its detection. The IQ system, based on specially-designed amplifier units, is described by Dent as "probably the biggest leap forward in break detection for many years." It is said to open up limitless new possibilities in localised process control.

A vital ancillary operation on yarn break detection is cutting and clamping of the yarn end, and Dent are able to meet this requirement through a manufacturing and distribution licence for the proven Uster cutter, developed by Zellweger Uster, of Switzerland. The unit is suited to cutting and clamping both at yarn breaks and for full packages.

## Data systems

Data collection and processing of the information gathered from yarn break detector signals is another area in which Dent have applied their technological expertise to devise a flexible solution. Their CAT (Continuous Assessment Technique) can use detector signals to give information on the performance of individual positions, sections and machines, as well as analyses of plant, shift, yarn batch and quality performance. Hardware and software is tailored to customer requirements.

An important new feature offers two-way communication with CAT systems through a cordless, hand-held computer, enabling remote data entry.

The Dent Vigilo detectors are suitable for a wide range of natural and synthetic yarns, including blends, as well as special uses on glass and carbon fibres and elastomerics.■