Monte Carlo simulation enhancement of neutron backscattering from buried CHNO materials using a carbon reflector

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الملخص:-

أجريت محاكاة مونت كارلو لحساب النيوترونات المرتدة المرنة لمصدري النيوترونات Cf-252 و Pu-Be من مواد تحتوي على عناصر الكربون والنيتروجين والأكسجين والهيدروجين ومدفونة في التربة. وأظهرت نتائج الدراسة حصول تعزيزلقمم أطياف النيوترونات المرتدة لجميع العينات عند استخدام عاكس من الكربون ضمن التصميم الهندسي.

Abstract

Monte Carlo simulations of elastically backscattered neutrons (EBS) from materials containing C, H, N and O elements buried in soil have been carried out. Five different samples were studied and two point neutron sources, Cf-252 and Pu-Be, were employed in the calculations. It was found in this study that the EBS neutron peak spectra were enhanced for all the samples when carbon reflector is considered within the geometry.

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Introduction

Detection and identification of hazardous materials has become a problem of concern for researchers. During the last two decades, at least 73,576 casualties in 119 countries have been identified .The most common hazardous materials often contain the elements H, C, N and O. Examples are TNT ($C_7 H_5 N_3 O_5$) ,Cocaine ($C_{17} H_{21} NO_4$), Morphine ($C_{17}H_{19}NO_3$), RDX ($C_3H_6N_6O_6$) and Urea ($CH_4N_2O_5$) . Therefore, nuclear techniques based on neutron backscattering have been employed to detect and identify such materials (1-7).

There are more than one detection approach based on neutron backscattering (8-12). The model used in this study involves a point fast neutron source of Cf-252 or Pu-Be to irradiate a matrix of soil within which a sample is buried containing C, H , N and O elements. The nuclei of these elements will cause the incident neutron to be elastically backscattered, and this can be used as a mark of these elements. Those EBS neutrons are then detected by an array of point detectors placed at fixed positions sideways from the point neutron source. The elements used in the samples interact with neutrons of different energies. Hydrogen interacts with relatively low neutron energy compared to Carbon, Nitrogen and Oxygen require higher neutron energies to be involved in interaction .Therefore, the two neutron sources Cf-252 and Pu-Be with average energies of 2 MeV and 5 MeV, respectively, are quite appropriate to cover interactions with all those elements . The use of carbon reflector within the setup geometry proved to be very useful in the enhancement for EBS neutron peak spectra for all samples. In addition, the use of a sizeable reflector slab above the neutron sources is expected to reduce the radiation dose when it is used in field work

The MCNP modeling

A Monte Carlo computer code was utilized to calculate the elastically backscattered (EBS) neutrons from hidden dangerous materials in soil or large container such as explosives and drugs. In this study, a soil matrix with dimensions of 100 cm x 100 cmx 50 cm and an

explosive material in the shape of a cylinder with a radius of 16.85 cm and a height of 5 cm is buried 5 cm deep into the soil. A neutron point source (either Pu-Be or Cf-252) is assumed to be located at y=10 cm above the surface of the soil. In addition, a carbon reflector of dimensions 100 cm x 5 cm x 50 cm is assumed to be located at y = 10 cm above the source. An array of point detectors are placed at the same level of the source to tally the EBS neutrons from the hidden materials at positions sideways from the source at x = ±5, ±10, ±15, ±20, ±25, ±30 and ±35 cm. The Monte Carlo setup used for the calculations is schematically shown in Fig.1.The general purpose Monte Carlo N-particle (MCNP) code, as described by the X5 Monte Carlo Team. [13], was used in the present study, with neutron cross – sections taken from the ENDF/B–VI library employed for all the simulation work. Simulations have been conducted on a PC with 4.0 GHZ Pentium IV processor .The average CPU time for each simulation was about 60 minutes and the data obtained were calculated within a statistical error of about 2% in all energy bins .Five classes of materials were studied, with their related data given in Table 1.

Table: Data for the five sample materials used in the study

CHNO Material	Chemical Formula	Density(gm/ cm^3)	Hydrogene n (wt %)
Cocaine	$C_{17}H_{21}NO_4$	1.26	50
Morphine	$C_{17}H_{19}NO_3$	1.31	48
RDX	$C_3H_6N_6O_6$	1.82	29
TNT	$C_7H_5N_3O_6$	1.65	27
Urea	CH_4N_2O	1.32	50

The simulation study explains the features of the EBS energy spectra from the hidden sample materials in soil. The two neutron point sources Cf-252 and Pu-Be were employed alternately in the calculations. The EBS relative neutron yield spectra were calculated by subtracting the background spectrum (soil) from the signal (soil and sample) i. e. ($I - I_0$) versus neutron energy where I and I_0 represent EBS neutron yield from soil with and without sample, respectively. The reflection parameter of neutrons for each of the hidden materials $\beta = (I - I_0) / \rho I_0$ (with ρ= sample density) were obtained at different detector positions: x=±5, ±10, ±15, ±20, ±25, ±30 and ±35 cm, at source position y = 10 cm, with and without carbon reflector.

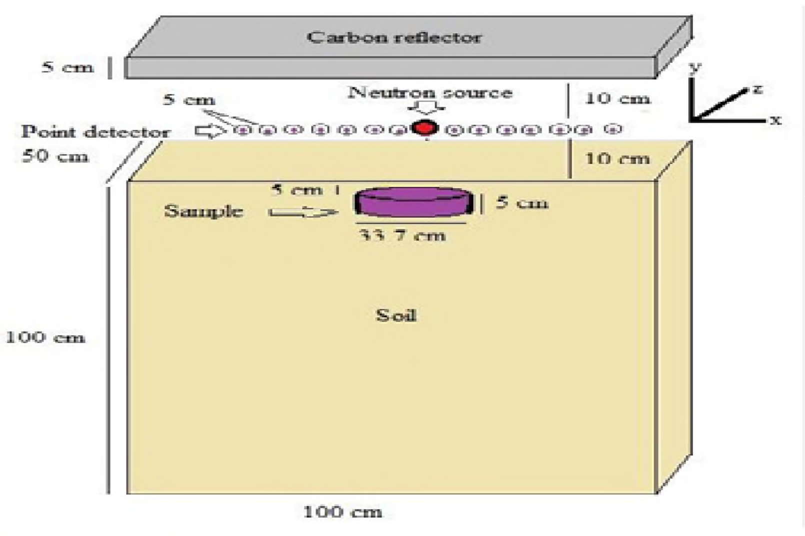

Fig.1View of the sample-soil- detector geometry as modeled with MCNP code.

Results and Discussion

The net elastically backscattered neutrons spectra of Cf-252 neutron source from the materials containing C, H, N and O elements hidden in the soil, with and without carbon reflector are shown in Figs. 2 - 6. Low energy peaks were observed with and without carbon reflector. In addition high and wide energy peaks were observed at energies 1.33 and 2.70 MeV. No EBS peaks were scored beyond 3 MeV. Wide and high intensity peaks at energies 1.4 and 2.6 MeV were observed in case of carbon reflector, which confirmed these peaks were from Carbon. variation of the value of $(I - I_0) / \rho I_0$ versus detector position for EBS neutrons spectra of Cf-252 neurons source from hidden C,H,N and O materials in soil, with and without carbon reflector, are shown in Fig. 7. High value of $(I - I_0) / \rho I_0$ for Cf-252 EBS neutrons is observed for cocaine (H wt 50% ; C wt 40.5%; N wt 2.4%; O wt 7.1%) over all detector positions, when compared with the other CHNO materials, while low values of $(I - I_0) / \rho I_0$ is observed for RDX (H wt 28.6% ; C wt 14.2%;N wt 28.6%; O wt 28.6%) in the two cases with and without carbon reflector.

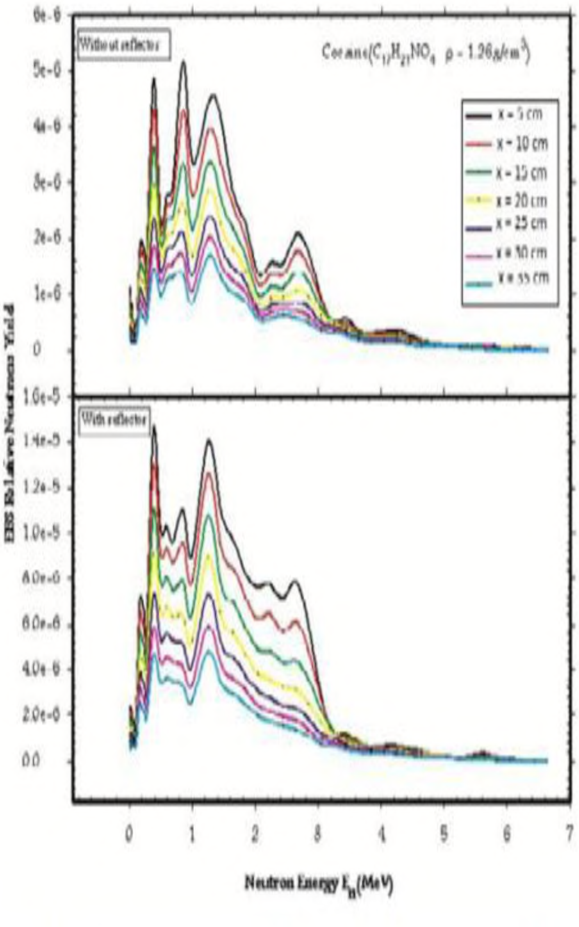

Fig. 2. Variation of net EBS of Cf-252 neutron spectra from Cocaine ($C_{17}H_{21}NO_4$, ρ =1.26 gm/cm^3) as a function of detector position with and without carbon reflector.

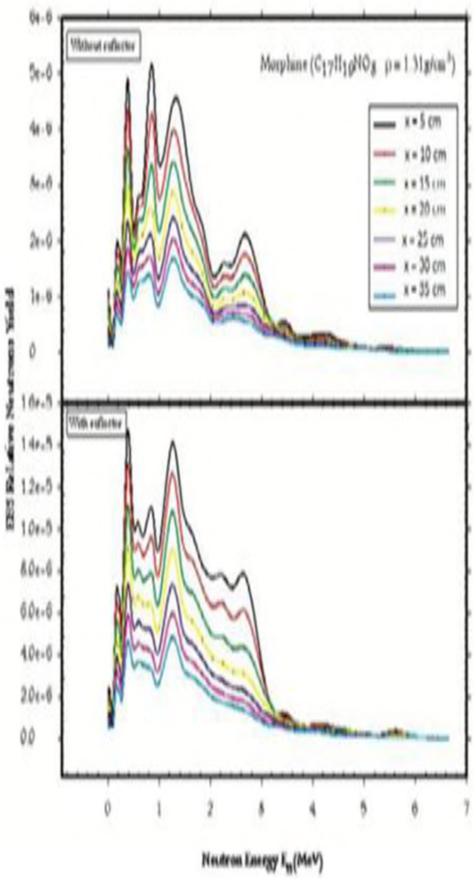

Fig.3. Variation of EBS of Cf-252 neutron spectra from Morphine ($C_{17}H_{19}NO_3$, ρ =1.31 gm/cm^3) as a function of detector position with and without carbon reflector.

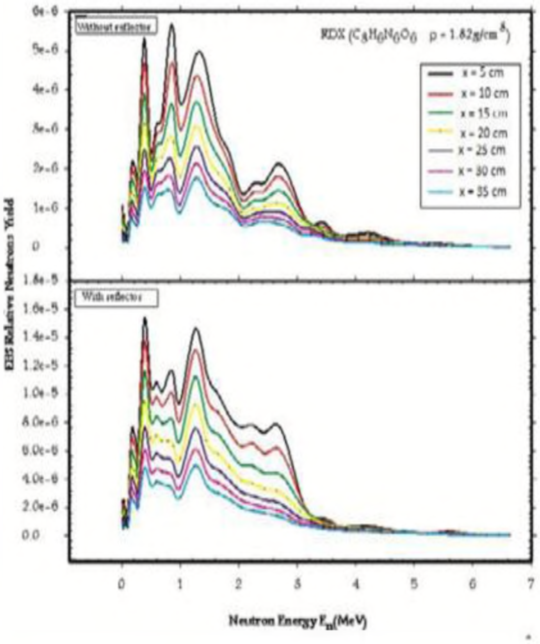

Fig .4. Variation of EBS of Cf-252 neutron spectra from RDX ($C3H_6N_6O_6$, ρ =1.82 gm/cm^3) as a function of detector position with and without carbon reflector

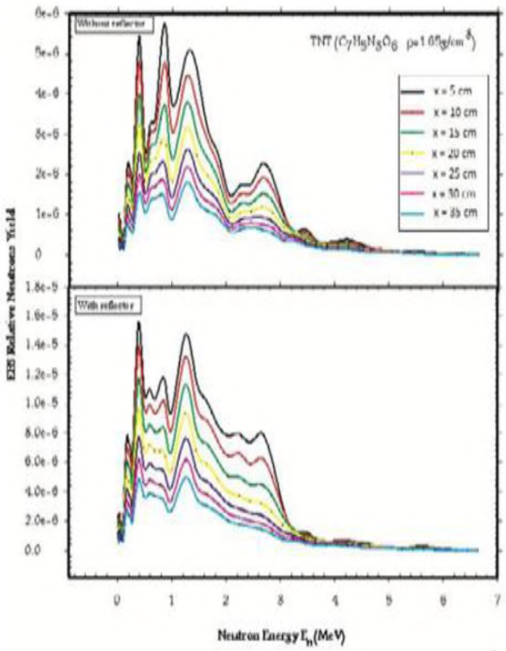

Fig .5.Variation of EBS of Cf-252 neutron spectra from TNT ($C_7H_5N_3O_6$, ρ =1.65 gm/cm^3) as a function of detector position with and without carbon reflector.

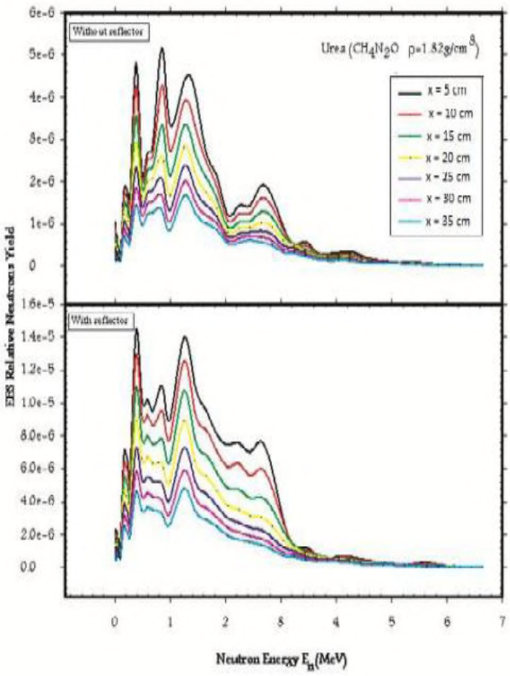

Fig .6. Variation of EBS of Cf-252 neutron spectra from Urea (CH_4N_2O, ρ =1.32 gm/cm^3) as a function of detector position with and without carbon reflector.

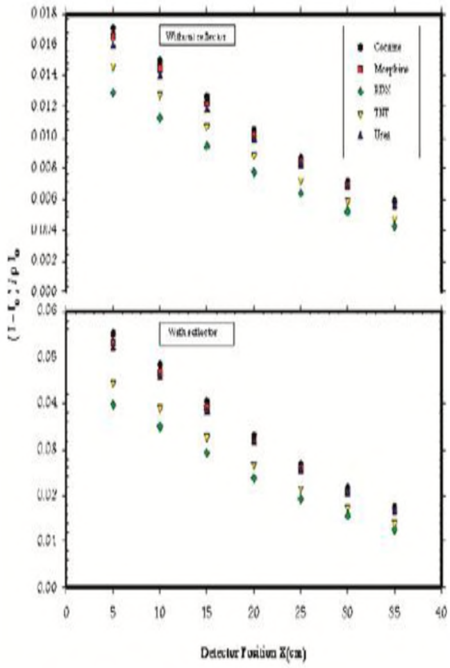

Fig .7.Variation of the value of $(I - I_0) / \rho I_0$ versus detector position for Cf-252 EBS neutron from CHNO materials with and without carbon reflector.

Net EBS neutrons energy spectra of Pu-Be neutrons source from hidden CHNO materials in soil, with and without carbon reflector, are shown in Figs. (8-12), relatively high peaks at low energy were observed which come from Hydrogen. High intensity peaks at energies 1.37, 2.67, 3.44, 4.24 and 5.60 MeV was observed in cases with and without reflector carbon reflector. The intensity of peaks decreased as the distance of the detector from source the increase. The variation value of $(I - I_0) / \rho I_0$ of EBS neutrons of Pu-Be neutrons source from hidden (CHNO-materials) in soil versus detector position is shown in Fig. 13. High value is observed for cocaine (H wt 50%; C wt 40.5%; N wt 2.4%; O wt 7.1%) over all detector positions, while low values of $(I - I_0) / \rho I_0$ is observed for RDX (H wt 28.6% ; C wt 14.2%; N wt 28.6%; O wt 28.6%). High values of $(I - I0) / \rho I_0$ is observed for TNT (H wt. 23.8% ; C wt 33.3%; N wt 14.3%; O wt 28.6%), when compared with the value in case of RDX (H wt 28.6% ; C wt 14.2%; N wt 28.6%; O wt 28.6%) that is attributed to high weight of carbon in case of TNT and high density of RDX. High values of $(I - I_0) / \rho I_0$ of EBS neutrons energy of Pu-Be neutrons source is observed in case of carbon reflector when compared with the case of without carbon reflector, that shows strong effect of carbon on the values of $(I - I_0) / \rho I_0$. High values of $(I - I_0) / \rho I_0$ is observed for TNT (H wt 23.8% ; C wt 33.3%; N wt 14.3%; O wt 28.6%), when compared with the case value of RDX(H wt 28.6% ; C wt 14.2%; N wt 28.6%; O wt 28.6%). High values of $(I - I_0) / \rho I_0$ of EBS neutrons spectra of Cf-252 neurons source is observed in case of carbon reflector when compared with the case of without carbon reflector that shows strong effect of carbon on the values of $(I - I_0) / \rho I_0$.

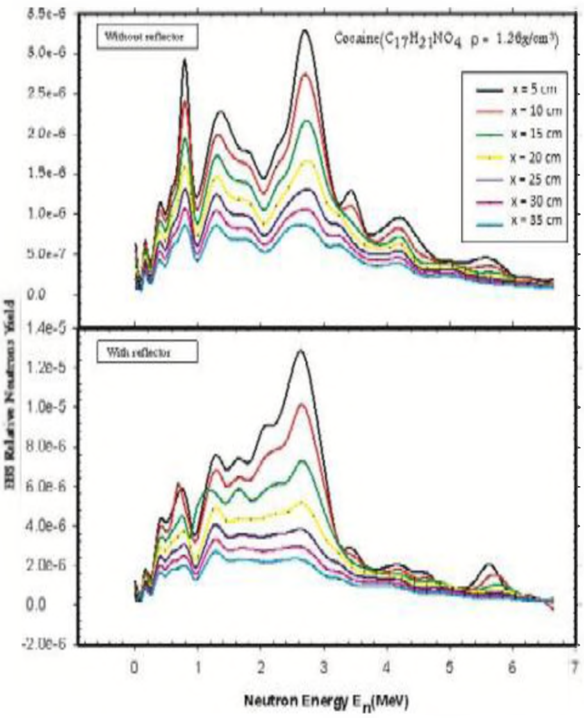

Fig.8.Variation of EBS of Pu-Be neutron spectra from Cocaine ($C_{17}H_{21}NO_4$, ρ =1.26 gm/cm^3) as a function of detector position with and without carbon reflector.

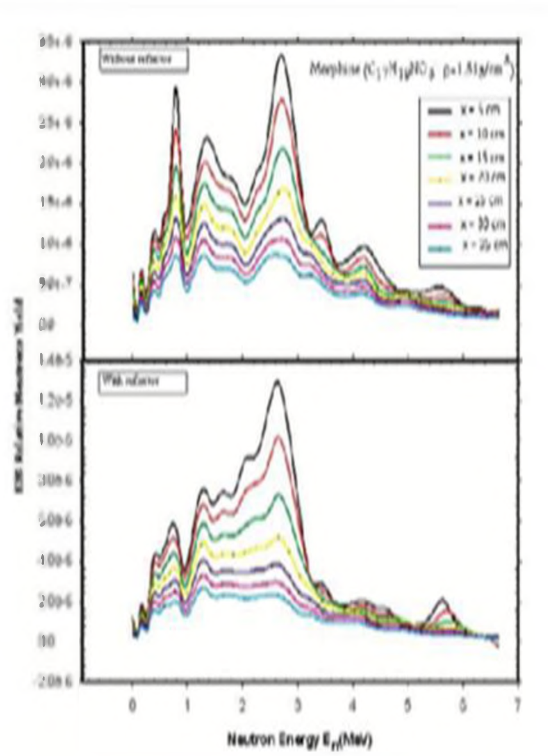

Fig.9 Variation of EBS of Pu-Be neutron spectra from Morphine ($C_{17}H_{19}NO_3$, ρ =1.31 gm/cm^3) as a function of detector position with and without carbon reflector

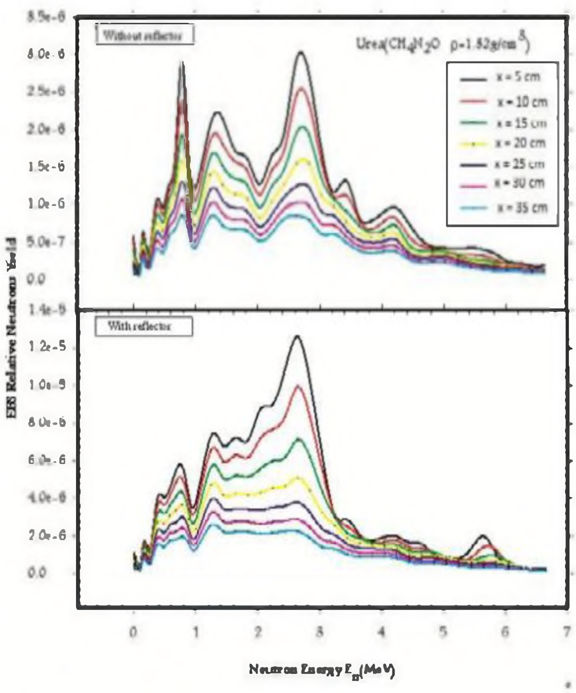

Fig.12. Variation of EBS of Pu-Be neutron spectra from Urea (CH_4N_2O, ρ =1.32 gm/cm^3) as a function of detector position with and without carbon reflector.

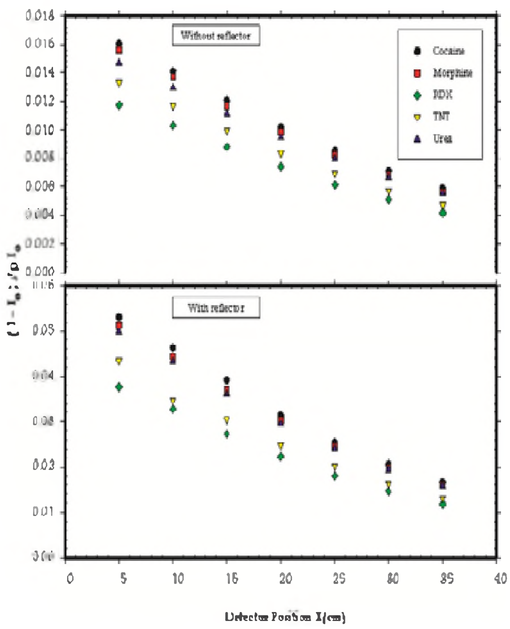

Fig .13. Variation of the value of $(I - I_0) / \rho I_0$ versus detector position for Pu-Be EBS neutron from CHNO materials with and without carbon reflector.

Conclusion

This simulation study has shown the major features from various hidden target materials containing C, H, N and O elements in soil. Monte Carlo simulations of EBS neutron sources for five sample materials hidden in soil were studied. The study shows that Monte Carlo simulations are useful to assess the limitations and possibilities to detect the dangerous materials containing H, C, N and O elements e. g. landmines and drugs using neutron backscattering technique. Peaks from hydrogen and carbon can be identified as well as nitrogen and oxygen despite the fact that the peaks from nitrogen and oxygen interfered with peaks from carbon. Additional peak at 5.6 MeV is observed in case of carbon reflector using Pu-Be source which is mainly from carbon. The use of carbon reflector showed enhanced and wider peaks, especially at energies 1.28 MeV and 2.64 MeV, when compared with the results obtained without carbon reflector.

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