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DESIGNING AND EVALUATING DRIP IRRIGATION UNIT BY COMPUTER AID

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ABSTRACT

To design and evaluate a drip irrigation unit, by an accurate, simple and quick method, a computer program called **OSAMA (2)** was developed. **OSAMA (2)** calculates the maximum lengths of lateral and manifold according to the following limitation: 1) Water velocity in the lateral and the manifold should not exceed, 1.0 and 1.5m s^{-1} respectively. 2) Friction losses in the lateral and manifold should not exceed 55 and 45 % of the total allowable losses, respectively. 3) Flow rate in the inlet of the unit should not exceed 12.5 and 25 m^3/h for single and double lateral unit, respectively. Mathematical comparison was used to prove the validity of **OSAMA (2)** program, the lateral lengths calculated by **OSAMA (2)** program and the corresponding ones calculated by ***Hanafy (1990)*** were closed. Field experiment was conducted to prove the validity of **OSAMA (2)** program. Two different drippers were chosen and calibrated. **OSAMA (2)** program was fed by their characteristic values of (X) and (K). **OSAMA (2)** program outputs were the maximum lateral length and dripper discharge rate at different flow variations. Correlation coefficient (r) between drippers discharge rates of both field lateral and output of **OSAMA (2)** program were (0.9678) and (0.9580). The input data of **OSAMA (2)** program were dripper characteristic (x and k) type of connection (on and in line), type of barb, lateral and manifold diameters distances between drippers, flow variation and type of unit (single or double). The output data of **OSAMA (2)** program were the maximum lengths, water velocity, friction losses for lateral and manifold and emission uniformity of the unit. While in the case of evaluating a field unit, the output data were compared to the characteristics of the field unit and the ones calculated by **OSAMA (2)**, which must be of values greater than field unit.

1. INTRODUCTION

Drip irrigation system design can be made by designing lateral line and manifold separately, or designing a unit which combines lateral lines and manifold together. It is important to analyze the hydraulics of irrigation system by considering complete drip irrigation unit. A drip by drip (DBD)

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analysis is one of methods used to analyze the hydraulics of drip irrigation unit of drip irrigation system *(Meshket and Warner, 1985; Karmeli et al. 1985; Pitts et al., 1986 and Sharaf 1996).*
Ahmed (1997) reported that the main problem in irrigation network planning is that there are no hard-fast scientific rules to depend on. Therefore, planning varies from one designer to another.

One of the most important advantages of the computer modeling, is the ability of analyzing interlaced or overlapping variables. In other words, if the change of one or more of the independent variables causes changing in other independent variables, and so on, this system, hence, is a complex system. Only computer modeling can trace these hundreds of operation and calculations till iteration steps in a specific condition. However, computer modeling is ideal for irrigation system analysis and design. And he added that the computer-aided design is necessary for accurate and quick design. So, bearing in mind the large number of alternatives under evaluation to select the optimal design, and the hardness of assessing each alternative. Hence, computer modeling must be used in this engineering process ***(El-Nesr 1999).***

The present study aimed to develop a computer model ***OSAMA*** **(*2*)** to optimize the design of drip irrigation unit and testing the validity of unit of drip irrigation network existing in the field.

2. THEORETICAL DEVELOPMENT

OSAMA (2) program calculates the specification of the maximum drip irrigation unit. This unit satisfies all boundary conditions such as allowable head losses, water velocity, in both lateral and manifold, and total water discharge delivered into the unit.

1.Design of lateral line:
There are many steps to design the maximum lateral length. These steps were:

A) Determine the allowable head losses in the lateral as 55 % of the total allowable head losses (TAHL) as recommended by (*Karmeli and Keller, 1975).*

b) The water velocity in the lateral not exceed 1 m/s as recommended by *(Keller and Bliesner, 1990).*

c) Calculate of the dripper connection losses:
The losses were calculated for three different on- line connection sizes: large,
medium and small connections, and one in-line connection.
According to *(Montalvo, 1983)* the equivalent length *(fe)* was as follow:

On line connection sizes:

Large size $$fe = \frac{23.04}{Dl^{1.84}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Medium size $$fe = \frac{18.91}{Dl^{1.87}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Small size $$fe = \frac{14.38}{Dl^{1.89}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where:

fe is the equivalent length, m ;
Dl - inside diameter, mm.

In line connection: $$fe = 0.23 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

The equivalent total length (Le) of the line in meter, could be expressed as proposed by ***(De Paco , 1985).***

$$Le = \frac{Se + fe}{Se} \times Ll = a \times Ll \ldots\ldots\ldots\ldots(5)$$

Where:

a is the coefficient represents minor head losses produced by dripper connections in the lateral;
Ll - lateral length, m;
Se - distance between drippers, m.

d) Estimation of the friction losses along the lateral:

To estimate the friction losses along the lateral, dripper by dripper technique was used according to ***(Karmeli et al., 1985) and (Sharaf, 1996).***

The optimum pressure head, lateral's diameter and length, dripper discharge rate and number of drippers were determined as follow:

$$Ql = \sum_{i=1}^{n} qe_{(i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$hfl_{(i)} = K\left(\frac{Ql}{3600 \times C}\right)^{1.852}\left(\frac{a \times Se}{Dl^{4.875}}\right)\ldots(7)$$

$$Hl_{(i+1)} = H_1 + \sum_{i=1}^{n} hfl_{(i)} \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$$Hl_{(i+1)} < \Delta Hl + H_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

$$V = \frac{40 \times Ql}{3.14 \times 36 \times Dl^2} \le 1 \ldots\ldots\ldots\ldots\ldots(10)$$

$$qe_{(i+1)} = Ke\left(Hl_{(i+1)}\right)^{x} \ldots\ldots\ldots\ldots\ldots\ldots(11)$$

$$Ll = \sum_{i=1}^{n} Se \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

Where:

Ql is the lateral flow rate, L/h;
qe -dripper flow rate, L/h;
hfl - friction losses, m;
C -Hazen-Williams roughness coefficient for pipe wall 150 according to ***(Keller and Bliesner, 1990);***
Hl - pressure head, m;
ΔHl - allowable head losses in the lateral, m;
V - water velocity , m/s;
Ke - drip constant ;
X - drip flow exponent;
H1 - pressure head at the last dripper, m; and
K - conversion constant, ($K= 1.212*10^{12}$).

2.Design of manifold line:

The design of manifold is identical to the design of a lateral, the only differences being that the outlets along the manifold are the laterals instead of drippers. The design manifolds procedure as:

a) The allowable head losses in the manifold was considered as 45 % from total allowable head losses (TAHL) as recommended by ***(Karmeli and Keller, 1975).***

b) **The water velocity in the manifold** should not exceed 1.5 m/s as recommended by ***(Keller and Bliesner, 1990).***

c) **The water discharge rate** should not exceed 25 m^3/h for double laterals unit (UDL) (where laterals are in north and south direction of manifold) and should not exceed 12.5 m^3/h for single lateral unit (USL) (where laterals are in one side direction of manifold).

d) **Calculation of the fitting losses:**

Different types of fittings (tees, elbows, valves, etc.) are located at several points along the manifold line. Consequently, corresponding head losses should be taken into account when designing a manifold line.

Those head losses could be calculated from the following equation of ***(Keller and Bliesner, 1990).***

$$hf = K_f \frac{V^2}{2g} \text{.......... ....}(13)$$

Where:

hf is the friction- head loss due to pipe fitting, m;
K_f - resistance coefficient for fitting or valve;
$V^2/2g$ - velocity head for a given discharge through pipe or fitting diameter, m;
g - gravitational acceleration , 9.81 m s^{-2}.

e) **Estimation of the friction losses along the manifold line:**

To estimate the friction losses along the manifold line, the same steps of lateral design according to ***(Karmeli et al., 1985)*** were used.

3. RESULTS AND DISCUSSION

Validity of **Osama (2)** program was proved through a mathematical comparison and field experiment.

1. Mathematical comparison:

Mathematical comparison used to prove the validity of Osama (2) program. Dripper characteristics and lateral diameter of ***Hanafy (1990)*** were fed to Osama (2) program as input data. The output data of Osama (2) program were compared with the results of ***Hanafy (1990).*** Table (1) shows the lateral lengths calculated by dripper, respectivly. This result proves the validty of Osama (2) program in the calculation of lateral length.

Table (1): Lateral lengths for three different diameters, lateral discharge exponent, flow variation and dripper flow rates with middle barb and dripper spacing of 0.5 m.

Lateral diameter, mm	Discharge Exponent (x)	Flow variation, %	Dripper Flow rate, L/h	Lateral length, m	
				H-C*	O-2P**
16	0.5	5	4	34	35
			2	53	55
		10	4	45	45
			2	71	71
	1	5	4	26	27.5
			2	41	43
		10	4	34	35
			2	53	54.5
18	0.5	5	4	49	48
			2	77	75
		10	4	64	61.5
			2	102	96.5
	1	5	4	42	40
			2	59	58.5
		10	4	49	47.5
			2	77	74.5
20	0.5	5	4	58	56
			2	92	88
		10	4	77	74
			2	121	114
	1	5	4	44	43.5
			2	70	68.5
		10	4	58	55.5
			2	92	87

***H-C**: Hanafy calculation ****O-2P**: Osama (2) program output.

Osama (2) program and the corresponding ones calculated by ***Hanafy (1990)*** at lateral diameters of 16, 18 and 20 mm, discharge exponents of 0.5 and 1.0, flow variations of 5% and 10% , dripper discharge rates 2 and 4 L/h and dripper spacing of 0.5 m.
Table (1) it could be noticed that lateral lengths resulted from Osama (2) program were close to the corresponding ones resulted by ***Hanafy (1990).*** This result proves the validity of Osama (2) program in calculating the maximum allowable lateral length.

2.Field experiment:

Two different drippers were used in this part. The two drippers were calibrated to find out their characteristics values of discharge exponent (X) and proportional coefficient (K). The dripper equations were:

$$\mathbf{q = 1.1017\ h^{0.5372} \quad and \quad q = 0.6056\ h^{0.61}}$$

The input data of Osama (2) program:

	Dripper (1)	Dripper (2)
Dripper discharge, L/h	3.8	2.5
Discharge exponent, (X)	0.5372	0.61
Proportional coefficient, (K)	1.1017	0.6056
Lateral diameter , mm	16	20
Distances between drippers, m	0.50	0.80

Flow variation ranged from (1 % to 10 %) as 1 % step, was choosing for each run.

The output of Osama (2) program:

The output of Osama (2) program was lateral length, inlet lateral pressure head and dripper discharge at inlet point of lateral at different flow variation steps for each drippers. The output data of Osama (2) program for the two drippers were summarized as shown in Table (2).
Correlation coefficient (r) between drippers discharge rates of both field lateral and output of Osama (2) program were shown on Figs (1 and 2). The correlation coefficient (r) was (0.9678) and (0.9580) for the first and second drippers, respectively.This result proves the validity of Osama (2) program in the calculation of lateral length.

Table (2): The lateral length, inlet pressure head and dripper discharge rate at the inlet of lateral at different flow variations as resulted by Osama (2) for the two drippers.

Flow variation, %	Lateral length, m		Inlet pressure, m		Dripper discharge, L/h	
	*$qe_{(3.8)}$	**$qe_{(2.5)}$	$qe_{(3.8)}$	$qe_{(2.5)}$	$qe_{(3.8)}$	$qe_{(2.5)}$
1	20.0	46.4	10.11	10.20	3.818	2.498
2	25.0	52.8	10.21	10.30	3.838	2.511
3	29.0	58.4	10.32	10.40	3.860	2.526
4	32.0	62.4	10.43	10.48	3.881	2.539
5	34.5	66.4	10.53	10.57	3.902	2.552
6	36.5	70.4	10.62	10.68	3.921	2.568
7	38.5	73.6	10.73	10.77	3.941	2.582
8	40.5	76.8	10.84	10.87	3.964	2.596
9	42.5	79.2	10.97	10.95	3.989	2.608
10	44.0	82.4	11.07	11.07	4.009	2.625

* $qe_{(3.8)}$= dripper discharge rate (3.8 L/h)

** $qe_{(2.5)}$= dripper discharge rate (2.5 L/h)

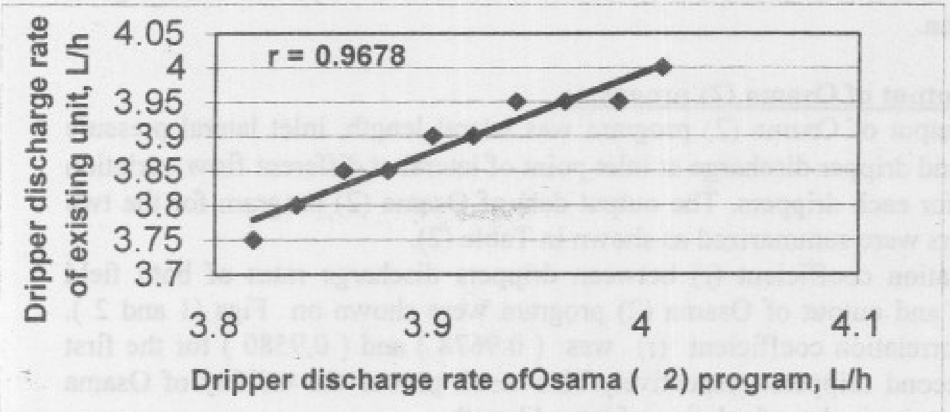

Fig. (1): Correlation coefficient (r) between dripper discharge rate of both field lateral and output of Osama (2) program for first dripper (3. 8L/h).

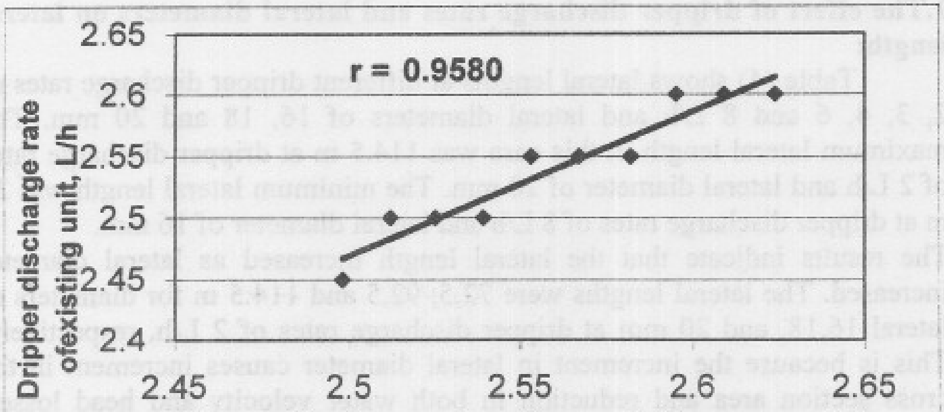

Fig. (2): Correlation coefficient (r) between dripper discharge rate of both field lateral and output of Osama (2) program for second dripper (2.5 L/h).

Studies on drip irrigation network designed by Osama (2) program:

To carry out that study, Osama (2) program was fed by drippers characteristics shown in Table (3), at lateral diameters of 16, 18 and 20 mm, manifold diameters of 50, 63, 75 and 90 mm, individually.

From Osama (2) program output results, the following studies were carried out:

- The effect of dripper discharge rates and lateral diameters on lateral length.
- The effect of manifold diameter on its length.
- The effect of dripper discharge rate on the area of single and double lateral unit.

Table (3): Some drippers' characteristics.

Dripper Discharge (q_e), L/h	Head Operation m	proportion factor (K)	Discharge exponent (x)	Coeff. of variation (CV)	barb diameter mm	Connection Type
2	10.000	0.6325	0.500	0.030	3.8	On- line
3	11.763	0.6428	0.625	0.031	3.8	On-line
4	10.000	1.2649	0.500	0.027	5.0	On-line
6	11.073	2.3378	0.392	0.020	5.0	On-line
8	10.000	2.5298	0.500	0.030	5.0	On-line

1.The effect of dripper discharge rates and lateral diameters on lateral length:

Table (4) shows lateral lengths at different dripper discharge rates of 2, 3, 4, 6 and 8 L/h and lateral diameters of 16, 18 and 20 mm. The maximum lateral length in this case was 114.5 m at dripper discharge rates of 2 L/h and lateral diameter of 20 mm. The minimum lateral length was 29 m at dripper discharge rates of 8 L/h and lateral diameter of 16 mm.

The results indicate that the lateral length increased as lateral diameter increased. The lateral lengths were 72.5, 92.5 and 114.5 m for diameters of lateral 16,18, and 20 mm at dripper discharge rates of 2 L/h, respectively. This is because the increment in lateral diameter causes increment in the cross section area and reduction in both water velocity and head losses, therefore it permits more water flow in the lateral. So, it allows longer lateral length.

Table (4) shows that lateral length decreased as dripper discharge rate increased. Lateral lengths were 72.5, 54, 45,39.5 and 29 m for dripper discharge rates of 2,3,4,6,and 8 L/h at lateral diameter of 16 mm, respectively. This is because water flow in lateral was limited by both water velocity (not exceed 1 m/s) and allowable friction losses. Increasing of dripper discharge rate will increase water velocity and friction losses. So, it will decrease lateral length and vice versa.

Table (4): Lateral lengths at different dripper discharge rates and lateral diameters.

Lateral diameter, mm	Dripper discharge rates, L /h				
	2	3	4	6	8
16	72.5	54.0	45.0	39.5	29.0
18	92.5	69.0	58.0	50.5	37.0
20	114.5	85.5	72.0	63.0	46.0

2.The effect of manifold diameter on its length:

Table (5) shows one and telescopic diameter manifold lengths of single and double lateral units at different manifold diameters of 50, 63, 75, and 90 mm. It also shows lateral diameter of 16mm and dripper discharge rate 3 L/h.

For single lateral units, the length of manifold increased as its diameter increased for one diameter manifold till it reached a constant length (68 m). This constant length was due to the quantity of water delivered into that manifold would not exceed boundary limit of 12.5 m^3/h for single units.

For double units, the length of manifold increased also as its diameter increased for one diameter manifold, manifold lengths were 24.50, 40.25, 57.25, and 68.25 m for 50, 63, 75 and 90 mm pipe diameter respectively. The first three lengths were due to velocity of delivered water reached the maximum of 1.5 m/s. While it didn't reach that velocity for 90 mm of diameter manifold. It reached the maximum allowable delivered water discharge rate of 25 m^3/h.

Table (5): One and telescopic diameter manifold lengths of single and double laterals units at different manifold diameters using lateral diameter of 16mm and dripper discharge rate 3 L/h.

Telescopic diameter One diameter			Manifold diameter, mm				Total telescopic length, m
Diameter, mm	Type of unit	Length, m	50	63	75	90	
50	S	49.00	-	-	-	-	49.00
	D	-	24.50	15.75	5.25	-	45.50
63	S	68.25	-	-	-	-	68.25
	D	-	-	40.25	15.75	-	56.00
75	S	68.25	-	-	-	-	68.25
	D	-	-	-	57.25	10.50	67.75
90	S	68.25	-	-	-	-	68.25
	D	-	-	-	-	68.25	68.25

3 The effect of dripper discharge rate on the area of single and double laterals unit:

Table (6) shows the single and double laterals unit for different dripper discharge rates of 2, 3, 4, 6 and 8 L/h at manifold diameter of 50 mm and lateral diameter of 16mm.

The Table indicates that the area of single and double laterals units were decreased as dripper discharge rates increased. The areas of single lateral unit were 0.94, 0.63, 0.60,0.43 and 0.33 fed. While, the areas of double lateral unit were 1.57, 1.17 1.01, 0.86 and 0.65 fed. for different dripper discharge rates of 2, 3, 4, 6 and 8 L/h, respectively, at manifold diameter of 50 mm and lateral diameter of 16mm.

This was due to that dripper discharge rate was the main factor affecting both lateral and manifold lengths. Those lengths decreased as dripper discharge rates increased. So, as a result, the area of the single or double laterals unit decreased. Because water delivered into the unit was limited with 12.5 m^3/h for single units and 25 m^3/h for double units, so, increment in dripper discharge rate caused decreasing in number of drippers in the unit and decreasing in both lateral and manifold lengths and unit area.

Water discharge delivered /unit = number of drippers/unit* dripper discharge rate

Table (6): Area of single and double lateral unit for different dripper discharge rates at manifold diameter of 50 mm and lateral diameter of 16mm.

Dripper discharge rates, L/h	Manifold diameter (50 mm)				
	Lateral length, m	Single lateral unit		Double lateral unit	
		Manifold Length, m	Area of unit, fed.	Manifold length, m	Area of unit, fed.
2	72.5	54.25	0.94	45.50	1.57
3	54.0	49.00	0.63	45.50	1.17
4	45.0	56.00	0.60	47.25	1.01
6	39.5	45.50	0.43	45.50	0.86
8	29	45.25	0.33	47.25	0.65

4. CONCLUSIONS

The present study aimed to develop a computer model ***OSAMA* (*2*)** to calculat optimize design of drip irrigation unit and test the validity of any unit of drip irrigation network existing in the field.

Validity of Osama (2) program was proved through a mathematical comparison and field experiment.The lateral lengths resulted from Osama (2) program were close to the corresponding ones resulted by Hanafy (1990).Correlation coefficient (r) between drippers discharge rates of both field lateral and output of Osama (2) program were (0.9678) and (0.9580) for 3.8L/h and 2.5L/h..This result proves the validity of Osama (2) program in the calculation of lateral length.

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الملخص العربي

تصميم و تقييم وحدة ري بالتنقيط بمساعدة الحاسب الآلي

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تهدف هذه الدراسة إلى تصميم وتقييم وحدة ري بالتنقيط بطريقة سريعة ودقيقة، لذلك صمم برنامج سمى أسامة (2). ولأجراء التصميم اخذ في الاعتبار الأسس الهيدرولية وأهمها الا تزيد سرعة المياه عن .،1، 1.5م /ث ولا يزيد الفقد بالاحتكاك عن 55%، 45% من الفواقد الكلية المسموح بها في الخط الفرعي والموزع على الترتيب كما انه لا تزيد كمية المياه المارة في الموزع عن 12.5، 25،م3/س للوحدات فردية وثنائية الخط الفرعي الري.

وتم إثبات صلاحية برنامج أسامة (2) عن طريق نوعين من الدراسة: نظرية ، وحقلية.

ففي الدراسة النظرية تم تغذية برنامج أسامة (2) بالخواص الهيدرولية للنقاط وقطر الخط الفرعي والنسبة المنوية لاختلاف التصرف بين أول وأخر نقاط في الوحدة والتي تم الحصول عليها من (Hanafy, 1995) وتم مقارنة النتائج المتحصل عليها من أسامة (2) مع نظيرتها و المتحصل عليها من (Hanafy, 1995) فكانت النتائج متقاربة جدا.

أما الدراسة الحقلية فقد تم اختيار نقاطين ومعايرتهم لمعرفة الخصائص الهيدروليية لهذين النقاطين فكانت قيمة (X) 5372،. ، 61،. ، قيمة (K) 1017،. ، 6056،. على الترتيب . تم تغذية برنامج أسامة (2) بخصائص كل نقاط على حدة وكذلك بالمسافة بين النقاطات (5، ، 8، م) للنقاطين على الترتيب.وكذلك قطر الخط الفرعي (16، 20مم) المستخدمين وتم التنفيذ العملي عند نسبة تغير مختلفة للتصرف وعند نفس الاطوال المتحصل عليه من برنامج أسامة (2) . وعند مقارنة النتائج النظرية مع العملية كان معامل الارتباط (r) 9678،. ، 9585،. للنقاطين على الترتيب . وهذا أيضا يثبت صلاحية برنامج أسامة (2) لتصميم وحدة ري بالتنقيط.

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