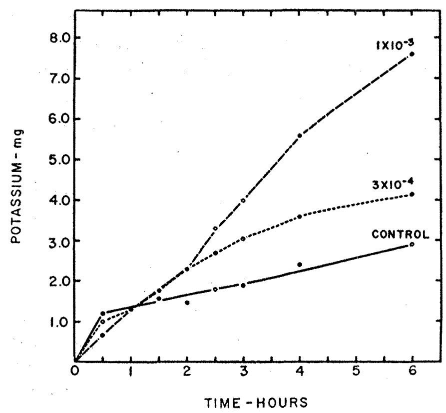

Fig. 1. Rate and extent of potassium uptake by excised barley roots in the presence of various levels of benzimidazole during a 6-hour period (7.5 gm fresh weight of barley roots in 200 ml of $1 \times 10^{-3}M$ K_2SO_4 at 25°C).

potassium salt. Roots pretreated with benzimidazole and then transferred to $1 \times 10^{-3}M$ K_2SO_4 attained a potassium content substantially higher than that of untreated excised roots placed in the potassium source for an equal time (0.68 mg of K per gram [fresh wt.] by the benzimidazole pretreated roots versus 0.32 mg/g [fresh wt.] by the untreated roots; pretreatment and uptake periods were each 3 hours).

The additional increment of potassium entering the roots in the presence of benzimidazole is mobile and becomes distributed through the plant. This was determined in experiments with intact barley seedlings, which, after exposure to $1 \times 10^{-3}M$ benzimidazole and K_2SO_4 for 24 hours, were transferred to potassium-free medium for 1 week to allow transport to the leaves to occur.

The benzimidazole enhancement of uptake is not peculiar to potassium but has been demonstrated also with sodium and calcium, with the use of excised barley roots. The response curves for the different ions do not appear to be identical; in fact, the benzimidazole concentration producing maximum calcium uptake is lower than that for potassium. There also appears to be an enhancement of nitrate uptake, but not of chloride, from their respective potassium salts. Increased potassium uptake has been shown to occur with excised pea roots, but could not be demonstrated with rooted tomato cuttings.

The evidence presently available is compatible with the view that the increased ion uptake induced by benzimidazole is brought about as the result of some enlargement of the specific accumulatory mechanism. The respiratory activity of root tips (Q_{O_2}) is unaffected by benzimidazole at the concentrations enhancing ion uptake. The increased accumulation of potassium is not cyanide-sensitive, and the potassium can be substantially but not completely removed from roots by treatment with excess $0.001N$ HCl for 3 hours. The normal pathways of ion uptake in barley roots generally favor potassium over sodium. The increase in sodium taken up from Na_2SO_4 when benzimidazole is present is not nearly as large as the increase in potassium from K_2SO_4 under similar conditions; thus the relative ease of entry of these two cations is not changed by bezimidazole.

Benzimidazole therefore may increase the number or capacity of the specific carrier sites, perhaps by incorporation in the carrier, or accelerate the rate-limiting, irreversible step at the inner surface of the membrane whereby the ion is split from the carrier, thus increasing the effective capacity of the carrier complex.

In considering such hypotheses, it would be helpful to know the effect of benzimidazole, if any, in the ion accumulatory systems of mammalian tissue, or of microorganisms (*4*).

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11 September 1959

Magnetic Damping of Rotation of the Vanguard I Satellite

Abstract. Explicit integration of integrals of the type basic to comparison of observed and predicted values of the earth's mean total magnetic field reveals an error in the numerical integration recently employed by Raymond H. Wilson, Jr., in making such a comparison for the special case of Vanguard I. Correction of this error destroys the satisfactory agreement he found between the value implied by rotational damping and the theoretical value.

Raymond H. Wilson, Jr., reports (*1*) satisfactory agreement between the mean total magnetic field of the earth, as deduced from the observed decreasing spin rate of satellite 1958β2, and the value of the earth's mean total magnetic field, as calculated from the theory of L. Bauer. The near agreement found by Wilson rests on his evaluation by numerical integration of the integral

$$h = \int_0^{\pi} \frac{dM}{(1 - 0.19 \cos M)^3} \qquad (1)$$

where the constant 0.19 in the integrand is the eccentricity of the orbit followed by satellite 1958β2, and the variable of integration, M, is the mean anomaly of the satellite. This numerical integration is in error, as is shown below. Furthermore, if other elliptic orbits of different eccentricities, e, are considered, each such orbit calls for a separate numerical integration, an obvious disadvantage.

Integrals of the type of Eq. 1 have been explicitly integrated by me in connection with a critical re-examination of the conjecture that the magnetic field of the earth is responsible for such remarkable concentrations of siderites as that within the so-called Farrington circle, a conjecture first subjected to an invalidating numerical test under certain simplifying assumptions some 20 years ago. (*2*).

If we consider the indefinite integral

$$I = \int \frac{dM}{(1 - e \cos M)^3}, \quad 0 \leqq e < 1 \qquad (2)$$

suggested by an obvious generalization of the definite integral (Eq. 1), it is not difficult to verify that, except for the integration constant $I = J/2(1 - e^2)^2$, where J is given by

$$J = \frac{(4e - 3e^2 \cos M - e^3)}{(1 - e \cos M)^2} \sin M - \frac{2 + e^2}{(1 - e^2)^{\frac{1}{2}}} \text{arc sin} \frac{\cos M - e}{1 - e \cos M} \qquad (3)$$

Since for the special case considered by Wilson, the term in Eq. 3 involving $\sin M$ as a factor vanishes at the limits of integration, while e has the value 0.19, it is found that

$$h = \frac{-2.0361}{2(0.9639)^{5/2}} \times \text{arc sin} \frac{\cos M - 0.19}{1 - 0.19 \cos M} \Bigg|_0^{\pi} = 1.11606\pi \qquad (4)$$

a value more than 11 percent in excess of the value $h = 1.0051\pi$ implied by Eq. 15 in Wilson's paper. The correct value of the time mean field according to Bauer's theory is therefore $\bar{H}_B = 0.15767$ gauss and not 0.142 gauss. The discrepancy between this value of $\bar{H}_B$ and the observed value $\bar{H}_0 = 0.138$ gauss is almost five times that obtained by adopting the erroneous value $\bar{H}_B = 0.142$ gauss.

In view of the importance of the problem attacked by Wilson, the unsatisfactory discrepancy between theoretical and observed $\bar{H}$-values here pointed out is an additional argument for acceleration of more precise studies of the sort he enumerates in the concluding paragraph of his interesting report.

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19 October 1959

Abstract. Continued numerical improvement of all parts of my previous report, based on later accumulation and rediscussion of data, has revealed several small random adjustments, including the arithmetical correction discussed by LaPaz. The consequent result remains a satisfactory agreement of the ground-observed geomagnetic dipole field with that deduced from rotational retardation of the Vanguard I satellite.

Had his services been available, an independent computer could probably have caught the arithmetical error in the evaluation of the integral of Eq. 15 of my report (*1*) before it crept into print. Fortunately, however, continued accumulation and discussion of new data on this Vanguard I problem have resulted in several mutually compensatory numerical adjustments, which, when generally accounted, as I shall do below, still preserve a good agreement between the magnetic field deduced from satellite rotational damping and that from previous geomagnetic theory.

When my attention was first called to the arithmetical error (*2*), I found among my earlier notes the closed general solution for the definite integral discussed by LaPaz:

$$I = \frac{(1 + e^2/2)\pi}{(1 - e^2)^{5/2}} \qquad (1)$$

which I overlooked in the final roundup for publication. My derivation of it consisted simply of direct use of formulas 308 and 300 in Peirce's tables (*3*); thus I arrived by a different route at a result equivalent to that of LaPaz.

Even so, my less elegant approach by numerical integration using Simpson's rule with five points, which, when corrected, gives $\bar{H} = 0.1574$ gauss, seems not altogether inappropriate, since, as stated seven lines above it in my report, the denominator of the integral is only a first approximation. The *exact* geocentric distance is

$$r = a\,(1 - e \cos E) \qquad (2)$$

where E is the eccentric anomaly in Kepler's famous transcendental equation

$$M = E - e \sin E \qquad (3)$$

so that the approximation shown used only the first-power term in an infinite alternating power series in the eccentricity e. Inclusion of further terms in this series for r (*4*) would render closed integration practically impossible, and such terms should be considered for the level of accuracy discussed by LaPaz. For example, inclusion of the second-power term, so that

$$r = a\left[1 - e \cos M + \frac{e^2}{2}(1 - 2 \cos 2M)\right] \qquad (4)$$

in the integral, would give $\bar{H} = 0.1505$ gauss. With this power series the truncation error of the integral is approximately $3(-e)^n\bar{H}/2(n-1)!$, where n is the order of the first omitted term. Hence, using $n = 3$, a final estimate for the integral, using the coefficient given in the report, would be $\bar{H} = 0.1515$ gauss, having an error of less than 0.1 percent.

However, the relevant uncertainties in the data and other physical assumptions of the report are at least as important as the above purely mathematical discussion. For a properly balanced conclusion it is therefore necessary to report here some significant progress on the physical side of the question since the previous article was published. In general these refinements seem to converge toward equalization of the mean magnetic field deduced from rotational damping with that from other means of measurement.

It was suggested by Richard Andryshak of this Center that, although the maximum geomagnetic inclination of the satellite orbit is about 45°, the mean would be the same as the geographical, namely, 34°, so that the latter value should replace $\pi/4$ everywhere in Eq. 14. Carrying out this correction, one obtains $\bar{H}_H = 0.286$ gauss, $\bar{H}_V = 0.175$ gauss, and $\bar{H}_0 = 0.335$ gauss. Substitution of the last number for 0.356 in Eq. 15 yields $\bar{H} = 0.148$ gauss, using the correction discussed by LaPaz, or $\bar{H} = 0.143$ gauss, using the higher order approximation for that integral.

New data on the satellite and its rotation are continually being accumulated, and the reductions correspondingly revised. The 10-day means of rotational speed, as recorded up to 1 December 1959 by the Tracking Systems Division of this Center, continue to waver about a straight line on a semilogarithmic grid, as shown in Fig. 1. However, the mean relaxation time deduced from this extended curve is now 230 days, a 10-percent increase over

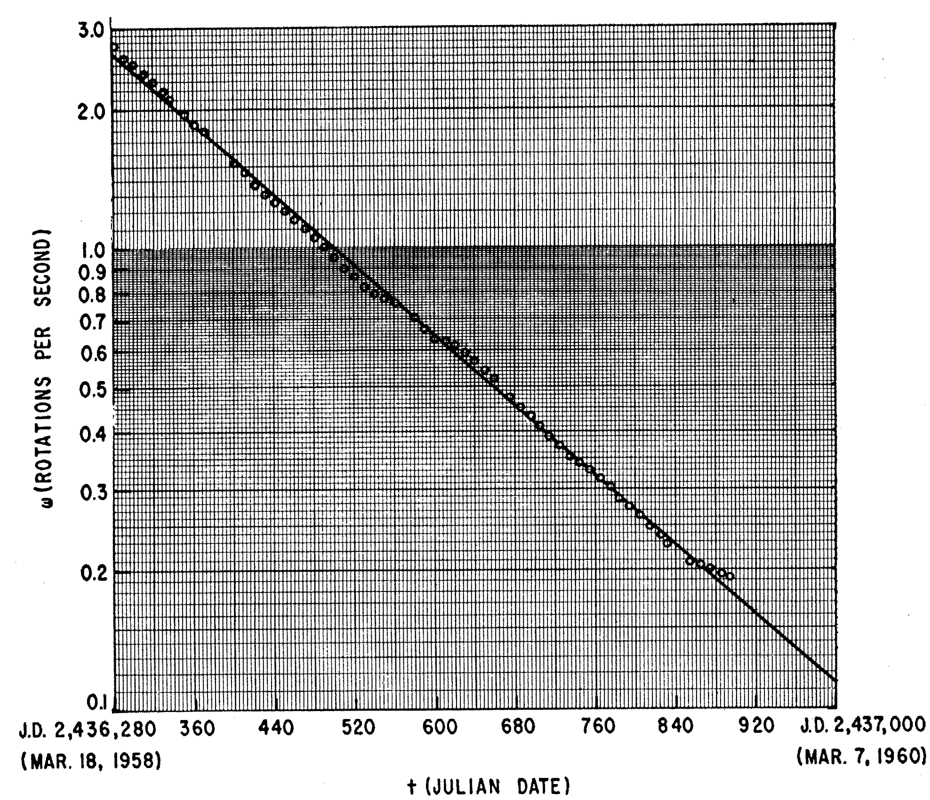

Fig. 1. Observed spin-rate versus time for satellite 1958β2 (Vanguard I), using data to 1 December 1959. The straight line represents exponential decay with a relaxation time of 230 days.