with x_i ranging from −1.9 to −8.0 in steps of 0.1. The $y(x)$ function was evaluated to an accuracy of at least six significant digits from Eq. 15 using Brent's numerical root-solving algorithm (4). The constants $b_1 - b_4$ of Eq. 7 were similarly evaluated with x_i ranging from −1.9 to 8.0 in steps of 0.1. The switch point $x = -1.9$ in the formula for $G(x)$ was derived empirically from preliminary observations which showed Eq. 4 starts to deviate significantly from $y(x)$ for $x > -1.9$, and the same is the case for Eq. 7 for $x < -1.9$. The maximum relative error $\epsilon = |y(x) - G(x)|/y(x)$ of Eq. 4 with the constants given is 0.078% ($x = -1.9$) in the range $x = -1.9$ to −8.0. From a mathematical analysis of Eq. 4 it can be shown that the relative error will continue to decrease beyond $x = -8$. This was confirmed by evaluating ϵ for $x = -8$ to −20. The maximum relative error for Eq. 7 with the constants given is 0.064% ($x = 2.2$) in the range −1.9–8. The relative error continues to decrease beyond $x = 8$ as expected from Eq. 7, and at about $x = 14$ reaches convergence and starts to oscillate tightly around the "machine precision value."

(1) S. L. Beal, *J. Pharmacokinet. Biopharm.*, **10**, 109 (1982).
(2) J. P. R. Toothill, "Progress in Industrial Microbiology," Vol. 2, Heywood and Company Ltd., London, 1960, p. 105.
(3) P. Veng-Pedersen, *J. Pharmacokinet. Biopharm.*, **5**, 513 (1977).
(4) R. P. Brent, *The Computer Journal*, **14**, 422 (1971).

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Pan Abrasion and Polymorphism of Titanium Dioxide in Coating Suspensions

Keyphrases □ Tablet-coating suspensions—titanium dioxide, pan abrasion from abrasive components □ Titanium dioxide—in coating suspensions, polymorphic modifications

To the Editor:

It is not generally recognized that aqueous tablet-coating suspensions may contain abrasive components which can cut into the surface of the coating pan causing deposition of metallic particles onto the tablets. Subsequent to a series of film-coating operations in a 24-in. coating pan[1], black specks were observed on the white tablet film coats derived from a commercial batch of color concentrate (Batch A)[2]. This phenomenon was not observed, however, when another batch of color concentrate (Batch B)[2] was employed. Isolation of the foreign material gave a positive test for iron, and it was confirmed that the actual rubbing of tablets coated with either batch against the pan surface produced black smudges. The streaks were, however, less intense on tablets coated with Batch B.

Titanium dioxide, an opacifier used in these aqueous film solutions, can exist in several polymorphic modifications, each with a different hardness (1). Anatase, for example, has a hardness on the Mohs' scale of 5.5–6, whereas rutile is in the range 6–6.5. For comparison, the common oxide of iron, hematite, gives values of 5–6 and magnetite, 5.5–6.5. The pan material itself, stainless steel 304, has a hardness range of 160–400 Brinnell (2). Conversion of the latter scale to the Mohs' scale (3) shows that the upper range lies somewhat below 6 on the Mohs' scale.

The Mohs' scale is a semiquantitative scale of hardness, which is a function of the elastic, plastic, and frictional properties of the surface. Materials with higher Mohs' numbers will scratch or abrade those with lower numbers.

In the range of Mohs' numbers considered here, the scale is linear and relatively sensitive, although hardness values tend to cluster at the high end. Abrasion or wear of the coating pan is essentially a surface phenomenon involving the removal of oxide films. A comparison of the Mohs' numbers shows that rutile is the harder of the two titanium dioxide polymorphs and would be expected to remove material through abrasion more readily than anatase. To confirm whether this could explain the observations, titanium dioxide was extracted from both batches of color concentrate and analyzed by X-ray powder diffraction. Batch A was found to contain 60:40 anatase/rutile in contrast to Batch B which was composed of 90:10 anatase/rutile.

Differences in surface roughness should theoretically not play a major role since, as the number of asperities in the film coating is increased, the number of contacting points would be increased proportionately. More scratches would be produced, but each would be of smaller cross-sectional area. This point was checked by measuring the advancing and receding contact angles of a series of liquids of varying surface tension on the film-coated tablet surfaces (4). There was no significant difference in surface roughness of films produced from either batch.

(1) "Handbook of Chemistry and Physics," 61st ed., CRC Press, Boca Raton, Fla., 1980–1981, pp. B202–207.
(2) R. B. Norden, in "Chemical Engineers' Handbook," 5th ed., R. H. Perry and C. H. Chelton, Eds., McGraw-Hill, New York, N.Y., 1973, chap. 23, p. 39.
(3) G. F. Kinney, "Engineering Properties and Applications of Plastics," Wiley, New York, N.Y.,1957, p. 137.
(4) W. A. Zisman, "Advances in Chemistry Series," #43, R. Gould, Ed., American Chemical Society, 1964, pp. 1–51.

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[1] Accela-Cota, Thomas Engineering, Hoffman Estates, Ill.
[2] Opaspray K-1-7000, Batch A, No. 30345, Batch B No. 29486; Colorcon, West Point, Pa.

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