Low GWP Multi-stage Flash-intercooling Ultralow-temperature Transcritical Refrigeration Cycle

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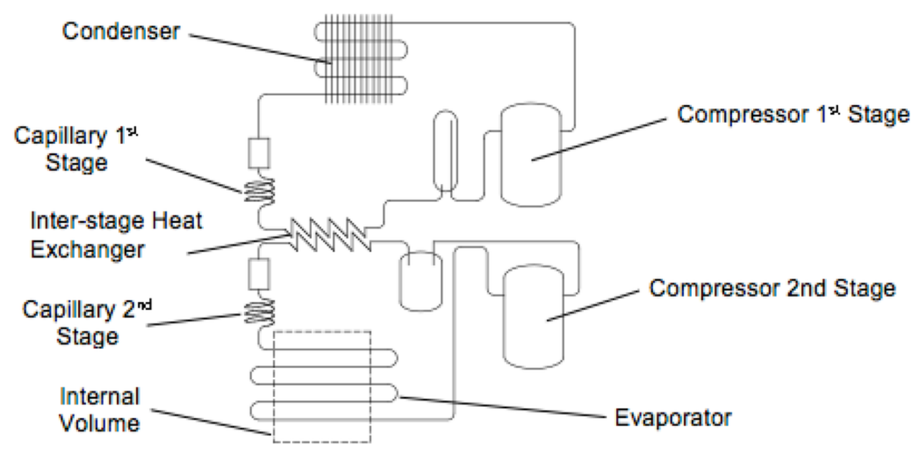
Introduction:

Global warming presents one of the most pressing challenges of our time, with profound implications for the environment and human society. The excessive emission of greenhouse gases, particularly carbon dioxide and fluorinated gases, contributes significantly to this phenomenon. Among these gases, refrigerants used in cooling systems stand out as potent contributors to global warming. Traditional refrigerants such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) have high global warming potentials (GWPs), exacerbating the climate crisis.



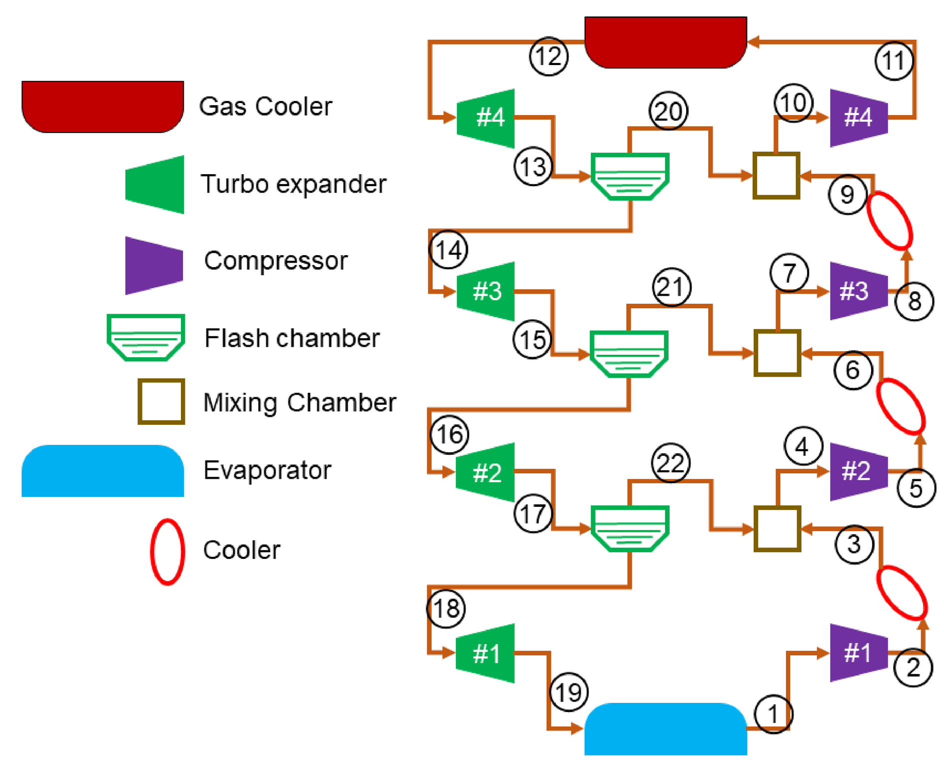
In response to the urgent need for mitigation strategies, the development of sustainable refrigeration technologies has gained momentum. Multi-stage refrigeration systems emerge as promising solutions to reduce the environmental impact of cooling processes. By employing multiple stages of compression and cooling, these systems offer enhanced efficiency and reduced reliance on high-GWP refrigerants. Through innovative design and optimization, multi-stage refrigeration holds the potential to significantly mitigate the carbon footprint associated with cooling applications.

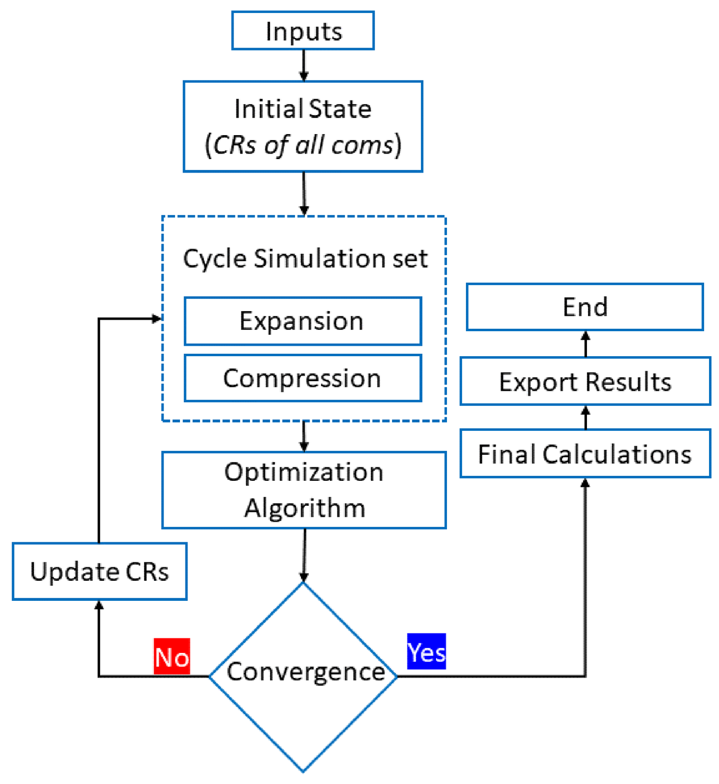
In this poster, we explore the intersection of global warming, refrigerants, and multi-stage refrigeration technologies. We investigate the environmental implications of traditional refrigerants and highlight the imperative for sustainable alternatives. Additionally, we examine the principles and advantages of multi-stage refrigeration systems in the context of climate change mitigation. Through comprehensive analysis and case studies, we aim to underscore the importance of adopting environmentally responsible refrigeration practices to combat global warming effectively.



Refrigerant	R23	R744a	R170	R1150
GWP	12,400	265	10.2	3.7
Boiling Point	-82.1°C	-88.5°C	-88.6°C	-103.7°C

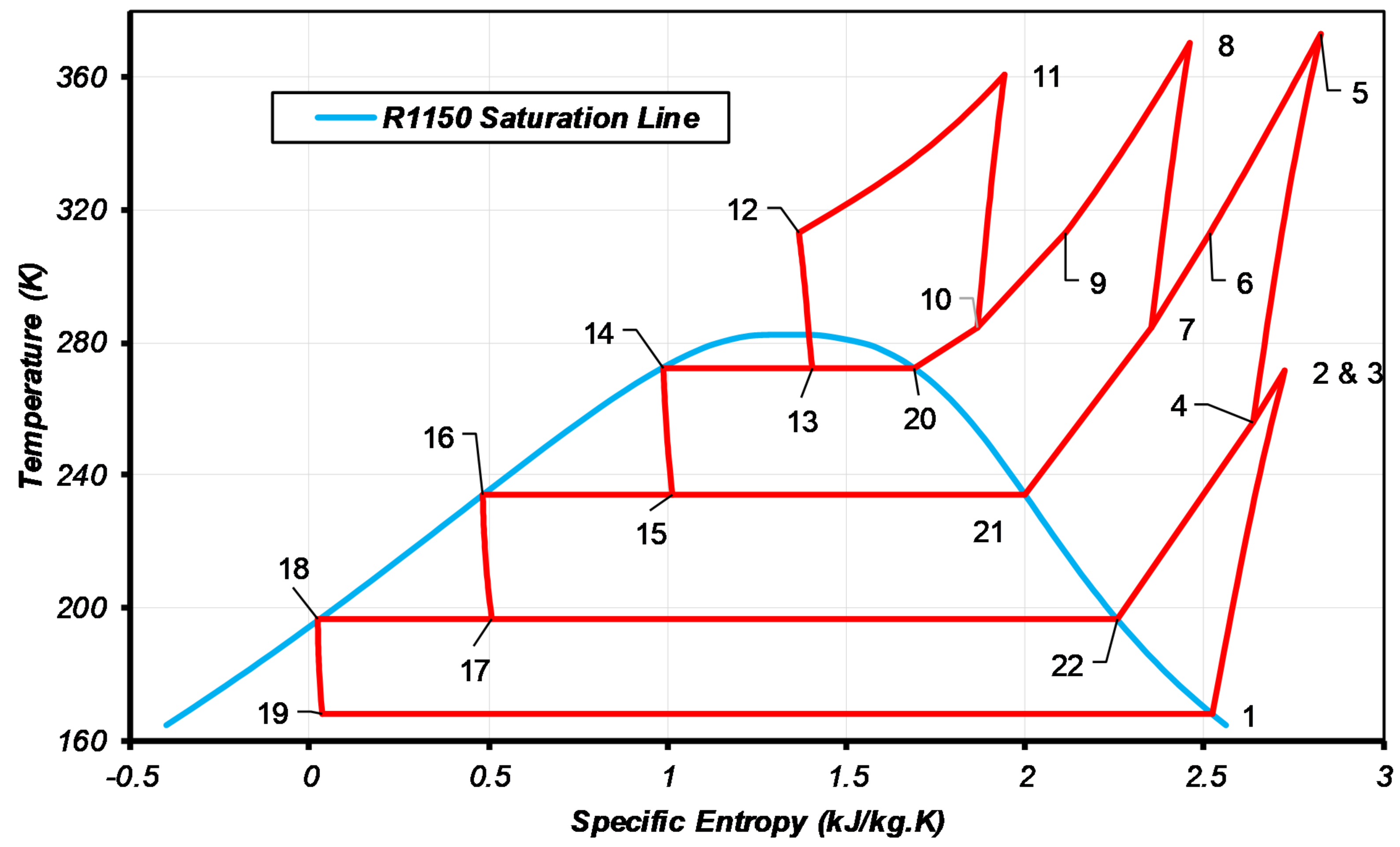
The cycle's schematics and simulation method:





$$\frac{\delta Q}{\delta t}-\frac{\delta W}{\delta t}=\frac{\delta}{\delta t}\iiint_{cv}\left(u+\frac{v^2}{2}+\frac{P}{\rho}+gz\right)\rho dV+\iint_{cs}\left(u+\frac{v^2}{2}+\frac{P}{\rho}+gz\right)\rho\vec{v}d\vec{A}$$

A first law analysis of a cycle is essential for understanding energy transfers within the system. It applies the principle that energy is conserved, allowing us to assess the balance of energy inputs and outputs, as well as cycle efficiency. By examining heat transfer, work done, and changes in internal energy, this analysis helps optimize cycle performance, crucial in addressing challenges like global warming by minimizing energy consumption and maximizing efficiency.

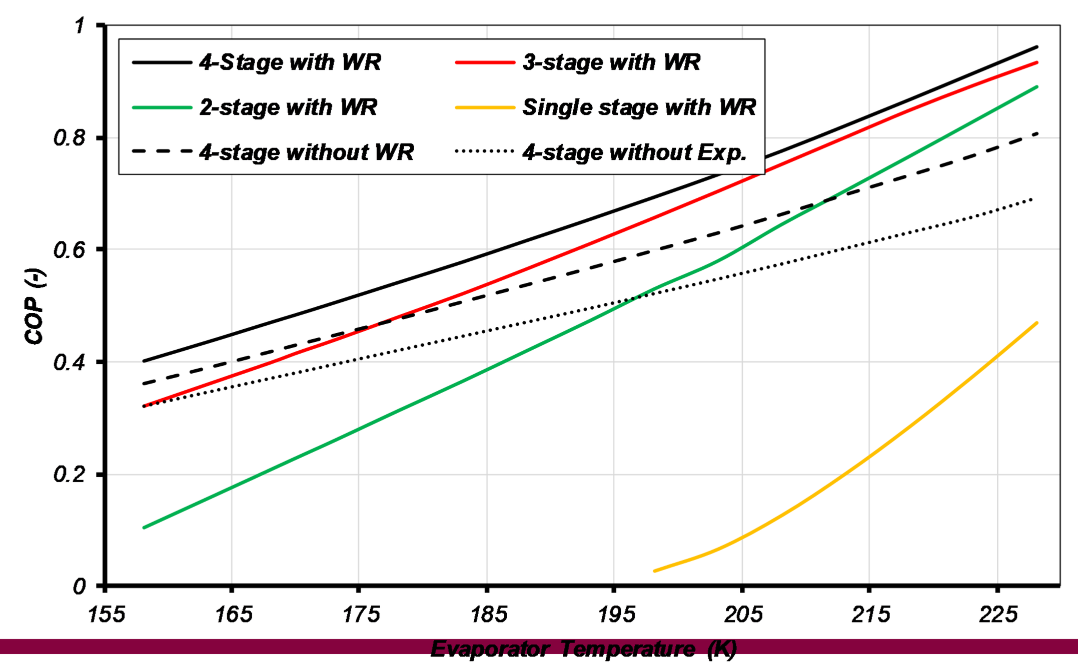


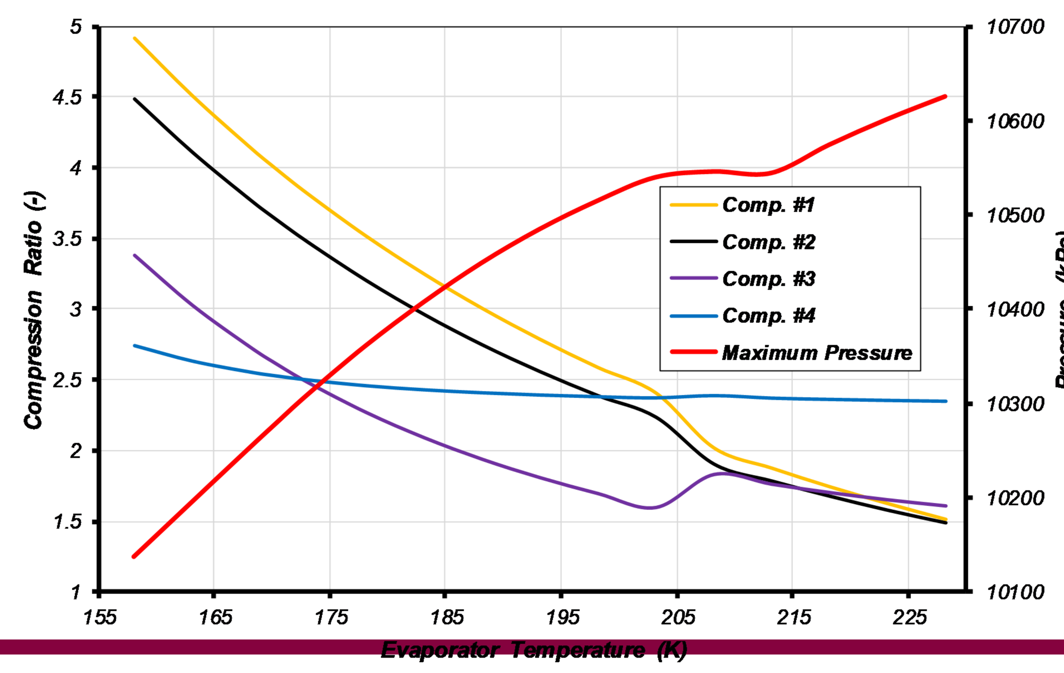
Single-refrigerant

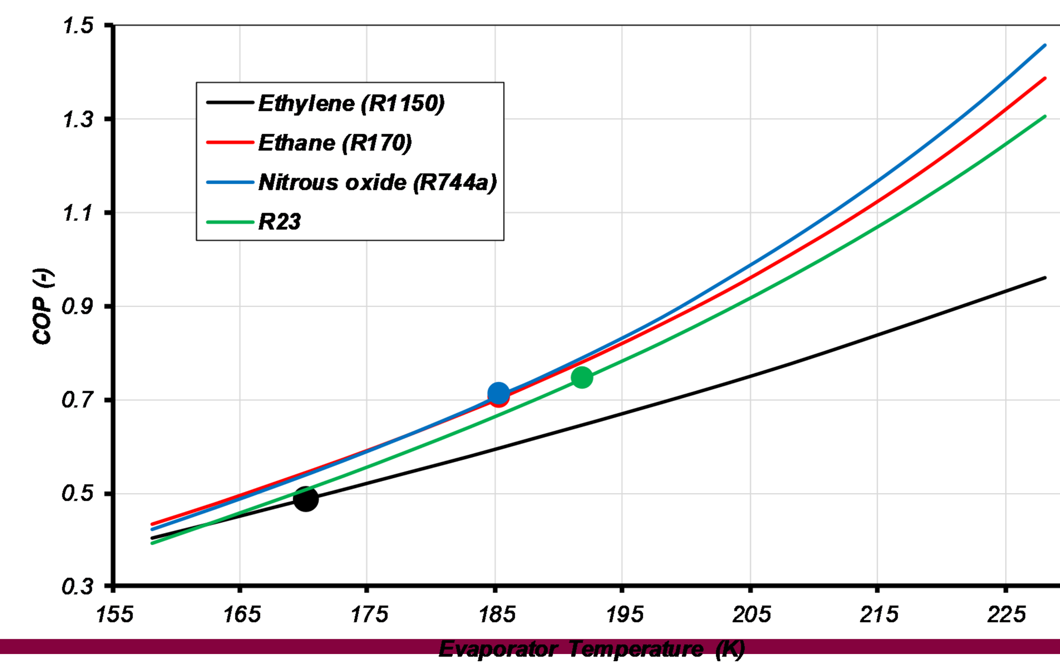
Go Transcritical!

No Internal Heat Exchangers!

Results:







Conclusions:

The complications and environmental challenges associated with ultralow-temperature (ULT) refrigeration are a matter of concern. This paper presents a novel approach to ULT refrigeration with a single-natural-refrigerant cycle. An optimized four-stage flash intercooling turboexpander transcritical cycle was modeled, thermodynamically analyzed, and optimized. This research trades the complexity of multi-refrigerants and multiple heat exchangers in a cascade cycle for flash intercooling compression in a transcritical single-refrigerant cycle without sacrificing performance, with a great potential for lower indirect Global Warming Potential (GWP). The intensive work required for a high compression ratio is minimized by multi-stage flash intercooling. On the other hand, the substantial pressure gap allows work recovery through turboexpanders, the importance and function of which are demonstrated in the parametric study presented in this paper. It is shown that in this configuration R1150 can be an environmental alternative to R23 for refrigeration below -85°C, while R744a (N_2O) and R170 are more environmentally and performantly suitable for refrigeration above -85°C than R23.