Maximum efficiency

Is it possible to construct a heat engine $A$ which is more efficient than the Carnot engine $C$?

Use engine $A$ to drive engine $C$ in the reverse i.e. as a refrigerator.

Heat transfers: $\Delta Q_A > 0$, $\Delta Q_{12} < 0$, $\Delta Q_{34} > 0$.

Work performance: $\Delta W = \Delta W^{(A)}_{\text{out}} = \Delta W^{(C)}_{\text{in}} > 0$.

Efficiencies: $\eta_A = \frac{\Delta W}{\Delta Q_A}$, $\eta_C = \frac{\Delta W}{|\Delta Q_{12}|}$

Since engine $C$ operates reversibly, $\eta_C$ is the same in the forward and reverse directions. Note: $\eta_C$ is not an efficiency in the reverse mode.

$\eta_A > \eta_C$ would imply $\Delta Q_A < |\Delta Q_{12}|$.

The two engines combined would then cause heat to flow from low to high temperature without work input, which is a violation of the second law.

Conclusions:

- Engine $A$ cannot be more efficient than engine $C$.
- All Carnot engines operating between $\Theta_H$ and $\Theta_L$ must have the same efficiency.