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Solar Energy Conversion into Electrical Energy with Alizarine Red S Photosensitizer in Photo Galvanic Cell System

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ABSTRACT
Solar radiation is radiant energy obtainable to us from the sun. It is a major source of renewable energy sources. Solar energy, harnessed through photovoltaic cells, has been significant growth due to advancements in technology. Photovoltaic cells while offering numerous advantages as renewable energy source also have disadvantages like high initial costs and energy storage challenges. The Photogalvanic cell overcomes the shortcomings of the PV cell. Although the conversion efficiency of Photogalvanic cell is low its inherent storage capacity makes it important. As technology continues to evolve, limitations of photogalvanic cell may be mitigate or overcome, further enhancing the appeal and viability of photogalvanic cells as a renewable energy solution.
The energy of solar radiation can be easily and directly convert into electrical energy through the photoelectrochemical reaction. Therefore a photogalvanic cell device has been used for this purpose. A photoelectrochemical system containing of Alizarin red S as photosensitizer, Galactose as reductant, NaOH as alkaline medium and Brij 35 as surfactant has been studied with the encouraging preliminary results. The short current, maxium current, photo potential and storage capacity for preliminary developed photoelectochemical device are reported as 12µA, 67µ A , 185mV and 24 min., respectively.
Keywords: Photogalvanic cell; Solar Radiation, Alizarine red S , Galactose , Brij 35.

I. INTRODUCTION

Solar energy can be converted into electrical energy by means of photogalvanic conversion. The photogalvanic effect was firstly observed by Rideal and Williams [1], later systematically investigated by Rabinowitch [2-3]. Lliterature study [8-19] reveals that various effective energy storing photochemical systems made of photosensitizer (dye) and reductant have been experimentally studied, yet there is no photochemical reaction has obtained which can produce an efficient cell with effective conversion efficiency and valuable storage capacity. In present work, the photogalvanic effect was studied in**,** Alizarine red S -Galactose (dye - reductant system) in presense of non-ionic surfactant Brij 35.

II. EXPERIMENTAL

Alizarine red S, , Galactose , Brij 35 and Sodium hydroxide were used in the present work. All the stock solutions of Alizarine red S (1×10^{-3} M), Galactose (1×10^{-2} M) and Brij 35 (1×10^{-2} M) were prepared in double distilled water. 1N solution of NaOH was freshly prepared by standardization with1 N oxalic acid using phenolphthalein indicator for every cell set-up. Dye solution was stored in darkened container to protect it from light exposure. The mixture of appropriate volume of dye, reductant, surfactant and NaOH(1N) was made up to 25.0 ml with double distilled water and taken into blackened H-shaped glass container. A platinum foil electrode of $1 cm^2$ electrode area was immersed into one limb of container which contained a transparent window through which electrode was exposed to light and a saturated calomel electrode (SCE) was immersed into another one. A water filter was used between the cell and light source (200W tungsten lamp) to prevent the reactive system from thermal radiation. The photopotential and photocurrent produced by developed photogalvanic cells were

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measured by digital pH meter and microammeter, respectively.

III. RESULTS AND DISCUSSION

3.1 study of potential with time

Prepared photogalvanic cell by filling reaction mixture of Alizarine red S (dye), Galactose (reductant) and Brij 35 (nonionic surfactant) in cell container is firstly placed in the dark until it attain a stable potential. Then platinum foil electrode is exposed to the light of intensity 10.4 $mWcm^{-2}$. The potential changes with time and attains a maximum constant value, then the illumination is stopped, the direction of change in potential becomes reversed and it obtained again stable dark potential value.

Variation of Potential with Time
[Alizarine red S] = 2.5×10^{-4} M pH = 12.78
[Galactose] = 2.0×10^{-3} M
Light Intensity = 10.4 $mWcm^{-2}$
[Brij 35] = 8.0×10^{-4} M
Temperature = 303 K

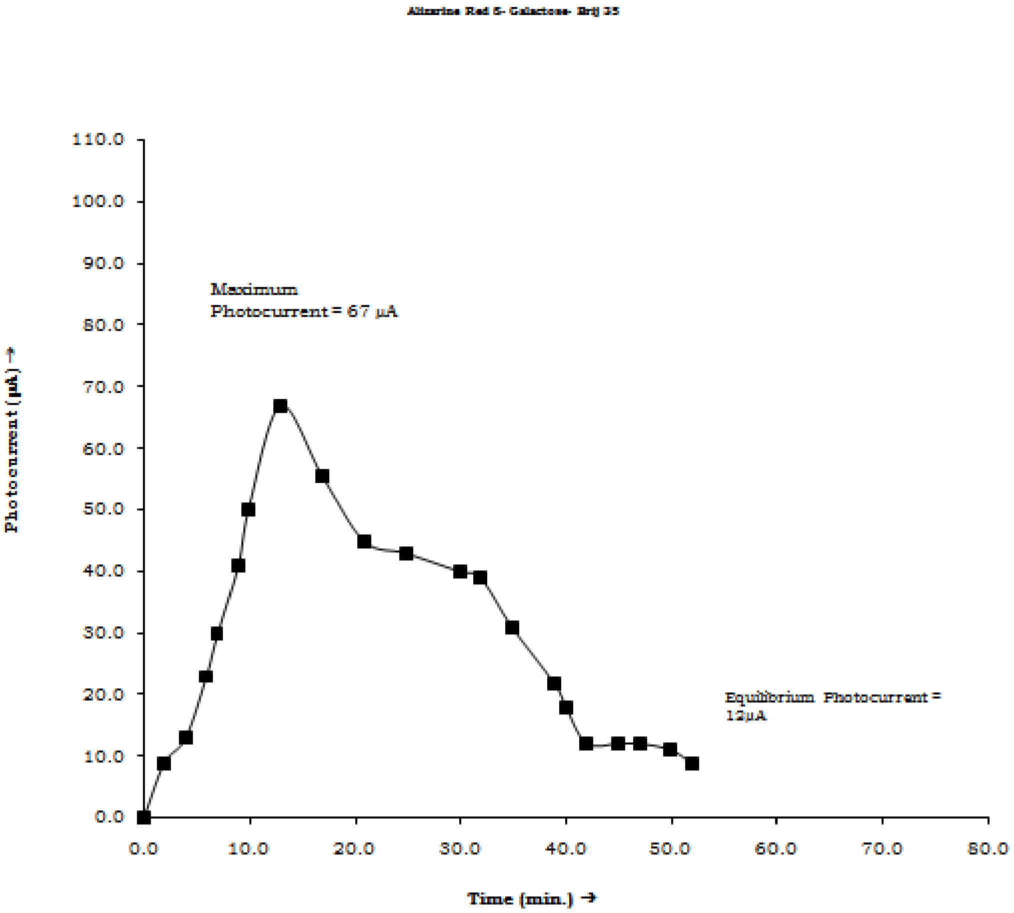

Fig. 1 VARIATION OF PHOTOCURRENT WITH TIME

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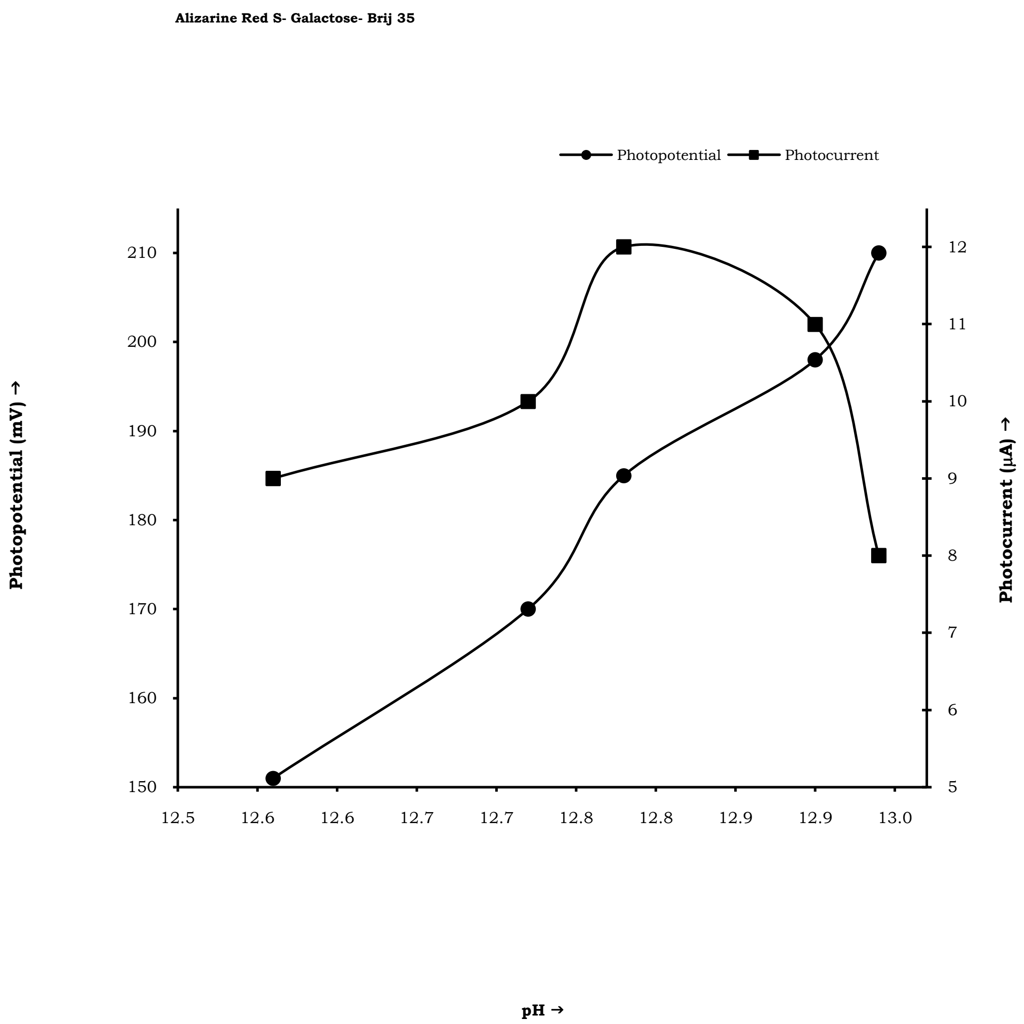

Fig. 2 VARIATION OF PHOTOPOTENTIAL AND PHOTOCURRENT WITH pH

3.2 study of current with time

On illumination, photocurrent of Alizarine red S – Galactose – Brij 35 system increases rapidly and it reaches at a maximum value (i_{max}) within few minutes. Then the photocurrent decreases gradually with the period of illumination finally reaching a constant value at equilibrium (i_{eq}). The photocurrent decreases continuously when illumination stopped. (Table 1 and Figure 1)

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Table 1

Variation of Current with Time
[Alizarine red S] = 2.5 x 10^{-4} M pH = 12.78
[Galactose] = 2.0 x 10^{-3} M Light Intensity = 10.4 $mWcm^{-2}$
[Brij 35] = 8 x 10^{-4} M Temperature = 303 K

Time (minutes)	Photocurrent (μA)
0.0	00.0
02.0	09.0
04.0	13.0
06.0	23.0
07.0	30.0
09.0	41.0
10.0	50.0
13.0	67.0
17.0	55.5
21.0	45.0
25.0	43.0
30.0	40.0
32.0	39.5
35.0	31.0
39.0	22.0
40.0	18.0
42.0	12.0
45.0	12.0
47.0	**12.0 (Illumination Stopped)**
50.0	11.0
52.0	09.0

3.3 Effect of variation of pH of the systems

Electrical output of photogalvanic cell is sensitive towards the pH value of the cell solution. The photocurrent increases with the increase in pH, reaches maximum at particular pH value (It may be due to better availability of reductant's donor form at that pH value) and then decreases with further increase in pH. (Table 2 and Figure 2)

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Table 2

Effect of Variation of pH
[Alizarine red S] = 2.5 x 10^{-4} M   Light Intensity = 10.4 $mWcm^{-2}$
[Galactose] = 2.0 x 10^{-3} M
Temperature = 303 K
[Brij 35] = 8 x 10^{-4} M

pH	Photopotential (mV)	Photocurrent (µA)	Power (µW)
12.56	151.0	09.0	1.359
12.72	170.0	10.0	1.700
12.78	185.0	12.0	2.220
12.90	198.0	11.0	2.178
12.94	210.0	08.0	1.680

3.4 Effect of variation of concentration of dye

As the dye solution in the photogalvanic cell absorbs the light radiation and initiates the cell reaction, its concentration affects the cell output. Electrical photocurrent output increases with dye concentration, reaches maximum value at [Alizarine red S] = 2.5 x 10^{-4} M and decreases with further increase in concentration of dye. Results of experimental observation with dye concentration variations are given in Table 3 and Figure 3.

Table 3

Effect of Variation of Alizarine red S Concentration
[Galactose = 2.0 x 10^{-3} M   pH = 12.78
[Brij 35] = 8 x 10^{-4} M
Light Intensity = 10.4 $mWcm^{-2}$
Temperature = 303 K

Concn. of Alizarine red S (x 10^{-4} M)	Photopotential (mV)	Photocurrent (µA)	Power (µW)
1.5	155.0	6.0	0.930
2.0	170.0	9.0	1.530
2.5	185.0	12.0	2.220
2.8	193.0	10.0	1.930
3.0	209.0	7.0	1.463

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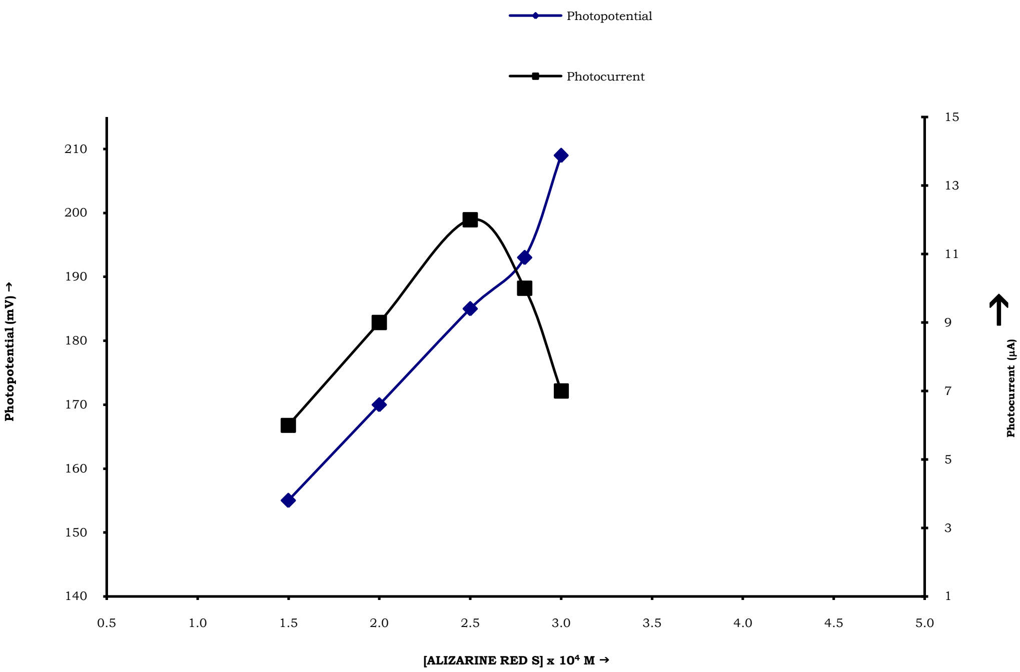

Fig. 3 VARIATION OF PHOTOPOTENTIAL AND PHOTOCURRENT WITH ALIZARINE RED S CONCENTRATION

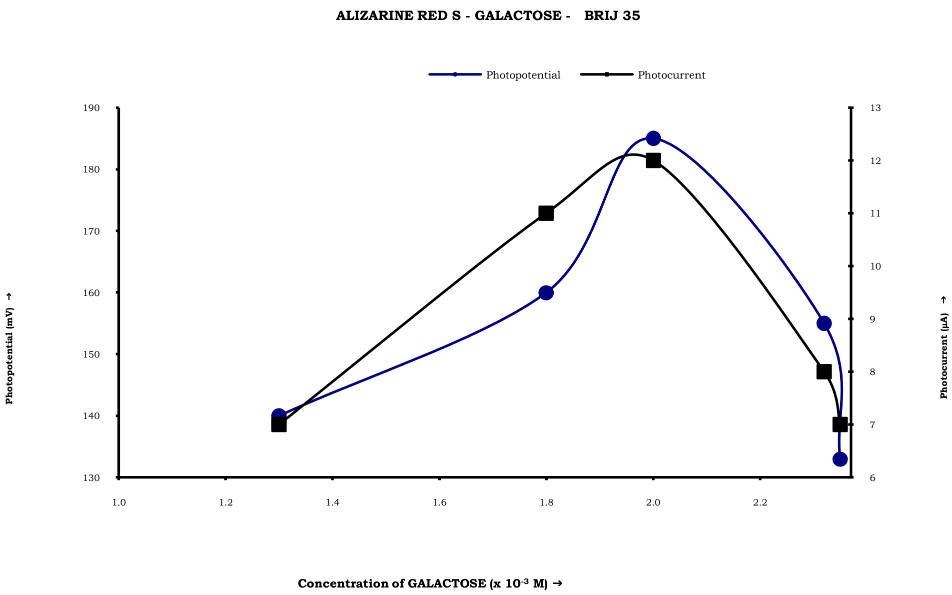

Fig. 4 **VARIATION OF PHOTOPOTENTIAL AND PHOTOCURRENT WITH GALACTOSE CONCENTRATION**

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3.5 Effect of variation of concentration of reductant

Variation of Galactose (reductant) concentration affects the cell photocurrent output in the similar manner as dye concentration variation due to photogalvanic behaviour of the system is result of dye-reductant interaction in solution under light condition.

Experimental results show that electrical output increases with increase in reductant concentration and obtains a maximum value; on further increase in reductant concentration, electrical output decreases (Table 4 and Figure 4)

Table 4

Effect of Variation of Galactose Concentration
[Alizarine red S] = 2.5 x 10^{-4} M pH = 12.78
[Brij 35] = 8 x 10^{-4} M
Light Intensity = 10.4 $mWcm^{-2}$
Temperature = 303 K

Concn. of Galactose (x 10^{-3} M)	Photopotential (mV)	Photocurrent (μA)	Power (μW)
1.3	140.0	7.0	1.218
1.8	160.0	11.0	1.760
2.0	185.0	12.0	2.220
2.32	155.0	8.0	1.240
2.35	133.0	7.0	0.931

3.6 Effect of variation of concentration of surfactant

The concentration of surfactant (Brij 35) also affects the photocurrent and photopotential of the cell. It is observed that electrical output of the cell increases with the concentration of surfactant and attains a maximum value. A further increase in the concentration of Brij 35 results into a fall in electrical output (mV and μA)(Table 5).

Table 5

Effect of Variation of Brij 35 Concentration
[Alizarine red S] = 2.5 x 10^{-4} M pH = 12.78
[Galactose] = 2.0 x 10^{-3} M
Light Intensity = 10.4 $mWcm^{-2}$
Temperature = 303 K

Concn. of Brij 35 (x 10^{-3}M)	Photopotential (mV)	Photocurrent (μA)	Power (μW)
7.30	153.0	5.0	0.765
7.82	172.0	9.0	1.548
8.0	185.0	12.0	2.220
8.5	191.0	7.0	1.337
9.0	210.0	3.0	0.630

3.7 Effect of variation of diffusion length

The platinum foil electrode and saturated calomel electrode (SCE) are immersed in two limbs of H-shaped cell solution container. The distance between these two electrodes is called diffusion length. Effect of diffusion length on the current parameters of the cell ($i_{max,}$ i_{eq} and initial rate of generation of photocurrent) is observed by using different dimension H-shaped container. i_{max} and rate of initial generation of current increases with diffusion length but i_{eq} shows a negligibly small decreasing behaviour.

3.8 Effect of variation of electrode area

The current parameters of the cell (i_{max} and i_{eq}) are influenced by the variation of electrode area. It is observed that with the increase in the electrode area maximum photocurrent (i_{max}) and equilibrium photocurrent (i_{eq}) both are affected but in reverse manner. With the increase in electrode area, the value of i_{max} increases whereas i_{eq} decreases.

3.9 Current - voltage characteristics of the cells

Under the continuous illumination of light, open circuit voltage (V_{oc}) and short circuit current (i_{sc}) of the cells were obtained by a digital pH meter (keeping the circuit open) and a microammeter (keeping the circuit close), respectively. The current and potential values in between these two extreme values are recorded (Table 6) with the help of a variable resistance (log 470K), connected in the circuit of microammeter, through which an external load was applied.

Table 6

Current and Power Output Characteristics of the Cell

[Alizarine red S] = 2.5 x 10^{-4} M pH = 12.78
[Galactose] = 2.0 x 10^{-3} M
Light Intensity = 10.6 mWcm^{-2}
[Brij 35] = 8 x 10^{-4} M
Temperature = 311 K

Potential (mV)	Photocurrent (µA)	Power (µW)	Fill factor (F_f)
432.0	0.0	0.0	
430.0	2.0	0.860	
380.0	3.0	1.140	
375.0	4.0	1.500	
362.0	5.0	1.810	
310.0	6.0	1.860	
272.0	7.0	1.904	
251.0	8.0	2.008	
228.0	9.0	2.052	0.3958
180.0	10.0	1.800	
102.0	11.0	1.122	
80.0	12.0	0.960	

3.10 Storage capacity, Conversion efficiency and Fill factor of the cell

By i- V characteristics, a point was obtained where product of current and potential found maximum called power point. Performance of the cell i.e., storage capacity denoted by $t_{1/2}$ were observed 24.0 minutes by keeping the cells at power point stage in dark and noted down the time required in fall of power output to its half value.

The conversion efficiency and fill factors of the cell (with platinum foil electrode of 1 cm^2 electrode area) were determined 0.01973% and 0.3958, respectively, with Alizarine red S system by following formula:

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$$\text{Conversion efficiency} = \frac{V_{pp} \times i_{pp}}{10.4\ \text{mW/cm}^2} \times 100\%$$

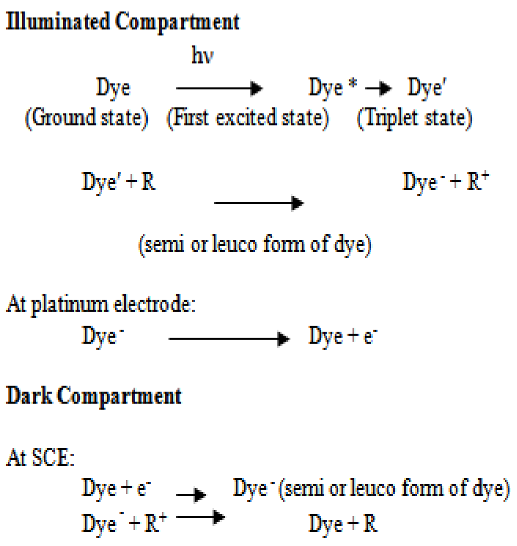
$$\text{Fill factor} = \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{sc}}$$

where V_{pp} and i_{pp} represents the value of potential and current at power point, respectively.

IV. MECHANISM

According to photochemistry of dyes in solution, chemically reactive species are the triplet state of dye. Specially, when certain dyes are excited by light in the presence of electron donating substances, the dyes are rapidly changed into colourless ("reduced") form. The dye is now a powerful reducing agent and will donate electron to other substances, with dye being returned to its oxidized state [20].

On the basis of above studies, a tentative mechanism for the cell reaction has been proposed as follows:



Where Dye, Dye^-, R and R^+ represents the Dye, reduced form of dye, reductant and oxidized form of reductant, respectively.

V. CONCLUSION

The new photogalvanic system, Alizarine red S- Galactose- Brij 35 in photogalvanic cell has been studied and analyzed. On the preliminary electrical parameter ground such as short circuit current, maximum current & photopotential, it found not suitable but it appeared in this preliminary experiments efficient from storage capacity & fill factor point of view.

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