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CORRECTION FACTORS FOR MEASUREMENTS WITH CADMIUM COVERED FOILS

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ABSTRACT

Cadmium-covered foils are frequently used to measure the neutron flux with energy above that represented by the cadmium cut-off point. Correction factors to account for the attenuation of the epicadmium neutrons by the cadmium are given and compared with results by earlier experimenters. In the present work, foil area, foil thickness, and cadmium ratio were varied with no detectible effect on the correction factor. Values are given for both indium and gold, and a further small correction to account for the leak-through of subcadmium or thermal neutrons is discussed.

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I. INTRODUCTION

Cadmium-covered foils are commonly used in neutron flux measuring experiments to determine the flux above the cadmium cut-off point which is located at about 0.4 ev. In conjunction with bare foils, they may also be used to obtain the thermal flux, or the flux below the cadmium cut-off. A correction factor is frequently used to account for the attenuation of the epicadmium neutrons by the cadmium, and a method of measuring this factor is described by Kunstadter.[1] This method consists of irradiating cadmium-covered foils with different thicknesses of cadmium covers and plotting their activities vs thickness on semi-log paper (see Fig. 1). The extrapolation of the straight-line tail of the resulting curve to zero cadmium thickness permits an evaluation of the customary correction factor, which is the extrapolated activity at zero thickness divided by the activity at any given cadmium thickness. Tittle[2] gives a list of the results of several experimenters who have measured this same factor with indium foils. The divergency of these results are attributed by Tittle to differences in foil thickness, but may possibly be due to the variety of sources, media, and foil sizes in the various experiments. It was felt that a measurement of the correction factor under the conditions met with in foil exposures at this laboratory would be desirable. In addition, this presented an opportunity to make consistent measurements while varying parameters such as foil size, thickness, and cadmium ratio.

II. DESCRIPTION OF EXPERIMENT

The cadmium-covered foils were exposed in groups of five or six by placing them on a rotating aluminum disc which was inserted into one of the removable graphite stringers of the North American Aviation water-boiler reactor. The disc, which is approximately 10 cm in diameter, is chain driven so as to turn at about 20 rpm. Use of the rotating disc eliminated any effect of positioning on the foils, and permitted the exposure of a number of foils simultaneously. Runs were made with the uniform flux disc in two positions: (1) in the center of the stringer, and (2) about 30 inches from the center. The cadmium ratios for 0.005 inch thick indium foils at these two points were about 6 and 16 respectively.

When the foils were in the center of the stringer, they were separated by about 2 inches of graphite from the edge of the spherical core of the reactor.

Cadmium covers from 0.005 inch to 0.090 inch thick were used with the indium foils, and from 0.020 inch to 0.090 inch thick with the gold foils. All foils were counted in each of three to five end-window beta counters. Statistical counting accuracy of about 0.1 per cent was obtained in most cases.

As a preliminary check, the epicadmium flux perturbation was investigated by measuring the effect of other nearby cadmium boxes on the cadmium-covered foil activity. This was done by comparing the activity of a cadmium-covered foil both with and without other cadmium boxes in the vicinity. No effect was detected.

Although of secondary importance, the perturbation of the flux below cadmium cut-off, caused by the cadmium boxes, was checked to determine whether the thermal flux in this region would be seriously affected. Several bare indium foils were exposed on the rotating aluminum disc along with a 0.090 inch cadmium box. The resulting depression of thermal flux, as indicated by Fig. 2, is evidently too small to have a significant effect on the measurements, since the activation by thermal neutrons is a small correction to cadmium covered foil measurements.

III. RESULTS

A typical curve of foil saturated activity <u>vs</u> thickness of cadmium covering is shown in Fig. 1. As may be seen, the points above 0.030 inch cadmium thickness lie along a straight line, which represents the attenuation of the epicadmium neutrons. The ratio between the relative activity when extrapolated back to zero cadmium thickness and the relative activity at a given cadmium thickness provides a correction factor, F_{Cd}, so that

$$A_B^{epi-Cd} = A_{Cd}^{T} \; F_{Cd} \qquad \ldots(1)$$

where A_B^{epi-Cd} is the corrected epicadmium activity or the activity of a bare foil due to epicadmium neutrons, and A_{Cd}^{T} is the total or measured activity of cadmium-covered foils. Values of F_{Cd} are given for indium and gold foils in Table I.

TABLE I

CORRECTION FACTORS FOR USE WITH CADMIUM-COVERED FOILS

Researcher	Foil Weight (mg/cm^2)	Foil Size (cm)	Medium	Cd Ratio (Approx)	Correction Factor for 0.040 inch Cd Thickness
Indium Foils					
Walker[3]	3.59	2 x 3.1	Water	10	1.077
Dacey, et al.[4]	58.8	3.02 (diam)	Water and solutions	10	1.120
Rush[5]	93.5	4 x 6.35	Water	10	1.123
Kunstadter[1]	94.5	4 x 6.35	Graphite	50	1.150
Martin	94	1.00 x 1.00	Graphite of WBNS	6	1.098
	88	1.00 x 1.00	Graphite of WBNS	6	1.094
	69	1.00 x 1.00	Graphite of WBNS	6	1.09
	29	1.00 x 1.00	Graphite of WBNS	6	1.09
	88	1.00 x 1.00	Graphite of WBNS	16	1.095
	88	0.20 x 1.00	Graphite of WBNS	6	1.10
Gold Foils					
Martin	238	1.00 x 1.00	Graphite of WBNS	6	1.02
	225	0.02 x 1.00	Graphite of WBNS	6	1.02

The correction factor, F_{Cd}, is given in the table for 0.040 inch cadmium in order to compare with earlier work. An error of ±1 per cent has been estimated for our values of F_{Cd}, although the consistency of the data is considerably better than this. The new values differ by more than the estimated error from Kunstadter's value of 1.150; however, within the limitations of our experiment, variation in foil thickness, foil area, or cadmium ratio do not seem to account for this difference.

IV. LEAKAGE OF THERMAL NEUTRONS THROUGH CADMIUM COVERS

For cadmium covers below about 0.030 inch in thickness, an additional small correction should be made due to the leakage of thermal, or "sub-cadmium" neutrons. To evaluate this, the straight line portion of the curve for indium foils shown in Fig. 1 was subtracted from the total activity, and the result is shown in Fig. 3. The point at zero cadmium thickness is obtained from a bare foil measurement. The fact that the curve does not seem to approach this point may be because, for structural reasons, the amount of cadmium in the edges of the boxes was not proportional to the thickness of the tops and bottoms. To a reasonable approximation, however, the neutrons separated into two groups, epicadmium and thermal, each being attenuated in an exponential manner.

In order to obtain the true epicadmium activity for thinly covered foils, the thermal neutron activation of cadmium-covered foils, A_{Cd}^{th}, which is represented in Fig. 3, should be subtracted from the total cadmium-covered activity, A_{Cd}^{T}, before the correction factor, F_{Cd}, is applied:

$$A_{B}^{epi\text{-}Cd} = (A_{Cd}^{T} - A_{Cd}^{th})\ F_{Cd} \quad . \qquad \ldots(2)$$

A_{Cd}^{th}, which is defined as the thermal part of the cadmium-covered foil activity, is proportional to A_{B}^{th} or the thermal neutron activation of a bare foil, so that

$$A_{Cd}^{th} = X\, A_{B}^{th} \quad ,$$

where X is a proportionality factor dependent only on the cadmium thickness. From the data of Fig. 3, X is 0.002 for a cadmium thickness of 0.020 inch. Equation (2) can thus be written,

$$A_B^{epi\text{-}Cd} = (A_{Cd}^T - X A_B^{th}) F_{Cd} \quad . \qquad \ldots(3)$$

Since the thermal part of the bare foil activity is the difference between the total bare foil activity and the epicadmium part of the bare foil activity,

$$A_B^{th} = A_B^T - A_B^{epi\text{-}Cd} = A_B^T - (A_{Cd}^T - X A_B^{th}) F_{Cd}$$

Solving for A_B^{th},

$$A_B^{th} = \frac{A_B^T - A_{Cd}^T F_{Cd}}{1 - X F_{Cd}} \qquad \ldots(4)$$

and, conversely, the epicadmium part of the bare foil activity is:

$$A_B^{epi\text{-}Cd} = A_B^T - A_B^{th} = F_{Cd} \frac{A_{Cd}^T - X A_B^T}{1 - X F_{Cd}} \qquad \ldots(5)$$

With the constants F_{Cd} and X known, Eqs. (4) and (5) give accurate expressions for the foil activity due to thermal neutrons and foil activity due to epicadmium neutrons in terms of a bare and a cadmium-covered foil measurement. It is to be pointed out that usually X is too small to be significant and Eq. (1) can be used instead of Eq. (5). However, for 0.020 inch or thinner cadmium the factor Xmay be important, in particular for high cadmium ratios where A_B^T is much larger than A_{Cd}^T.

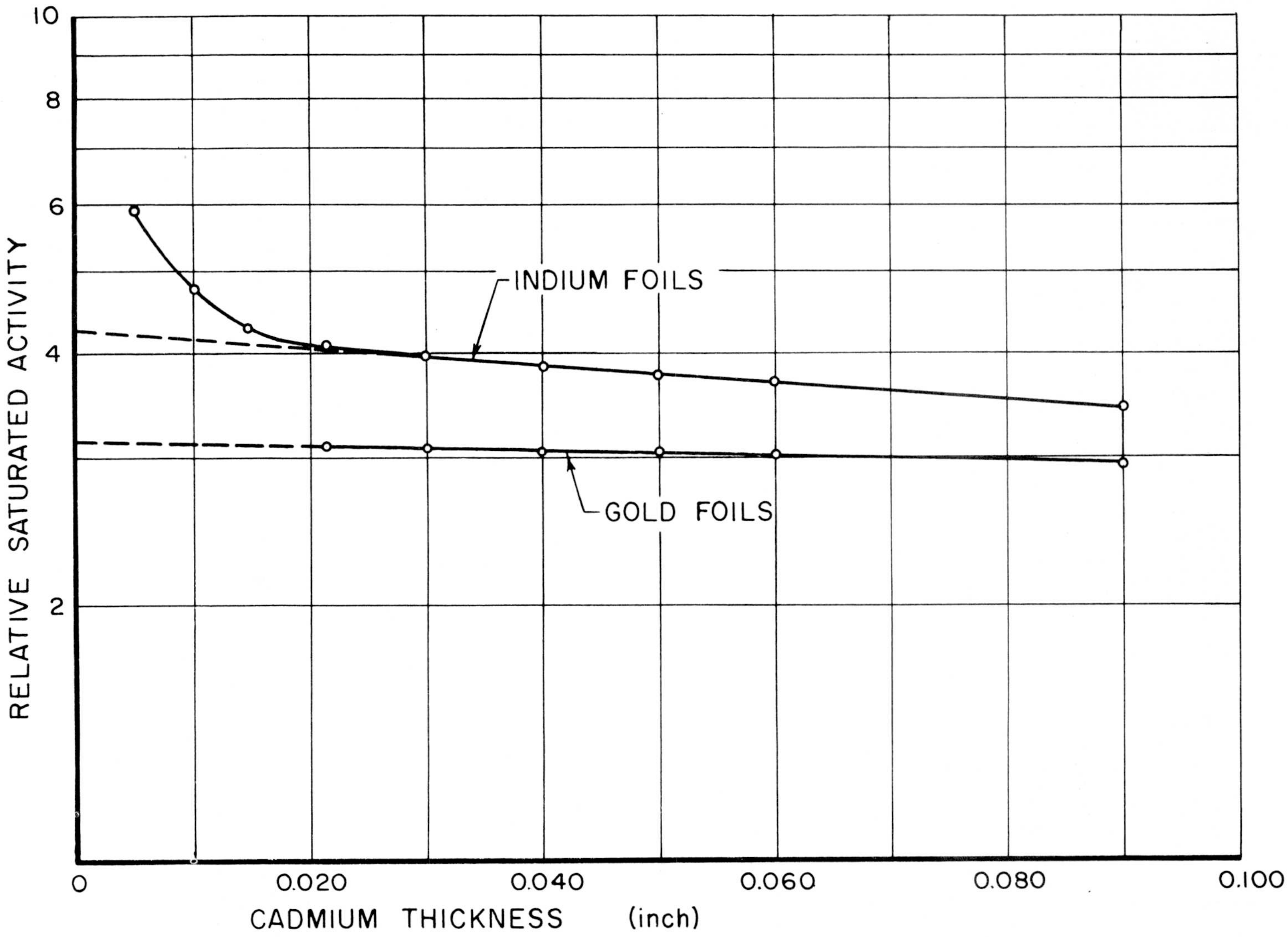

Fig. 1. Relative Saturated Activity vs Cadmium Thickness

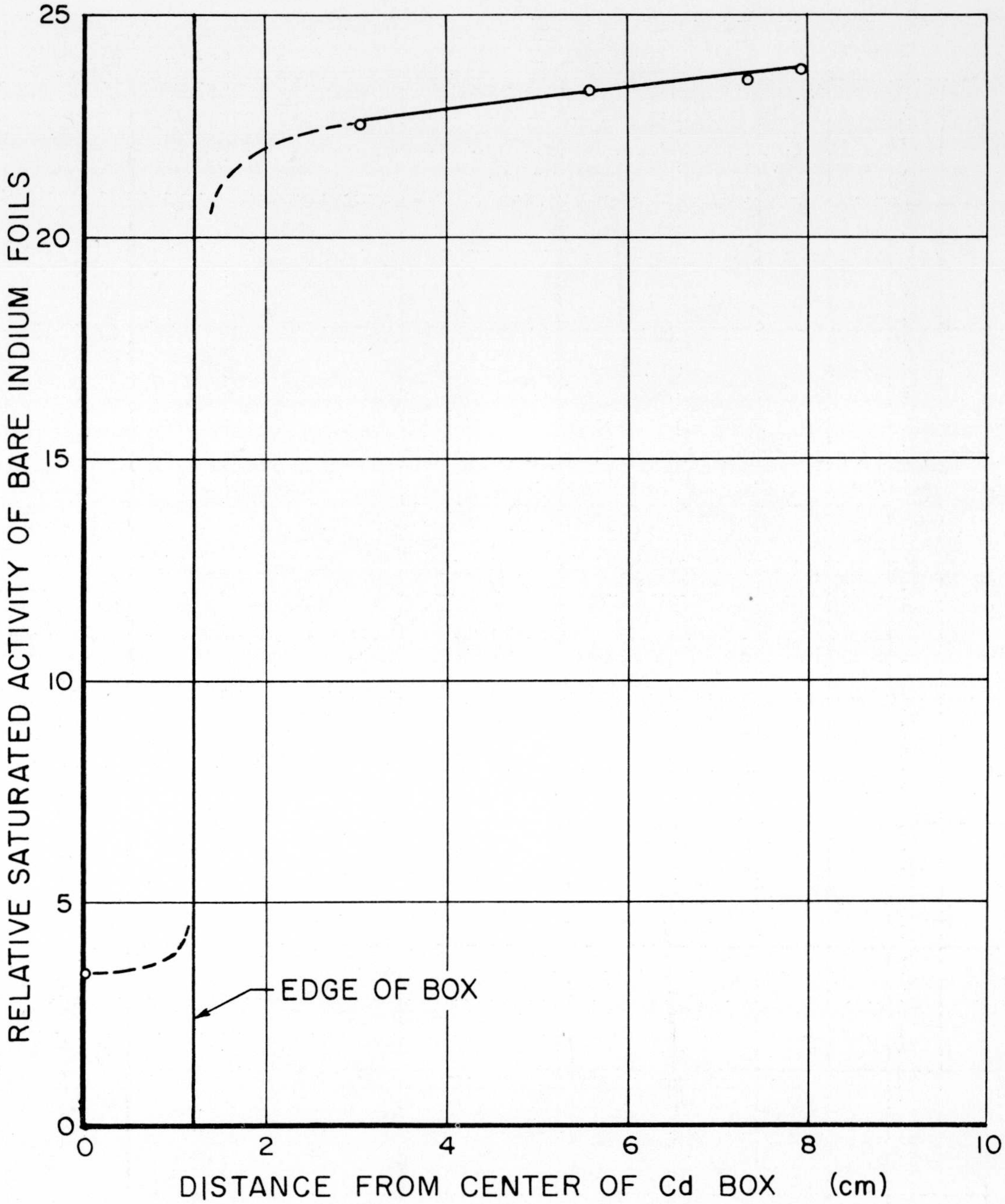

Fig. 2. Depression of Activity of Bare Indium Foils in the Vicinity of a Cadmium Box with Walls 0.090 inch Thick

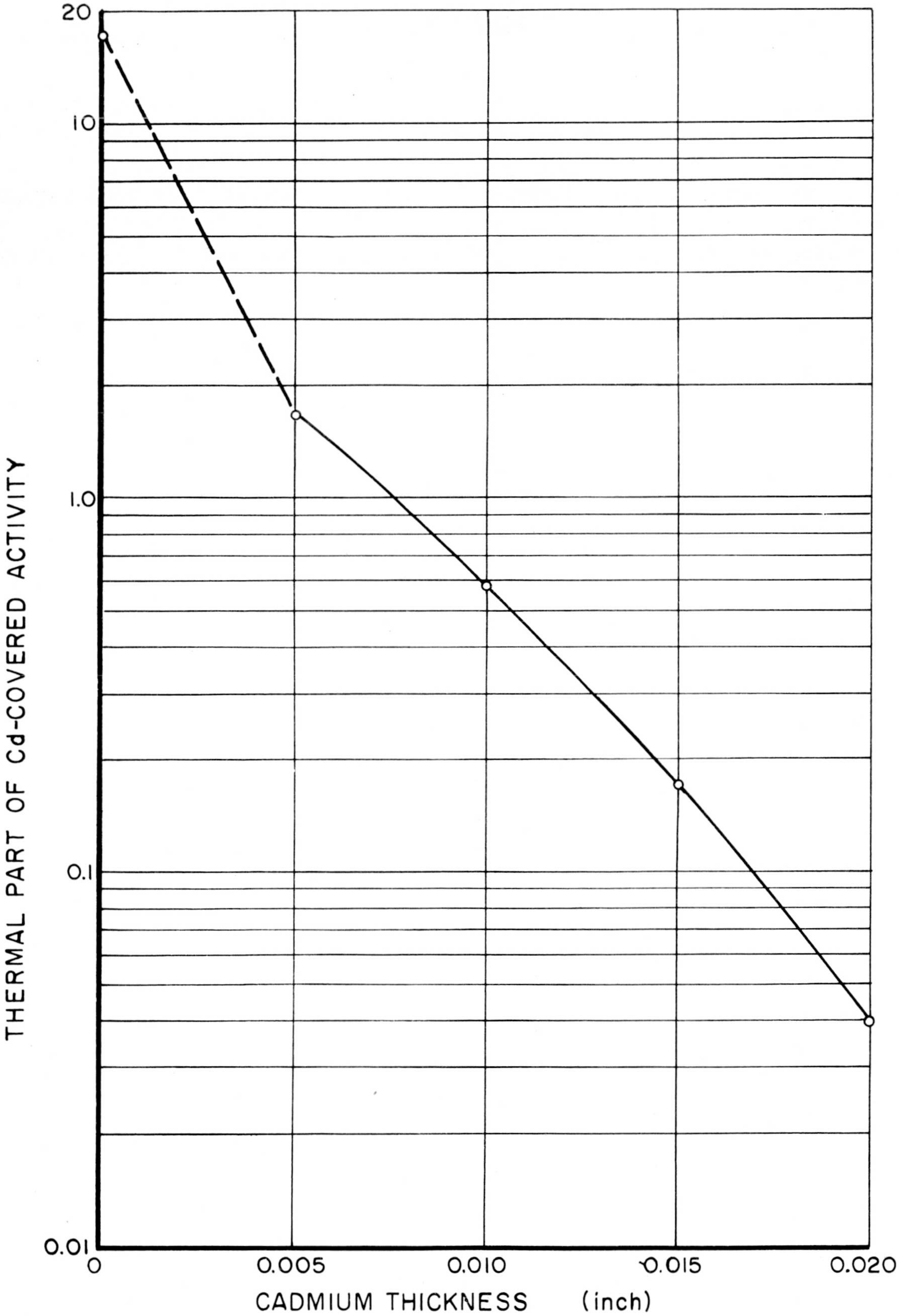

Fig. 3. Thermal Neutron Activation of Cadmium Covered Indium Foils

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