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Model to Design Drip Hose Lateral Line Using Two Spacing between Emitters

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Abstract**.** *The use of non-pressure compensating drip hose in horticultural and annual cycle fruits is growing in Brazil. In this case, the challenge for designers is getting longer lateral lines with high values of uniformity. The objective of this study was to develop a model to design longer lateral lines using non-pressure compensating drip hose. Using the developed model, the hypotheses to be evaluated were: a) the use of two different spacing between emitters in the same lateral line allows longer length; b) it is possible to get longer lateral lines using high values of pressure variation in the lateral lines since the distribution uniformity stays below allowable limits. A computer program was developed in Delphi based on the model developed and it is able to design lateral lines in level using non-pressure compensating drip hose. The input data are: desired distribution uniformity (DU); initial and final pressure in the lateral line; coefficients of relationship between emitter discharge and pressure head; hose internal diameter; pipe cross-sectional area with the dripper; and roughness coefficient for the Hazen-Williams equation. The program allows calculate the lateral line length with three possibilities: selecting two spacing between emitters and defining the exchange point; using two pre-established spacing between emitters and calculating the length of each section with different spacing; using one emitter spacing. Results showed that the use of two sections with different spacing between drippers in the lateral line didn't allow longer length but got better uniformity when compared with lateral line with one spacing between emitters. The adoption of two spacing increased the flow rate per meter in the final section which represented approximately 80% of the lateral line total length and this justifies their use. The software allowed DU above 90% with pressure head variation of 40% and the use of two spacing between emitters. The developed* *model/software showed to be accurate, easy to handle and useful for lateral line design using* non-*pressure* compensating *drip hose.*

Keywords. Emitter spacing, Localized irrigation, emission uniformity.

Introduction

The design criterion for non-pressure compensating drip hose is normally to have 10% of flow variation (∆q) in the lateral line, corresponding to 20% of head pressure variation (∆H).

Longer lateral lines in drip irrigation systems using conventional drippers provide cost reduction, but it is necessary to obtain to the uniformity of irrigation (ANDRADE, 2009). The use of Δq higher levels can provide longer lateral lines. Wu (1997) proposes the use of a 30% Δq and he found that this value resulted in distribution uniformity over 80%.

Andrade (2009) considered it is possible to extend the lateral line length using two emitters spacing in different section. He assumed that the spacing changing point would be at 40% of the total length, because this is approximately the location of the average flow according with Bliesner & Keller (1990). Talens (2002) found that, for practical purposes, the average pressure is located at 40% of the length of the lateral line and that until this point it has already consumed 75% of total pressure head loss (*hf*). In this case, the system design consists in the determination of the two emitters spacing utilized and the changing point between spacing.

It is important to study procedures and criteria to obtain longer lateral lines when using non-pressure compensating emitters. The design should be optimized and it can be obtained with the use of mathematical simulation models.

This study aimed to evaluate the possibility of increasing the lateral line length of an irrigation system using non-pressure compensating drip hose with different spacing between emitters but, maintaining irrigation uniformity at appropriate levels. For this, a comparison was carried out between a Delphi® developed simulation model and the usual design procedure.

Literature Review

In drip irrigation systems water is applied directly in the root system region, with high efficiency, but this system has the disadvantage of possible emitters clogging and its installation has a high cost (Mantovani et al., 2009). Basically the emitters can be compensating or non-pressure compensating. The compensating drippers provide constant flow rate under pressure variations along the lateral line, allowing longer lengths but they are more expensive. Non-pressure compensating emitters are widely used for the irrigation of vegetables and orchards on level, and the flow rate decreases as the pressure is reduced, resulting in shorter lateral lines in order to obtain the desired uniformity.

It is important to study procedures and criteria to obtain longer lateral lines when using non-pressure compensating emitters. Andrade (2009) considered it is possible to extend the lateral line length using two emitters spacing in different section. He assumed that the spacing changing point would be at 40% of the total length, because this is approximately the location of the average flow according with Bliesner & Keller (1990). Talens (2002) found that, for practical purposes, the average pressure is located at 40% of the length of the lateral line and that until this point it has already consumed 75% of total pressure head loss (*hf*).

The lateral line pressure head loss (*hf*) determination can be performed by the empirical equations of Hazen-Williams or Darcy-Weisbach. It is important to estimate the localized head loss at dripper (*hfe*), which is integrated inside the hose, reducing the flow section and causing a partial flow obstruction (Andrade, 2009; Rettore Neto et al., 2009).

In the non-pressure compensating emitters in the design usually is adopted a flow variation (Δq) of 10% and a corresponding pressure variation (∆H) of 20%, allowing uniformity distribution between 95 and 98% (Wu, 1997; Talens, 2002). It is possible to obtain uniformity coefficient higher than 80% even if discharge variation of 30% is used (Wu, 1997). To evaluate the irrigation uniformity two indicators can be used: distribution uniformity (*DU*) which is the ratio between the average 25% lower flow values and the average, expressed as a percentage (CLEMMENS and SOLOMON, 1997; STYLES et al., 2008); and the emission uniformity (*EU*), which considers the emitters characteristics and the operational unit hydraulic configuration (MARCUSSI and Saad, 2006).

The emitter flow can be characterized empirically as a function of the operational pressure, according to equation 1 (Howell and Hiler, 1974; Howell et al., 1983).

$$q = K\ H^{x} \qquad (1)$$

where:

q = emitter flow (L h^{-1});

K= proportionality factor;

H = emitter pressure head (m.c.a);

X= exponent of flow which characterizes the flow regime.

The simulation can be used to solve problems with multiple alternatives, facilitating the design. Delphi® language is largely used to create computer models, making possible to find a viable solution among the various possibilities.

Methodology

A simulation model was developed using the Delphi® programming language. To evaluate the model performance it was compared with the usual design method.

As an example a commercial non-pressure compensating drip hose was adopted, the characteristics are shown in Table 1.

Table 1. Non-pressure compensating drip hose characteristics.

Parameters	**Values**
Service pressure head (m.c.a.)	10
Minimum pressure head (m.c.a.)	6
Pipeline diameter (mm)	16
K coefficient	0.46297
Expoent (x)	0.503
Drip hose section with dripper (mm²)	188.73
Emitter coefficient of manufacturing variation (Cvf)	0.0353

Table 2. Input data.

Data	Delphi®	Usual
Discharge per linear meter (L.h-1)	3.5	-
Maximum discharge variation per linear meter (%)	20	-
Minimum distribution uniformity (%)	80	-
Friction coefficient (Hazen-Williams equation)	140	-
Dripper spacing (m)	0.4	0.4
Multiple outlet adjustment coefficient	-	0.35

The computer software DiLLIG - Dimensioning of lateral line for drip irrigation was developed to design the lateral line from last emitter to the first emitter. The input parameters are: distribution uniformity (%), the operational pressure, the inlet pressure, the desired flow rate per linear meter, the variation of flow per linear meter, the emitter proportionality factor, the emitter discharge exponent, the pipe diameter, the cross-sectional area of the pipe with the dripper (mm^2) and the roughness coefficient for the Hazen- Williams equation.

The program allows three design options: Option 1 - the model defines the length of the two sections of the lateral line and the two spacing between drippers ranging from 1 in 1 cm (called CALC - 1 cm), option 2 - the model defines the length of the two sections of the lateral line and the two spacing between drippers ranging from 5 by 5 cm (CALC - 5 cm), option 3 - the model defines the length of each section of the lateral line using two spacing defined by the user (CALC - pre).

The program steps for the calculations were organized to make the functional program, the first calculation made of the DH. Thereafter, for options 1 and 2 of the program, we obtain the spacing between drippers, by determining the flow from the drip of entry and end, and the limits of flow per meter. With these data, the program calculates two spaces per segment and calculates the average in each section by finding the gaps that will be used in the calculations. For sizing, the drip emitter, the calculations are initiated from the last transmitter as can be seen in Figure 1.

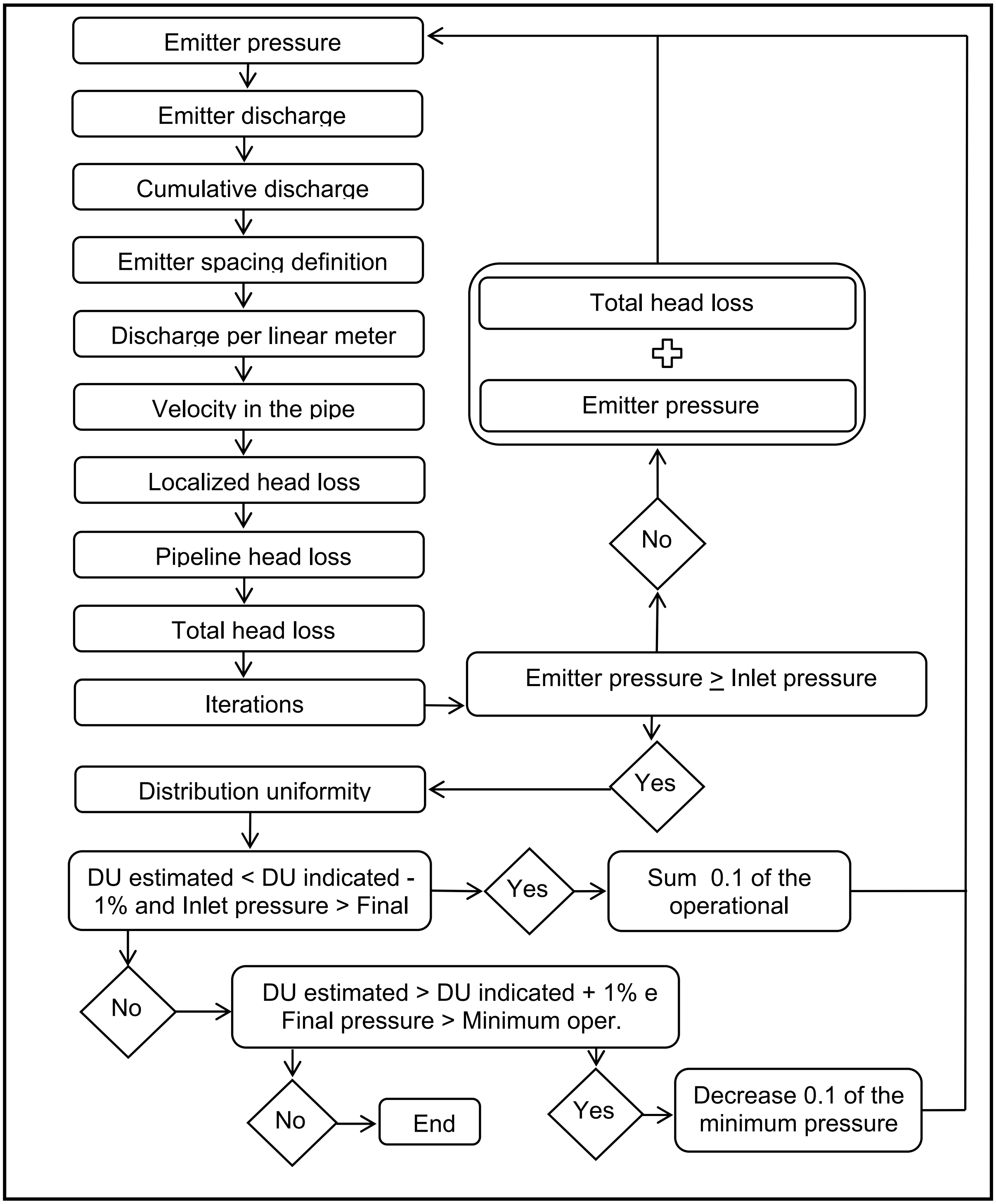

Figure 1. Delphi® model flowchart.

At first step, the pressure in the last emitter is considered equal to minimum pressure indicated in the input data, which should always be greater than the minimum operating pressure of the emitter. This value was programmed to change until the UD estimated be ±1% of the UD indicated.

The total head loss is calculated in three steps. At first, the program calculates the localized head loss, hfe. The second step is to estimate the pipeline head loss using the Hazen-Williams equation. Finally it calculates the total head loss from the sum of the localized head loss and the pipeline head loss. After the calculation for the last dripper, the model begins repetitions for each emitter, successively. For this, the model sums the emitter pressure and the total head loss of the emitter above, obtaining the pressure in the subsequent emitter.

The repetitions are carried out until the pressure in the emitter equals or exceeds the set in the input data. After reaching this point the software indicates the number of emitters, and calculates the length of the line, the sum of the spacing between emitters, the variation of flow, and finally the distribution uniformity. If the calculated distribution uniformity is smaller than the indicated minus 1%, and the inlet pressure is greater than the final pressure, the model will add 0.1 and the final pressure of repeated calculations. But if the calculated distribution uniformity is greater than the indicated plus 1%, and the pressure at the final outlet is greater than the minimum operational pressure, the model decreases of 0.1 the minimum pressure and it repeats the calculations. This repetition occurs until the DU and the final pressure are within the limits established from the input data.

The usual procedure to determine the lateral line is based on the equations of Darcy-Weisbach and Blasius, considering Q = (L / Se).Q and making appropriate mathematical arrangements, obtaining the equation 2.

$$L = \left(\frac{1281{,}11650554 \; hf' \; Se^{1{,}75} \; D^{4{,}75}}{q^{1{,}75} \; F} \right)^{1/2{,}75} \qquad (2)$$

where:

Hf' = total head loss in the lateral line;

Se = emitters spacing (m);

D= pipe diameter (m);

q= emitter discharge (L h^{-1});

F= Multiple outlet adjustment coefficient.

Two pressure variation were used, 20 and 40%, to compare the NLP model and the usual procedure.

Results and Discussion

The software DiLLIG, developed in Delphi®, allowed the design using one and two emitter spacing in the lateral line for the three design possibilities (CALC - 1 cm; Calc - 5 cm and calc - pre), as shown in Table 3. It was found that the spacing used in the model were close to 0.40 m. The use of a single spacing resulted in lateral line longer when compared with the adoption of two spacing in the same lateral line. The longest line was of 193.2m and it was obtained with drippers spaced of 0.40 m and pressure variation of 40%, being 21.7 m longer than the value obtained using two spacing (Table 3).

Table 3. Design options and inlet pressure, spacing between emitters, emitter number per section, section length, total lateral line length for the ∆H evaluated.

ΔH	Option	H ent. (m.c.a)	Emitter spacing (m)		Number of emitter in the section		Length (m)		
			Initial	Final	Initial	Final	Initial	Final	Total
20%	CÁLC - 1 cm	10.01	0.42	0.38	61	289	25.62	109.82	135.44
	CÁLC - 5 cm	10.02	0.40	0.40	350		140		140.00
	CÁLC - pré	10.02	0.40		350		140.00		140.00
40%	CÁLC - 1 cm	10.01	0.42	0.33	87	409	36.54	134.97	171.51
	CÁLC - 5 cm	10.04	0.40	0.35	93	402	37.20	140.70	177.90
	CÁLC - pré	10.06	0.40		483		193.20		193.20

For the design option which uses spacing variation of 1 cm, the first section length corresponded to approximately 20% of the total lateral line length. At the spacing change point the pressure head loss varied from 44.50 to 49.30% of the total. However, with the use of varying spacing of 5 by 5 cm, the head loss in the line at the spacing changing point was of 48.81% for the DH 40%. In all options and DH evaluated the flow variation was under the limit recommended by Wu (1997), with the maximum value 22.88% obtained with the use of single spacing and DH 40 % (Table 4).

Table 3. Discharge (Q), distribution uniformity (DU), emission uniformity (EU), discharge variation per linear meter (Δql), discharge variation (Δq) and lateral line length, obtained usinf the simulation model developed.

ΔH	Option	Q (L.h^{-1})	UD (%)	UE (%)	Δql (%)	Δq (%)	L (m)
20%	CÁLC - 1 cm	475.27	97.09%	92.69	9.47%	10.64%	135.44
	CÁLC - 5 cm	475.80	96.98%	92.58	10.73%	10.73%	140.00
	CÁLC - pré	475.80	96.98%	92.58	10.73%	10.73%	140.00
40%	CÁLC - 1 cm	606.90	93.30%	89.00	21.36%	22.71%	171.51
	CÁLC - 5 cm	607.27	93.08%	88.77	13.65%	22.83%	177.90
	CÁLC - pré	594.31	92.79%	88.51	22.88%	22.88%	193.20

The EU showed lower values when compared to DU values. However, it is noted that EU values were also above 88%. Analyzing the flow rate per linear meter, using two emitter spacing, the biggest difference occur at the spacing changing point and it is directly proportional to the DH, as shown in Figure 2 and Figure 3.

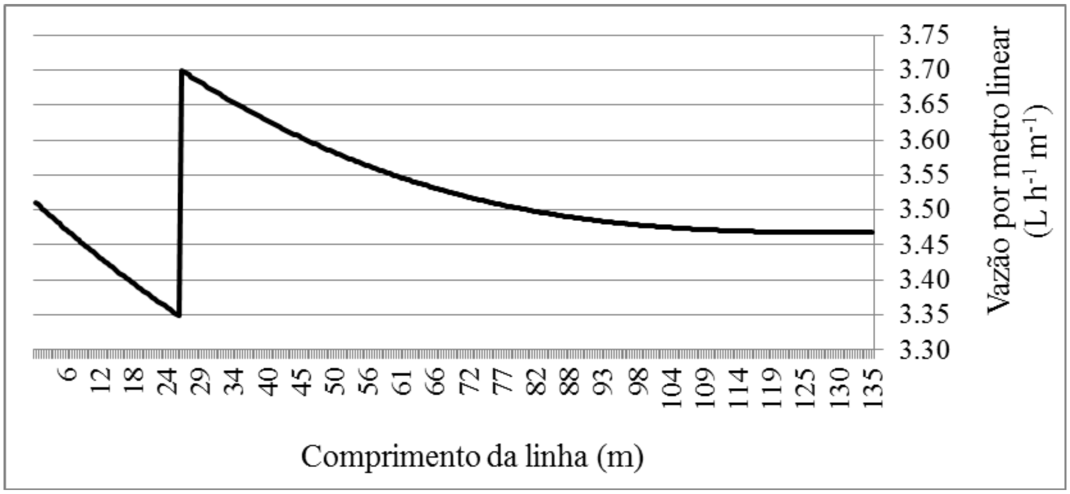

Figure 2. Discharge per linear meter as a function of the lateral line length, for the 20% pressure variation.

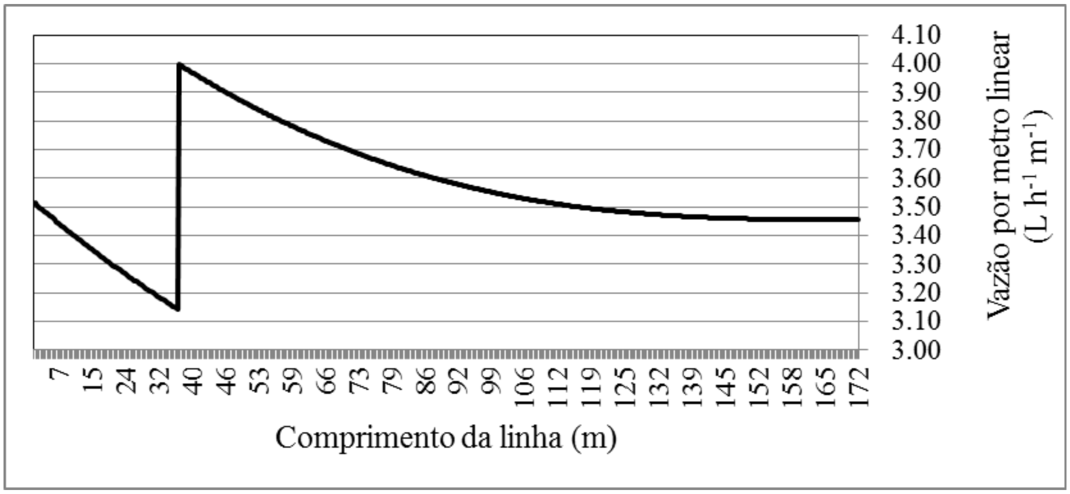

Figure 3. Discharge per linear meter as a function of the lateral line length, for the 40% pressure variation.

The results for the usual procedure (equation 2) are shown in Table 5. This method underestimated the lateral line length because it does not use the total pressure variation allowed.

Table 4 – Inlet pressure (H ent), pressure variation (ΔH), emitters number, discharge, lateral line length (L), distribution uniformity (DU), emission uniformity (EU), discharge variation per linear meter (Δql), discharge variation between emitters (Δq), for the pressure variation of 20 and 40%.

ΔH (%)	H ent. (m.c.a)	H fim (m.c.a)	ΔHc (%)	Nº de gotejadores	Q (L h^{-1})	L (m)	UD (%)	UE (%)	Δql (%)	Δq (%)
20	10.00	8.29	17.14	327	450.02	130.80	97.50	93.09	9.02	9.02
40	10.00	6.95	30.49	420	543.12	168.00	95.04	90.69	16.72	16.72

Analyzing Table 6 and 7 and considering the distribution uniformity, uniformity of emission, the variation of flow rate and lateral line length it was observed that the use of pressure variation of 40% was better than the use of 20%.

Table 6 - Discharge (Q), distribution uniformity (DU), emission uniformity (EU), discharge variation per linear meter (Δql), discharge variation between emitters (Δq), for the design options and for pressure variation of 20%.

Method	Options	L (m)	Q (L.h^{-1})	DU (%)	EU (%)	Δql (%)	Δq (%)
Delphi®	CALC-1cm	135.44	475.27	97.09%	92.69	9.47%	10.64%
	CALC-5cm	140.00	475.80	96.98%	92.58	10.73%	10,73%
	CALC-pré	140.00	475.80	96.98%	92.58	10.73%	10.73%
Usual	1	130.80	450.02	97.50%	93.09	9.02%	9.02%

Table 7 - Discharge (Q), distribution uniformity (DU), emission uniformity (EU), discharge variation per linear meter (Δql), discharge variation between emitters (Δq), for the design options and for pressure variation of 40%.

Method	Options	L (m)	Q (L.h^{-1})	DU(%)	EU (%)	Δql (%)	Δq (%)
Delphi®	CALC-1cm	171.51	606.90	93.30	89.00	21.36	22.71
	CALC-5cm	177.90	607.27	93.08	88.77	13,65	22.83
	CALC-pré	193.20	594.31	92.79	88.51	22.88	22.88
Usual	1	168.00	543.12	95.04	90.69	16.72	16.72

Conclusions

The DiLLIG simulation model is easily manipulated and showed reliable results.

The usual procedure underestimated the lateral line length because it did not use the entire range of allowable pressure.

The adoption of high flow variation under acceptable standards of uniformity is feasible and ensures the best results.
The initial hypothesis that the adoption of two spacing would increase the length of the lateral line was not confirmed when the design was calculated using the developed model.

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