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CFD Analysis of Shell and Tube Heat Exchanger with Different Baffle Orientation & Baffle Cut

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Abstract

This paper emphasizes on the effects of certain baffle orientation and baffle cut for a simple shell and tube heat exchanger. As heat being transferred between separate medium might contribute some heat loss to the surroundings resulting in an ineffective heat transfer, this calls for the remedy to minimize the loss and improve heat transfer characteristics. This is where baffle orientation and baffle cut plays its role and improves the heat transfer phenomena. The analysis is performed using a commercial CFD software package FLUENT. Among different turbulence models k-ε (2-eqn) is considered for this study. A number of simulations is conducted by varying the Reynolds number, baffle cut, and orientation of baffles. After examining the result it is noticed that pressure drop and heat transfer coefficient both decreases as the baffle cut is increased for a particular Reynolds number, but as the Reynolds number is increased keeping the baffle cut constant, pressure drop and heat transfer coefficient both increases. Last but not the least the above findings can be used for further study and there is also scopes for some improvement of the current study.

Keywords: shell and tube heat exchanger, baffle orientation, baffle cut.

1. Introduction

A heat exchanger is an abstract term which can constitute anything from a simple room heater to more complicated instrument such as an engine radiator. It is a piece of equipment in which heat is exchanged between two fluids that are at different temperatures and which in most of the cases are separated by a solid wall [1]. Different heat exchangers are named according to their applications. For example, heat exchangers being used to condense are known as condensers, similarly heat exchangers for boiling purposes are called boilers [2].
Among heat exchangers Shell and tube heat exchangers are undoubtedly the most widespread and commonly used. In these heat exchangers, one fluid flows through tubes while the other fluid flows in the shell across the tube bundle. This configuration allows for the passage of fluids without them being in direct contact with each other. This is very convenient for many processes, especially when product purity needs to be ensured. This arrangement also allows for large quantities of heat to be transferred quickly, and it is relatively easy to maintain consistent operating conditions. Heat exchangers run on the principles of convective and conductive heat transfer. Though radiation can occur in any process the amount of contribution from it is very small [3].

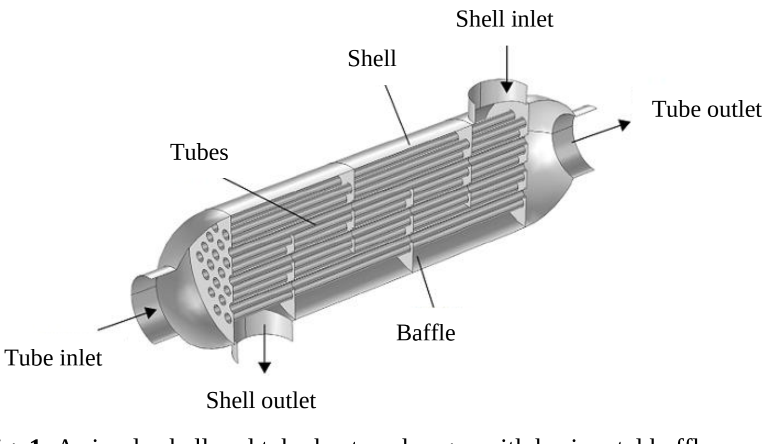


Fig. 1. A simple shell and tube heat exchanger with horizontal baffles

Though heat exchangers are very capable of transferring heat, they might not be able to work up to their full potential due to heat loss to the surroundings or other mechanical losses. Thus there should be some ways to reduce the losses and improve the overall efficiency. One of the ways that can be done is by employing baffles (sheet of metal used to restrain the flow of fluid inside the shell) inside the heat exchanger. Figure 1 represents a similar kind of heat exchanger with baffles mentioned above. They can be placed inside the shell in horizontal, vertical or inclined position. The openings of the baffle are termed as baffle cut which is represented as the percentage of shell inside diameter. In this study both the baffle orientation and baffle cut will be varied and the flow characteristics inside the shell will be investigated.

2. Modeling details

In this study a shell and tube heat exchanger is used as shown in Fig. 2. The cold fluid flows inside the shell & a constant temperature is set for flow through the tubes. The working fluid is water. There are 7 tubes inside the shell & 10 baffle placed at a particular distance. Two baffle orientation is used for separate studies. Three baffle cut values are selected, they are- 25%, 30% and 36%. For each orientation and baffle cut different Reynolds no. has been considered for the shell side flow. To perform the analysis at first the geometry is created then it is meshed using appropriate parameters. After that in the solver setup, along with some other parameters k-epsilon turbulence model is selected and finally the calculation is performed.
The geometry of the aforementioned shell and tube heat exchanger is shown below:

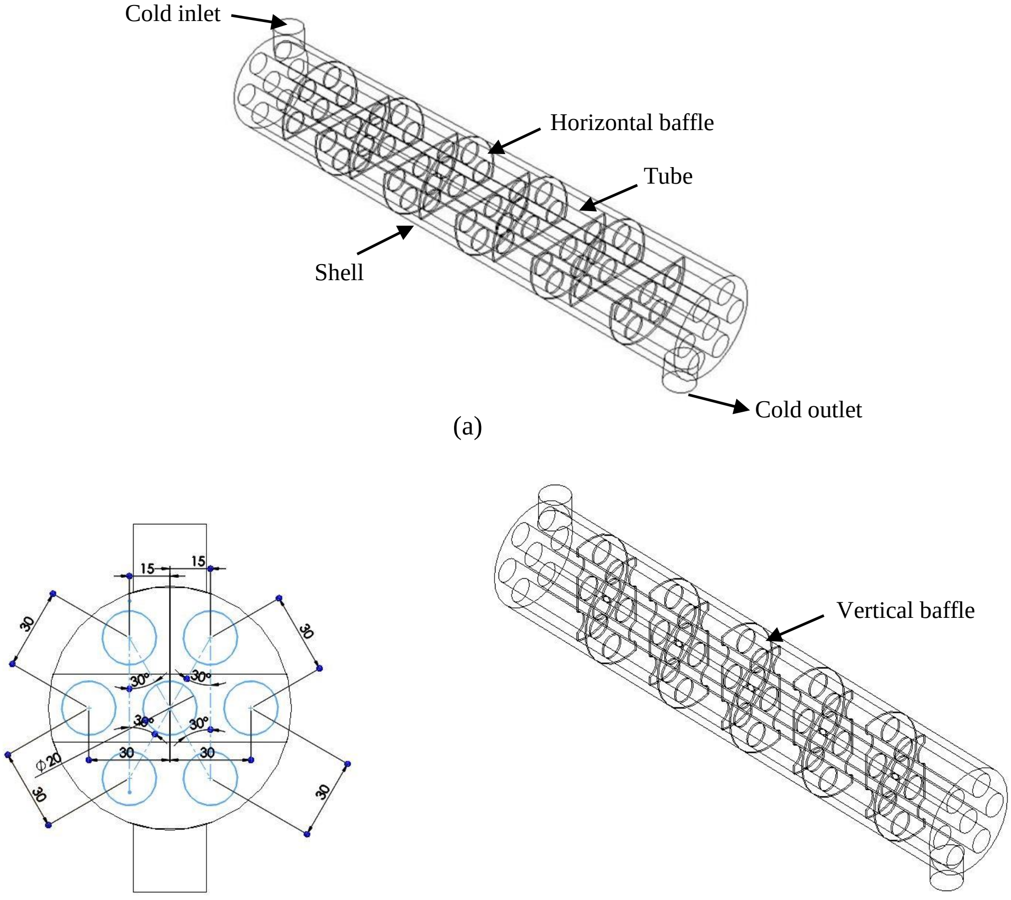


Fig. 2. (a) Boundaries and flow directions for horizontal baffle (b) Position of the tubes (c) Shell and tube heat exchanger with vertical baffle

Boundary conditions

The dimensions of the heat exchanger is given below-

Table 1. Design parameters

Shell diameter, D_s	90 mm
Tube outer diameter, d_o	20 mm
Tube bundle geometry and pitch	Triangular, 30 mm
Number of tubes, N_t	7
Heat exchanger length, L	500 mm
Number of baffles	10
Central baffle spacing	41.50 mm
Baffle cut, B_c	25%, 30%, 36%

The boundary conditions for each inlet, outlet and wall are defined as follows:

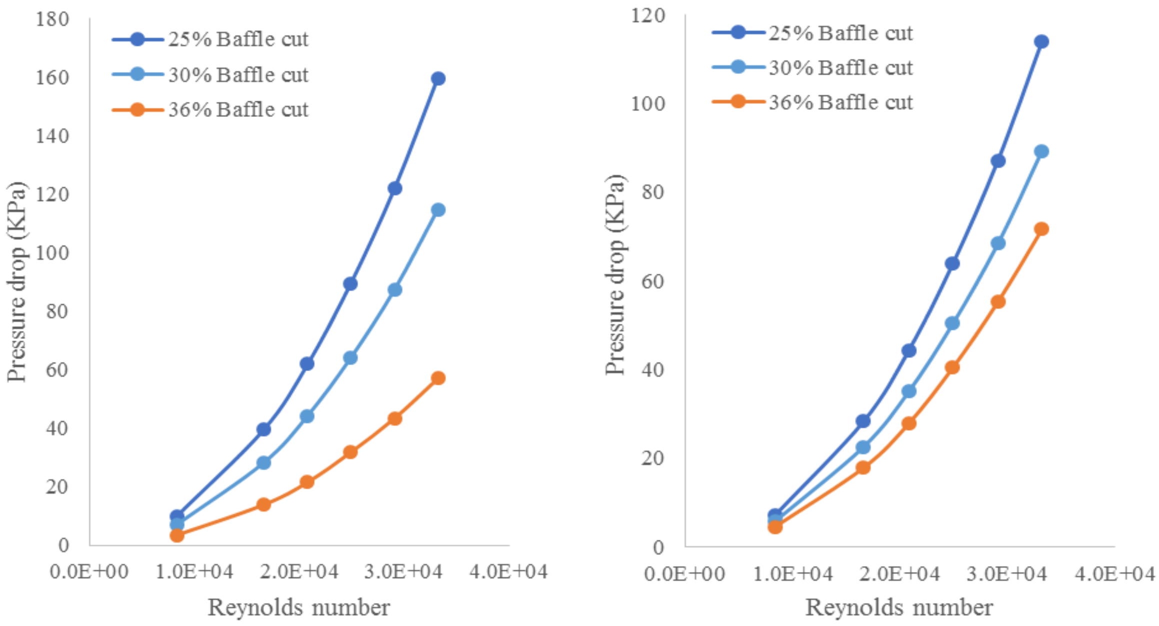
Table 2. Boundary conditions for different regions

s-inlet	mass flow inlet	mass flow rate = 0.5 to 2 kg/s, y-component flow direction = -1
s-outlet	pressure outlet	gauge pressure = 0 pa
s-wall	wall	Heat flux = 0 w/m^2
t-wall	wall	Constant temperature = 450 K

3. Results and discussion

Effect of baffle orientation and baffle cut on pressure drop

Here, investigation of the pressure drop variation for different configuration was carried out by taking different mass flow rates inside the shell. The mass flow rate was then used to calculate the Reynolds no. For each mass flow rate pressure drop at the outlet was found by using CFD analysis. The Pressure drop values were then plotted against the Reynolds no. to draw the following chart:-



(a) (b)

Fig. 3. Pressure drop vs. Reynolds no. curves for (a) Horizontal baffle orientation and (b) Vertical baffle orientation

From Fig. 3. it is clearly seen that pressure drop increases by increasing the Reynolds no. Also horizontal baffle orientation causes higher pressure drop than vertical baffle orientation at high Reynolds no. At low Reynolds no. the pressure drop variations are very negligible.
To further analyze the effect of baffle cut on pressure drop the following chart is prepared. Here pressure drop is compared against different baffle cut values.

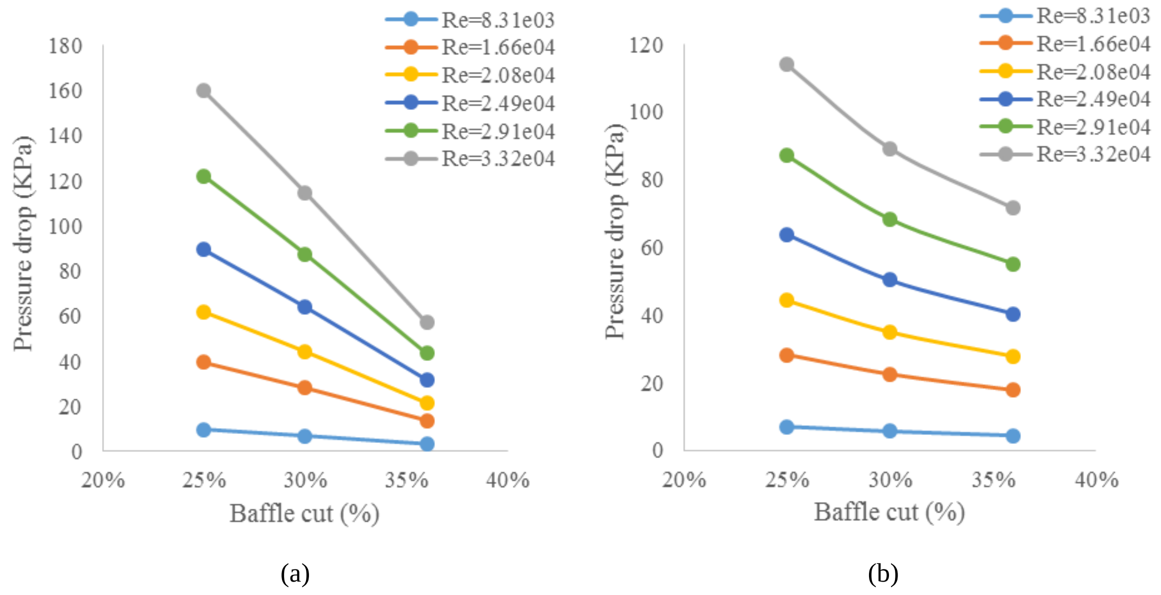


Fig. 4. Pressure drop as a function of baffle cut for different Reynolds no. where (a) Horizontal baffle orientation and (b) Vertical baffle orientation

Fig. 4. shows that increasing the baffle cut causes decrease in pressure drop. This is due to the fact that as baffle cut is increased the flow is less disturbed and can travel through the shell easily.

Effect of baffle orientation and baffle cut on heat transfer

Here, similar analysis is done as described earlier for finding the effect of baffle orientation and baffle cut on pressure drop. The surface heat transfer coefficient corresponding to different Reynolds no is found by using CFD analysis. Following charts were prepared for visualizing the effect:-

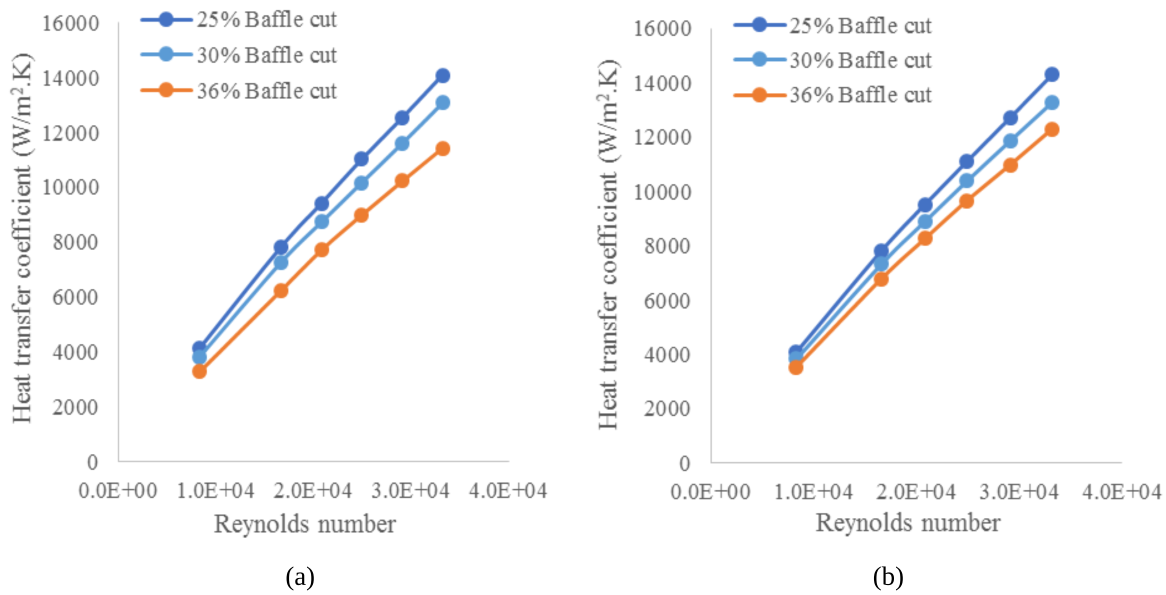
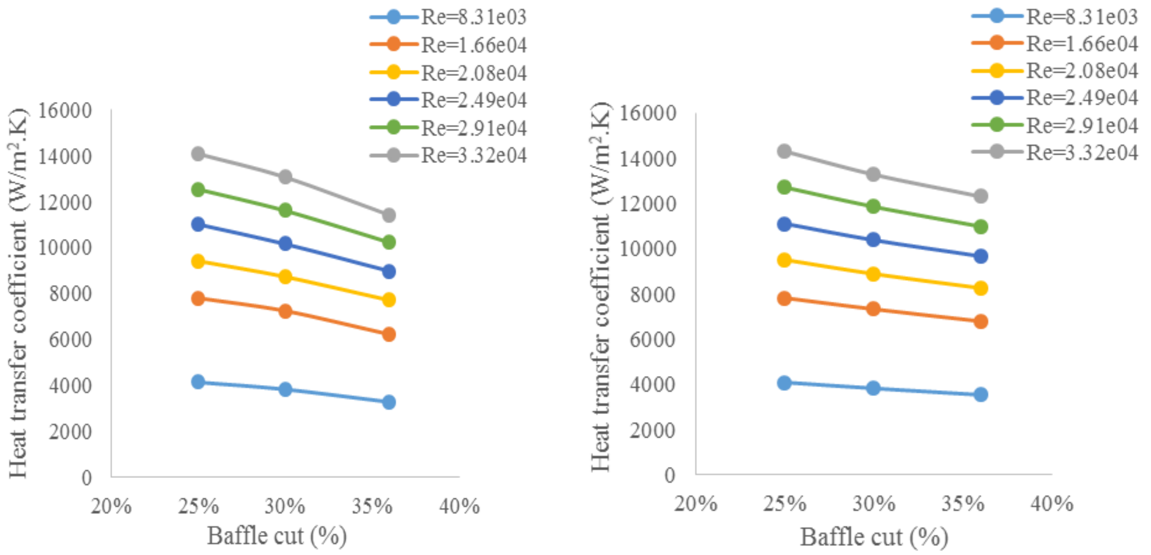


Fig. 5. Heat transfer coefficient vs. Reynolds no. curves for (a) Horizontal baffle orientation and (b) Vertical baffle orientation

From Fig. 5. it is seen that Heat transfer coefficient increases rapidly by increasing the Reynolds no. At low Reynolds no. the change is very negligible.
Another chart showing heat transfer coefficient as a function of baffle cut is prepared and is shown below:-



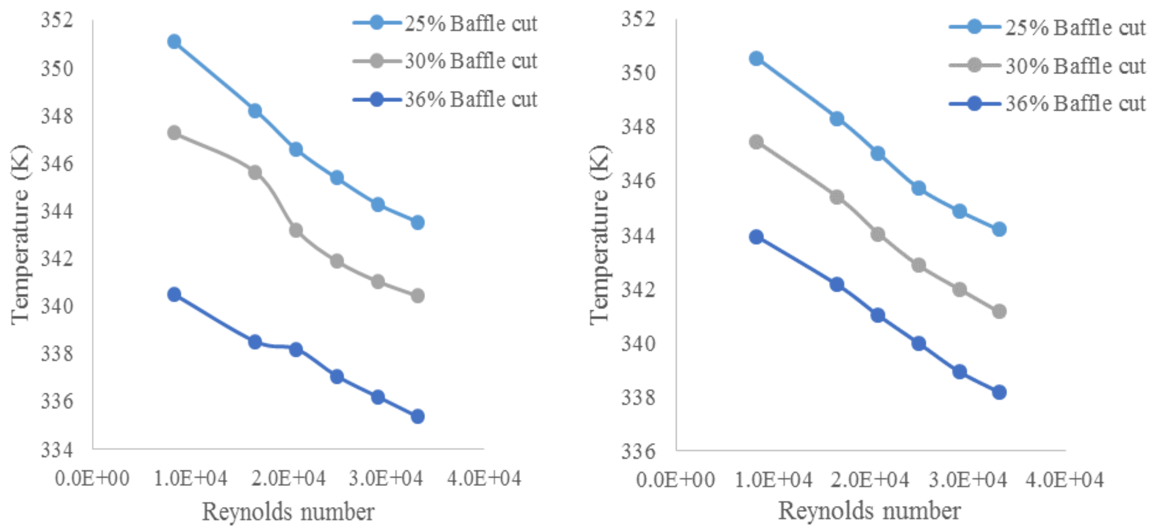
(a) (b)

Fig. 6. Heat transfer coefficient as a function of baffle cut for different Reynolds no. where (a) horizontal baffle orientation and (b) Vertical baffle orientation.

Fig. 6. shows that increasing the baffle cut causes decrease in heat transfer coefficient.

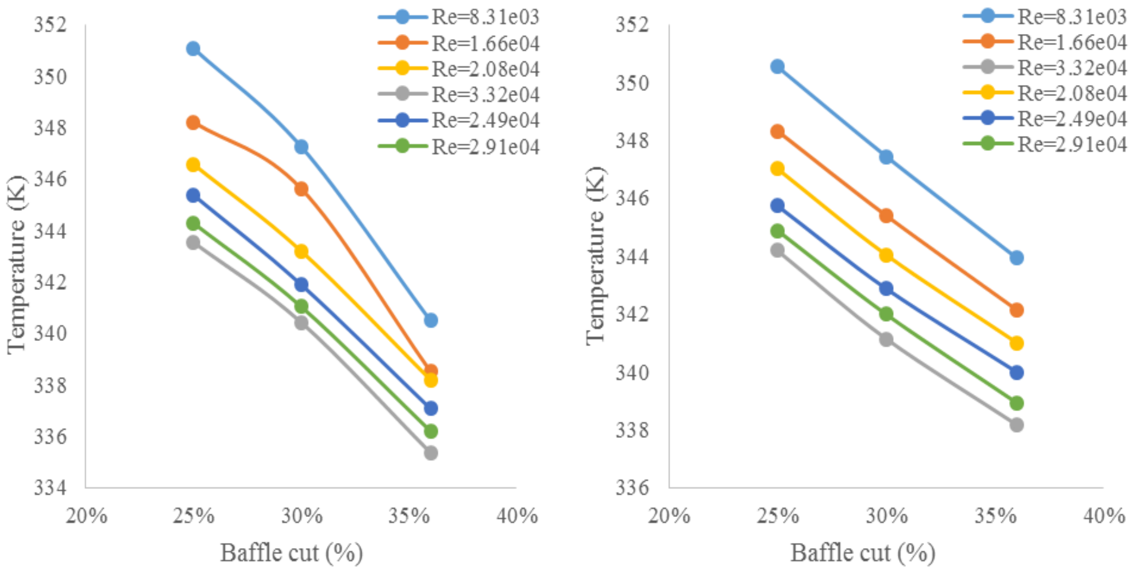
Effect of baffle orientation and baffle cut shell outlet temperature

Outlet temperature plays an important role in any heat exchanger design. It can be increased or decreased by changing the geometry of heat exchanger, mass flow rate at inlet and material used. Below are some charts showing outlet temperature as a function of Reynolds no. and baffle cut:-



(a) (b)

Fig. 7. Outlet temperature vs. Reynolds no. curves for (a) Horizontal baffle orientation and (b) Vertical baffle orientation



(a) (b)

Fig. 8. Temperature as a function of baffle cut for different Reynolds no. where (a) horizontal baffle orientation and (b) Vertical baffle orientation

From Fig. 7. and Fig. 8. it can be seen that temperature decreases rapidly as Reynolds no. is increased. At low Reynolds no. horizontal baffle orientation tends to show slightly higher outlet temperature than the vertical baffle orientation. But for high Reynolds no. vertical baffle orientation gives higher outlet temperature than the horizontal one. Baffle cut also has an influence on outlet temperature as shown above. It was observed that as baffle cut is increased temperature at outlet reduces drastically.

4. Acknowledgement

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5. References

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