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MULTIPLICATIVE *ABC, GA*, *AG*, AUGMENTED AND HARMONIC STATUS INDICES OF GRAPHS

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ABSTRACT

In this study, we introduce the multiplicative atom bond connectivity status index, multiplicative geometric-arithmetic status index, multiplicative arithmetic-geometric status index, multiplicative augmented status index and multiplicative harmonic status index of a graph. We compute these multiplicative status indices for complete graphs, cycles, complete bipartite graphs, wheel graphs and friendship graphs.

Key words: *Multiplicative ABC status index, multiplicative GA status index, multiplicative augmented status index, multiplicative harmonic status index, graph.*

Mathematics Subjects Classification: *05C05, 05C07, 05C35, 05C90.*

1. INTRODUCTION

Let $G= (V(G), E(G))$ be a simple, finite, connected graph. The degree $d_G(u)$ of a vertex u is the number of vertices adjacent to u. The distance between two vertices u and v, denoted by $d(u, v)$, is the length of the shortest u -v path in a graph G. The status of a vertex u in G is defined as the sum of its distance from every other vertex in G and is denoted by $\sigma(u)$. For graph theoretic terminology, we refer [1].

A graph index is a numerical parameter mathematically derived from the graph structure. Several graph indices have their applications in various disciplines of Science and Technology, see [2, 3]. Many status indices of a graph such as harmonic status index [4], first and second status connectivity indices [5], first and second hyper status indices [6], multiplicative first and second status indices [7], multiplicative F-status index [8], multiplicative (a, b)-status index [9], first and second status coincides [10], geometric- arithmetic status index [11] studied in the literate of graph indices.

We introduce the multiplicative atom bond connectivity status index, multiplicative geometric- arithmetic status index, multiplicative arithmetic-geometric status index, multiplicative augmented status index, multiplicative harmonic status index of a graph as follows:

The multiplicative atom bond connectivity status index of a graph G is defined as

$$ABCSII(G)=\prod_{uv\in E(G)}\sqrt{\frac{\sigma(u)+\sigma(v)-2}{\sigma(u)\sigma(v)}}.$$

The multiplicative geometric-arithmetic status index of a graph G is defined as

$$GASII(G)=\prod_{uv\in E(G)}\frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u)+\sigma(v)}.$$

The multiplicative arithmetic-geometric status index of a graph G is defined as

$$AGSII(G)=\prod_{uv\in E(G)}\frac{\sigma(u)+\sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}}.$$

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The multiplicative augmented status index of a graph G is defined as

$$ASIII(G)=\prod_{uv\in E(G)}\left(\frac{\sigma(u)\sigma(v)}{\sigma(u)+\sigma(v)-2}\right)^3.$$

The multiplicative harmonic status index of a graph G is defined as

$$HSII(G)=\prod_{uv\in E(G)}\frac{2}{\sigma(u)+\sigma(v)}.$$

Recently, some new multiplicative indices were studied, for example, in [12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30. 31, 32]. In this paper, some new multiplicative status indices of complete graphs, wheel graphs friendship graphs are determined.

2. RESULTS FOR COMPLETE GRAPHS

Theorem 1: Let K_n be a complete graph with n vertices and $\frac{n(n-1)}{2}$ edges. Then

(1) $ABCSII(K_n)=\left[\frac{2n-4}{(n-1)^2}\right]^{\frac{1}{4}n(n-1)}.$

(2) $GASII(K_n) = 1.$

(3) $AGSII(K_n) = 1.$

(4) $ASIII(K_n)=\left[\frac{(n-1)^2}{2n-4}\right]^{\frac{3}{2}n(n-1)}.$

(5) $HSII(K_n)=\left(\frac{1}{n-1}\right)^{\frac{1}{2}n(n-1)}.$

Proof: For any vertex u in K_n, $\sigma(u) = n - 1$. Therefore

(1) $ABCSII(K_n)=\prod_{uv\in E(K_n)}\sqrt{\frac{\sigma(u)+\sigma(v)-2}{\sigma(u)\sigma(v)}}=\left[\frac{n-1+n-1-2}{(n-1)(n-1)}\right]^{\frac{1}{2}\times\frac{n(n-1)}{2}}=\left[\frac{2n-4}{(n-1)^2}\right]^{\frac{1}{4}n(n-1)}.$

(2) $GASII(K_n)=\prod_{uv\in E(K_n)}\frac{\sigma(u)+\sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}}=\left(\frac{n-1+n-1}{2\sqrt{(n-1)(n-1)}}\right)^{\frac{n(n-1)}{2}}=1.$

(3) $AGSII(K_n)=\prod_{uv\in E(K_n)}\frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u)+\sigma(v)}=\left(\frac{2\sqrt{(n-1)(n-1)}}{n-1+n-1}\right)^{\frac{n(n-1)}{2}}=1.$

(4) $ASIII(K_n)=\prod_{uv\in E(K_n)}\left(\frac{\sigma(u)\sigma(v)}{\sigma(u)+\sigma(v)-2}\right)^3=\left(\frac{(n-1)(n-1)}{n-1+n-1-2}\right)^{\frac{3}{2}n(n-1)}=\left[\frac{(n-1)^2}{2n-4}\right]^{\frac{3}{2}n(n-1)}$

(5) $HSII(K_n)=\prod_{uv\in E(K_n)}\frac{2}{\sigma(u)+\sigma(v)}=\left(\frac{2}{n-1+n-1}\right)^{\frac{1}{2}n(n-1)}=\left(\frac{1}{n-1}\right)^{\frac{1}{2}n(n-1)}.$

3. RESULTS FOR COMPLETE BIPARTITE GRAPHS

Theorem 2: Let $K_{p,q}$ be a complete bipartite graph with $p+q$ vertices and pq *edges*. Then

(1) $ABCSII(K_{p,q})=\left[\frac{3(p+q)-6}{2(p^2+q^2)-6(p+q)+5pq+4}\right]^{\frac{1}{2}pq}.$

(2) $GASII(K_{p,q})=\left(\frac{2\sqrt{2(p^2+q^2)-6(p+q)+5pq+4}}{3(p+q)-4}\right)^{pq}.$

(3) $AGHII\left(K_{p,q}\right)=\left(\dfrac{3(p+q)-4}{2\sqrt{2\left(p^2+q^2\right)-6(p+q)+5pq+4}}\right).$

(4) $ASIII(K_{p,q})=\left(\dfrac{2\left(p^2+q^2\right)-6(p+q)+5pq+4}{3(p+q)-6}\right)^{3pq}.$

(5) $HSII(K_{p,q})=\left(\dfrac{2}{3(p+q)-4}\right)^{pq}.$

Proof: The vertex set of $K_{p,q}$ can be partitioned into two independent sets V_1 and V_2 such that $u \in V_1$ and $v \in V_2$ for every edge uv in $K_{p,q}$. Thus $d_G(u) = q$, $d_G(v) = p$. Then $\sigma(u) = q + 2(p-1)$ and $\sigma(v) = p+2(q-1)$. Therefore

(1) $$ABCSII\left(K_{p,q}\right)=\sqrt{\frac{\sigma(u)+\sigma(v)-2}{\sigma(u)\sigma(v)}}=\left[\frac{q+2p-2+p+2q-2-2}{(q+2p-2)(p+2q-2)}\right]^{\frac{1}{2}pq}$$

$$=\left[\frac{3(p+q)-6}{2\left(p^2+q^2\right)-6(p+q)+5pq+4}\right]^{\frac{1}{2}pq}.$$

(2) $GASII(K_{p,q})$

$$=\prod_{uv\in E(K_{p,q})}\frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u)+\sigma(v)}$$

$$=\left(\frac{2\sqrt{(q+2p-2)(p+2q-2)}}{q+2p-2+p+2q-2}\right)^{pq}$$

$$=\left(\frac{2\sqrt{2\left(p^2+q^2\right)-6(p+q)+5pq+4}}{3(p+q)-4}\right)^{pq}.$$

(3) $AGSII(K_{p,q})$

$$=\prod_{uv\in E(K_{p,q})}\frac{\sigma(u)+\sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}}$$

$$=\left(\frac{q+2p-2+p+2q-2}{2\sqrt{(q+2p-2)(p+2q-2)}}\right)^{pq}$$

$$=\left(\frac{3(p+q)-4}{2\sqrt{2\left(p^2+q^2\right)-6(p+q)+5pq+4}}\right)^{pq}.$$

(4) $ASIII(K_{p,q})$

$$=\prod_{uv\in E(K_{p,q})}\left(\frac{\sigma(u)\sigma(v)}{\sigma(u)+\sigma(v)-2}\right)^{3}$$

$$=\left(\frac{(q+2p-2)(q+2p-2)}{q+2p-2+p+2q-2-2}\right)^{3pq}$$

$$=\left(\frac{2\left(p^2+q^2\right)-6(p+q)+5pq+4}{3(p+q)-6}\right)^{3pq}.$$

(5) $HSII(K_{p,q})$

$$=\prod_{uv\in E(K_{p,q})}\frac{2}{\sigma(u)+\sigma(v)}=\left(\frac{2}{q+2p-2+p+2q-2}\right)^{pq}$$

$$=\left(\frac{2}{3(p+q)-4}\right)^{pq}.$$

4. RESULTS FOR CYCLES

Theorem 3: Let C_n be a cycle with n vertices and n edges. Then

(1) $ABCSII(C_n) = \left(\frac{8(n^2-4)}{n^4}\right)^{\frac{n}{2}}$, if n is even,

$= \left(\frac{8(n^2-5)}{(n^2-1)^2}\right)^{\frac{n}{2}}$, if n is odd.

(2) $GASII(C_n) = 1$, if n is even,

$= 1$, if n is odd.

(3) $AGSII(C_n) = 1$, if n is even,

$= 1$, if n is odd.

(4) $ASIII(C_n) = \left(\frac{n^4}{8(n^2-4)}\right)^{3n}$, if n is even,

$= \left(\frac{(n^2-1)^2}{8(n^2-5)}\right)^{3n}$, if n is odd.

(5) $HSII(C_n) = \left(\frac{4}{n^2}\right)^{n}$, if n is even,

$= \left(\frac{4}{n^2-1}\right)^{n}$, if n is odd.

Proof:

Case-1: Suppose n is even. Then $\sigma(u) = \frac{n^2}{4}$ for any vertex u in C_n. Thus

(1) $$ABCSII(C_n) = \prod_{uv\in E(C_n)} \sqrt{\frac{\sigma(u)+\sigma(v)-2}{\sigma(u)\sigma(v)}} = \left[\frac{\frac{n^2}{4}+\frac{n^2}{4}-2}{\frac{n^2}{4}\times\frac{n^2}{4}}\right]^{\frac{n}{2}} = \left(\frac{8(n^2-4)}{n^4}\right)^{\frac{n}{2}}.$$

(2) $$GASII(C_n) = \prod_{uv\in E(C_n)} \frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u)+\sigma(v)} = \left(\frac{2\sqrt{\frac{n^2}{4}\times\frac{n^2}{4}}}{\frac{n^2}{4}+\frac{n^2}{4}}\right)^{n} = 1.$$

(3) $$AGSII(C_n) = \prod_{uv\in E(C_n)} \frac{\sigma(u)+\sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}} = \left(\frac{\frac{n^2}{4}+\frac{n^2}{4}}{2\sqrt{\frac{n^2}{4}\times\frac{n^2}{4}}}\right)^{n} = 1.$$

(4) $$ASIII(C_n) = \prod_{uv\in E(C_n)} \left(\frac{\sigma(u)\sigma(v)}{\sigma(u)+\sigma(v)-2}\right)^3 = \left[\frac{\frac{n^2}{4}\times\frac{n^2}{4}}{\frac{n^2}{4}+\frac{n^2}{4}-2}\right]^{3n} = \left(\frac{n^4}{8(n^2-4)}\right)^{3n}.$$

(5) $$HSII(C_n) = \prod_{uv\in E(C_n)} \frac{2}{\sigma(u)+\sigma(v)} = \left(\frac{2}{\frac{n^2}{4}+\frac{n^2}{4}}\right)^{n} = \left(\frac{4}{n^2}\right)^{n}.$$

Case-2: Suppose n is odd. Then $\sigma(u)=\frac{n^2-1}{4}$ for any vertex u in C_n. Therefore

(1) $ABCSII(C_n) = \prod_{uv\in E(C_n)}\sqrt{\frac{\sigma(u)+\sigma(v)-2}{\sigma(u)\sigma(v)}} = \left[\frac{\frac{n^2-1}{4}+\frac{n^2-1}{4}-2}{\frac{n^2-1}{4}\times\frac{n^2-1}{4}}\right]^{\frac{n}{2}} = \left(\frac{8(n^2-5)}{(n^2-1)^2}\right)^{\frac{n}{2}}.$

(2) $GASII(C_n) = \prod_{uv\in E(C_n)}\frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u)+\sigma(v)} = \left(\frac{2\sqrt{\frac{n^2-1}{4}\times\frac{n^2-1}{4}}}{\frac{n^2-1}{4}+\frac{n^2-1}{4}}\right)^n = 1\lim_{x\to\infty}$

(3) $AGSII(C_n) = \prod_{uv\in E(C_n)}\frac{\sigma(u)+\sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}} = \left(\frac{\frac{n^2-1}{4}+\frac{n^2-1}{4}}{2\sqrt{\frac{n^2-1}{4}\times\frac{n^2-1}{4}}}\right)^n = 1$

(4) $ASIII(C_n) = \prod_{uv\in E(C_n)}\left(\frac{\sigma(u)\sigma(v)}{\sigma(u)+\sigma(v)-2}\right)^3 = \left[\frac{\frac{n^2-1}{4}\times\frac{n^2-1}{4}}{\frac{n^2-1}{4}+\frac{n^21}{4}-2}\right]^{3n} = \left(\frac{(n^2-1)^2}{8(n^2-5)}\right)^{3n}.$

(5) $HSII(C_n) = \prod_{uv\in E(C_n)}\frac{2}{\sigma(u)+\sigma(v)} = \left(\frac{2}{\frac{n^2-1}{4}+\frac{n^2-1}{4}}\right)^n = \left(\frac{4}{n^2-1}\right)^n.$

5. RESULT FOR WHEEL GRAPHS

A wheel graph W_n is the join of C_n and K_1. A graph W_n has n+1 vertices and 2n edges. A graph W_n is presented in Figure 1.

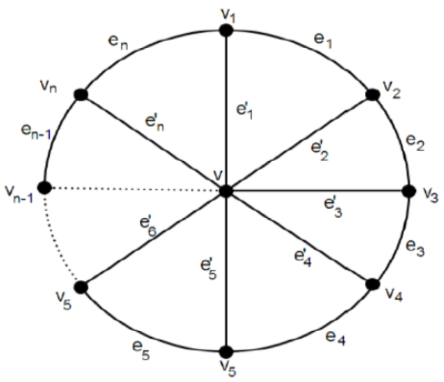

Figure-1: Wheel graph W_n

In W_n, there are two types of edges as given in Table 1.

$d_{W_n}(u), d_{W_n}(v) \setminus uv \in E(W_n)$	(3, 3)	(3, n)
Number of edges	n	n

Table-1: Edge partition of W_n

Therefore , there are two types of status edges in W_n as given in Table 2.

$\sigma(u), \sigma(v) \setminus uv \in E(W_n)$	(2n – 3, 2n – 3)	(n, 2n – 3)
Number of edges	n	n

Table-2: Status edge partition of W_n

Theorem 4: Let W_n be a wheel graph with n+1 vertices and $2n$ edges. Then

(1) $ABCSII(W_n) = \left(\frac{2\sqrt{n-2}}{2n-3}\right)^n \times \left(\frac{3n-5}{n(2n-3)}\right)^{\frac{n}{2}}.$

(2) $GASII(W_n) = \left(\frac{2\sqrt{a^2+b^2}}{3n-3}\right)^n$

(3) $AGSII(W_n) = \left(\frac{3n-3}{2\sqrt{n(2n-3)}}\right)^n$

(4) $ASIII(W_n) = \left(\frac{(2n-3)^2}{4(n-2)}\right)^{3n} \times \left(\frac{n(2n-3)}{3n-5}\right)^{3n}.$

(5) $HSII(W_n) = \left(\frac{1}{2n-3}\right)^n \times \left(\frac{2}{3n-3}\right)^n.$

Proof: By definitions and by using Table 2, we obtain

(1) $$ABCSII(W_n) = \prod_{uv\in E(W_n)} \sqrt{\frac{\sigma(u)+\sigma(v)-2}{\sigma(u)\sigma(v)}} = \left(\frac{2n-3+2n-3-2}{(2n-3)(2n-3)}\right)^{\frac{n}{2}} \times \left(\frac{n+2n-3-2}{n(2n-3)}\right)^{\frac{n}{2}}$$

$$= \left(\frac{2\sqrt{n-2}}{2n-3}\right)^n \times \left(\frac{3n-5}{n(2n-3)}\right)^{\frac{n}{2}}.$$

(2) $$GASII(W_n) = \prod_{uv\in E(W_n)} \frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u)+\sigma(v)} = \left(\frac{2\sqrt{(2n-3)(2n-3)}}{2n-3+2n-3}\right)^n \times \left(\frac{2\sqrt{n(2n-3)}}{n+2n-3}\right)^n$$

$$= \left(\frac{2\sqrt{n(2n-3)}}{3n-3}\right)^n.$$

(3) $$AGSII(W_n) = \prod_{uv\in E(W_n)} \frac{\sigma(u)+\sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}} = \left(\frac{2n-3+2n-3}{2\sqrt{(2n-3)(2n-3)}}\right)^n \times \left(\frac{n+2n-3}{2\sqrt{n(2n-3)}}\right)^n$$

$$= \left(\frac{3n-3}{2\sqrt{n(2n-3)}}\right)^n.$$

(4) $$ASIII(W_n) = \prod_{uv\in E(W_n)} \left(\frac{\sigma(u)\sigma(v)}{\sigma(u)+\sigma(v)-2}\right)^3 = \left(\frac{(2n-3)(2n-3)}{2n-3+2n-3-2}\right)^{3n} \times \left(\frac{n(2n-3)}{n+2n-3-2}\right)^{3n}$$

$$= \left(\frac{(2n-3)^2}{4(n-2)}\right)^{3n} \times \left(\frac{n(2n-3)}{3n-5}\right)^{3n}.$$

(5) $$HSII(W_n) = \prod_{uv\in E(W_n)} \frac{2}{\sigma(u)+\sigma(v)} = \left(\frac{2}{2n-3+2n-3}\right)^n \times \left(\frac{2}{n+2n-3}\right)^n$$

$$= \left(\frac{1}{2n-3}\right)^n \times \left(\frac{2}{3n-3}\right)^n.$$

4. RESULTS FOR FRIENDSHIP GRAPHS

A friendship graph F_n is the graph obtained by taken $n \geq 2$ copies of C_3 with vertex in common. A graph F_4 is shown in Figure 2.

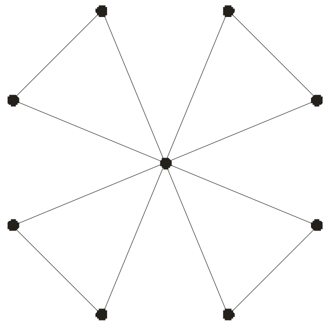

Figure-2: Friendship graph F_4

A graph F_n has $2n+1$ vertices and $3n$ edges. In F_n, there are two types of edges as follows:

$E_1 = \{uv \in (F_n) \mid d_{F_n}(u) = d_{F_n}(v) = 2\}$, $\qquad |E_1| = n$.

$E_2 = \{uv \in (F_n) \mid d_{F_n}(u) = 2, d_{F_n}(v) = 2n\}$, $\qquad |E_1| = 2n$.

Therefore, there are two types of status edges in F_n as given in Table 3.

$\sigma(u), \sigma(v) \setminus uv \in E(F_n)$	$(4n-2, 4n-2)$	$(2n, 4n-2)$
Number of edges	n	$2n$

Table-3: Status edge partition of F_n

Theorem 5: Let F_n be a friendship graph with $2n+1$ vertices and $3n$ edges. Then

(1) $ABCSII(F_n) = \left(\dfrac{8n-6}{(4n-2)^2}\right)^{\frac{n}{2}} \times \left(\dfrac{3n-2}{n(4n-2)}\right)^n.$

(2) $GASII(F_n) = \left(\dfrac{\sqrt{2n(4n-2)}}{3n-1}\right)^{2n}.$

(3) $AGSII(F_n) = \left(\dfrac{3n-1}{\sqrt{2n(4n-2)}}\right)^{2n}.$

(4) $ASIII(F_n) = \left(\dfrac{(4n-2)^2}{8n-6}\right)^{3n} \times \left(\dfrac{n(4n-2)}{3n-2}\right)^{6n}.$

(5) $HSII(F_n) = \left(\dfrac{1}{4n-2}\right)^{n} \times \left(\dfrac{1}{3n-1}\right)^{2n}.$

Proof: by using definitions and Table 3, we deduce

(1) $$ABCSII(F_n) = \prod_{uv\in E(F_n)} \sqrt{\frac{\sigma(u)+\sigma(v)-2}{\sigma(u)\sigma(v)}} = \left(\frac{4n-2+4n-2-2}{(4n-2)(4n-2)}\right)^{\frac{1}{2}n} \times \left(\frac{2n+4n-2-2}{2n(4n-2)}\right)^{\frac{1}{2}\times 2n}$$
$$= \left(\frac{8n-6}{(4n-2)^2}\right)^{\frac{n}{2}} \times \left(\frac{3n-2}{n(4n-2)}\right)^n.$$

(2) $$GASII(F_n) = \prod_{uv\in E(F_n)} \frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u)+\sigma(v)} = \left(\frac{2\sqrt{(4n-2)(4n-2)}}{4n-2+4n-2}\right)^n \times \left(\frac{2\sqrt{2n(4n-2)}}{2n+4n-2}\right)^{2n}$$
$$= \left(\frac{\sqrt{2n(4n-2)}}{3n-1}\right)^{2n}.$$

(3) $$AGSII(F_n) = \prod_{uv\in E(F_n)} \frac{\sigma(u)+\sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}} = \left(\frac{4n-2+4n-2}{2\sqrt{(4n-2)(4n-2)}}\right)^n \times \left(\frac{2n+4n-2}{2\sqrt{2n(4n-2)}}\right)^{2n}$$
$$= \left(\frac{3n-1}{\sqrt{2n(4n-2)}}\right)^{2n}.$$

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(4) $ASIII\,(F_n)$ $$= \prod_{uv\in E(F_n)} \left(\frac{\sigma(u)\sigma(v)}{\sigma(u)+\sigma(v)-2}\right)^3 = \left(\frac{(4n-2)(4n-2)}{4n-2+4n-2-2}\right)^{3n} \times \left(\frac{2n(4n-2)}{2n+4n-2-2}\right)^{6n}$$

$$= \left(\frac{(4n-2)^2}{8n-6}\right)^{3n} \times \left(\frac{n(4n-2)}{3n-2}\right)^{6n}.$$

(5) $HSII\,(F_n)$ $$= \prod_{uv\in E(F_n)} \frac{2}{\sigma(u)+\sigma(v)} = \left(\frac{2}{4n-2+4n-2}\right)^{n} \times \left(\frac{2}{2n+4n-2}\right)^{2n}$$

$$= \left(\frac{1}{4n-2}\right)^{n} \times \left(\frac{1}{3n-1}\right)^{2n}.$$

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