A COMPACT REMOTE HEAT TRANSFER DEVICE FOR SPACE CRYOCOOLERS

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Outline

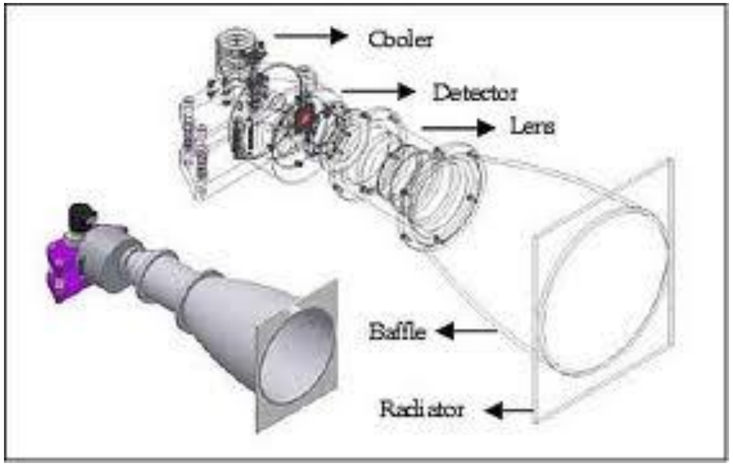
➢ Introduction

◆Space infrared detecting systems are more and more popular in recent years in many countries.

◆Infrared detectors generally cooled by space cryocoolers.

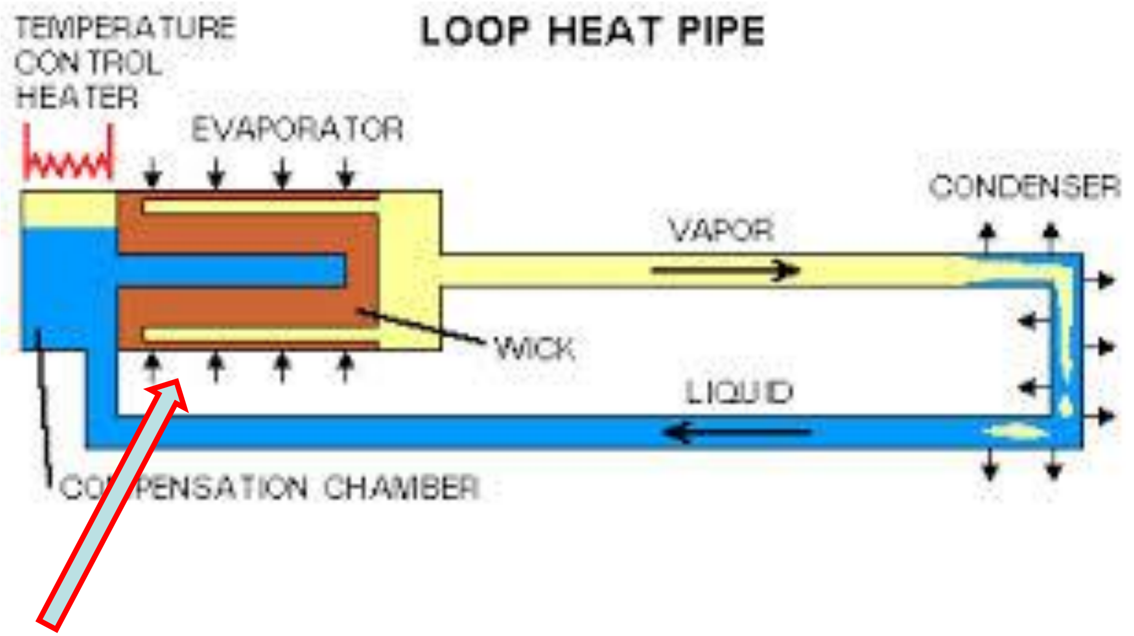
As a most widely used configuration, an infrared detector is generally directly contacted with the cold tip of a cryocooler.

In some cases there is not enough space behind the detector, therefore a remote cryogenic heat transfer device is required.



➢ Introduction

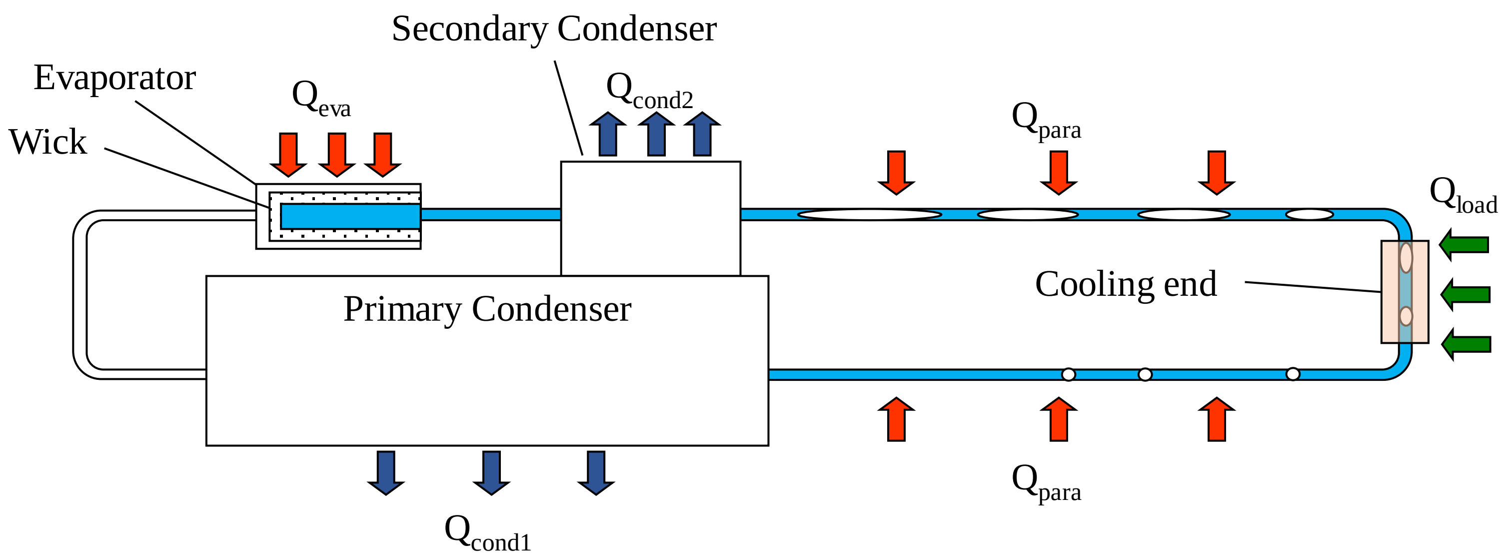
Cryogenic loop heat pipes (CLHPs) are promising cryogenic heat transfer devices.



While CLHP has a big head, not easy for use……

➢ Structure and working principle of CRHD

CRHD: compact remote heat-transfer device

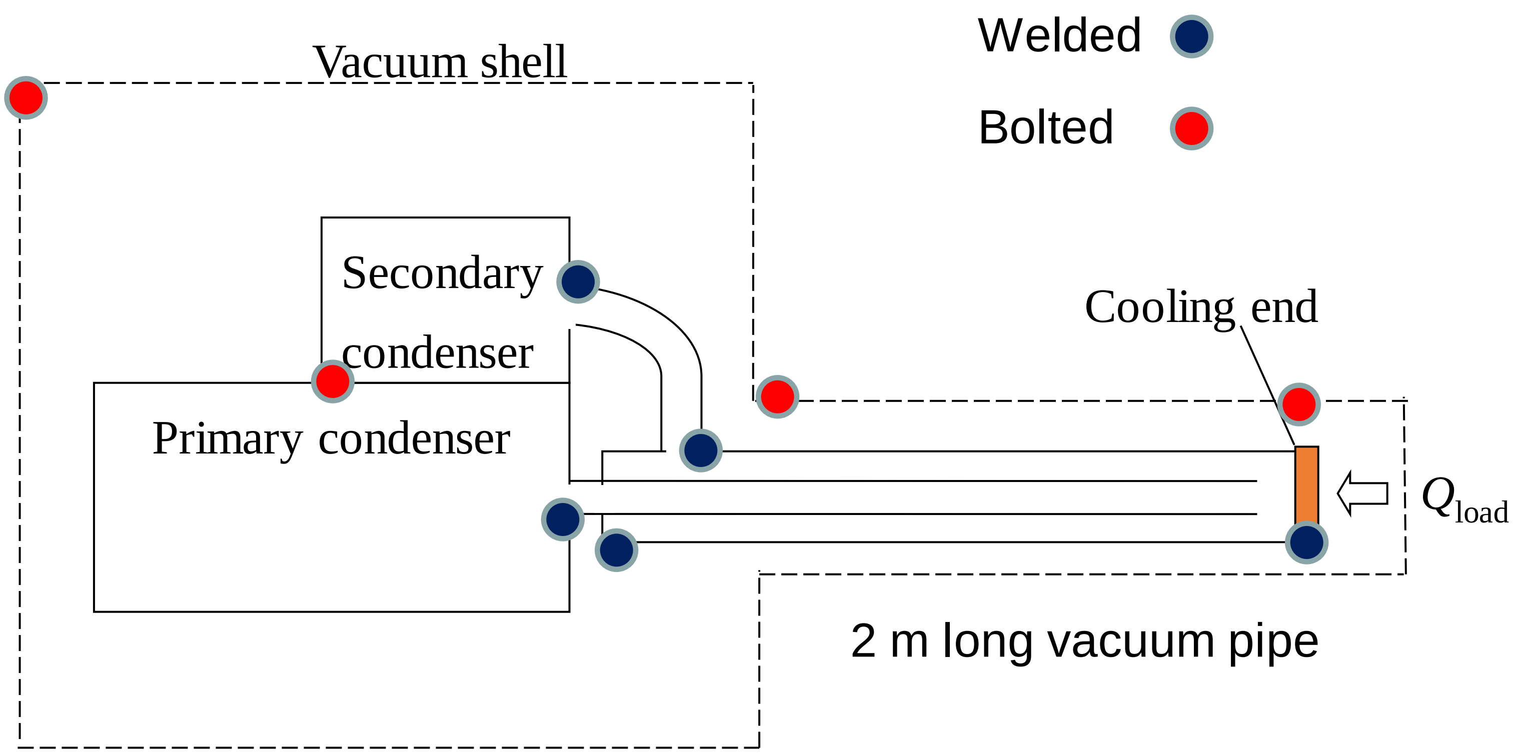


Energy balance: $$Q_{eva}+Q_{load}+Q_{para}=Q_{cond1}+Q_{cond2}$$

Heat transfer efficiency: $$\eta=\frac{Q_{load}}{Q_{eva}+Q_{load}+Q_{para}}=\frac{Q_{load}}{Q_{cond1}+Q_{cond2}}$$

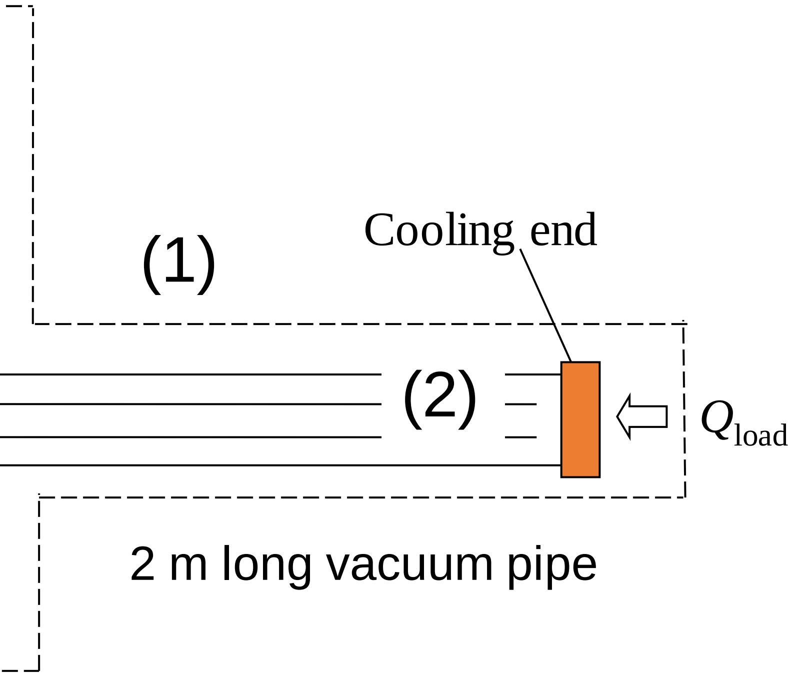
Design and fabrication of CRHD

CRHD with a vacuum shell



➢ Design and fabrication of CRHD

Advantage of such a design:

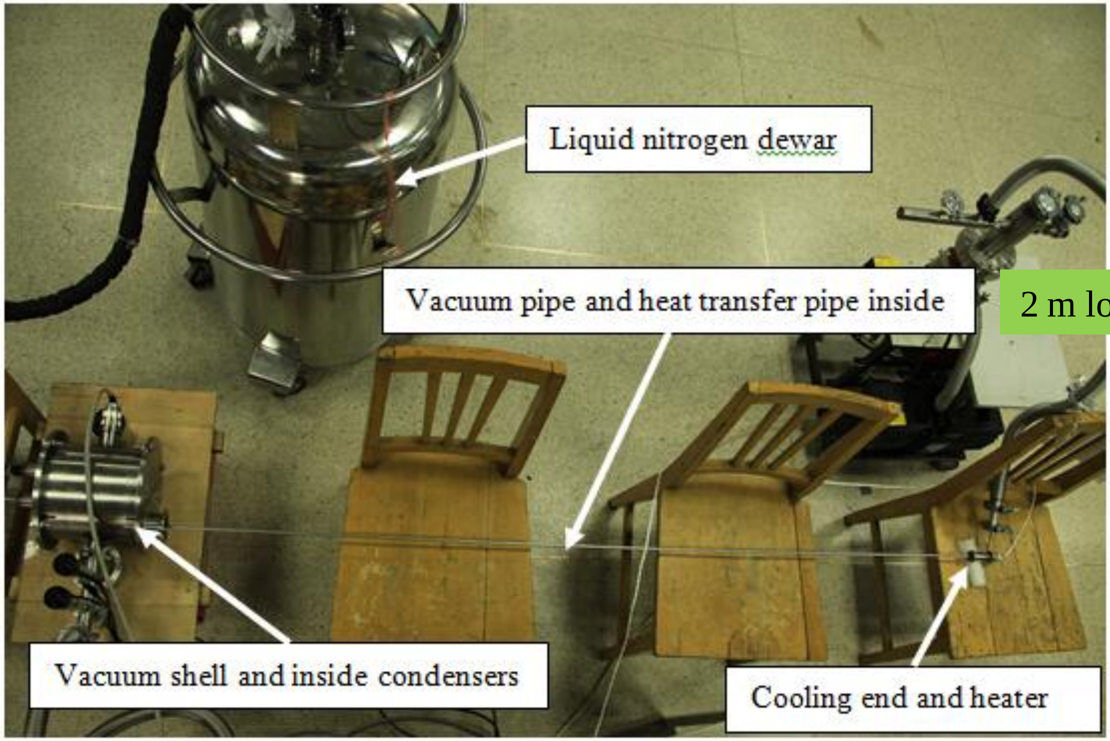


(1) Compactness: only a 6 mm in diameter pipe when looked at from outside

(2) Protecting liquid pipe: liquid pipe blocked from surrounding parasitic heat load by outer two-phase pipe

➢CRHD prototype

Left: cooling source, CRHD eva., cond.,
Middle: CRHD inner & outer pipe, vacuum pipe
Right: cooling end, heater

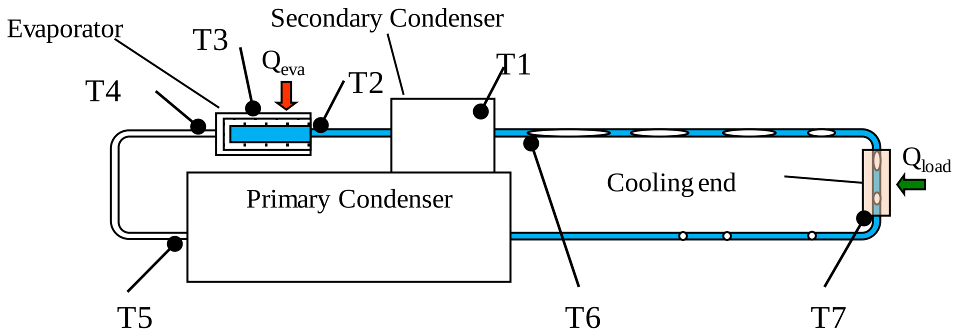


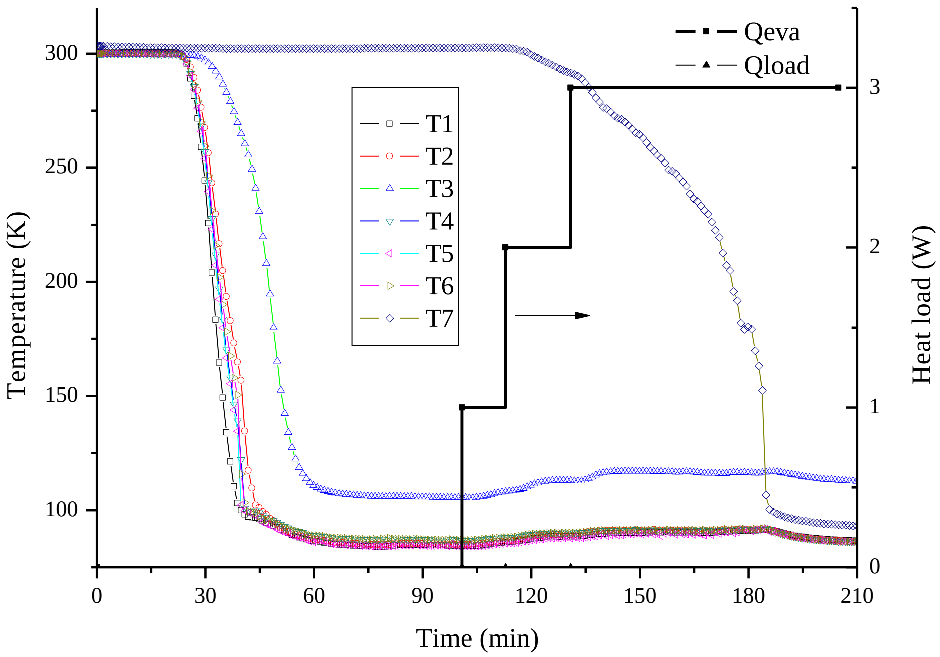
2 m long and 6 mm OD

➢ Experiment Procedure

•Charge a certain amount of nitrogen into the CRHD;
•Fill in liquid nitrogen to cool the cold plate and the condensers;
•After the evaporator is filled with liquid, apply a load Q_{eva} to the evaporator to push liquid from the primary condenser to the cooling end;
•After the cooling end is filled with liquid, apply a load Q_{load} to the cooling end, simulating a remote heat load from the cooling source;
•Change the operation parameters and study the temperature profile.

➢ Cooling down process

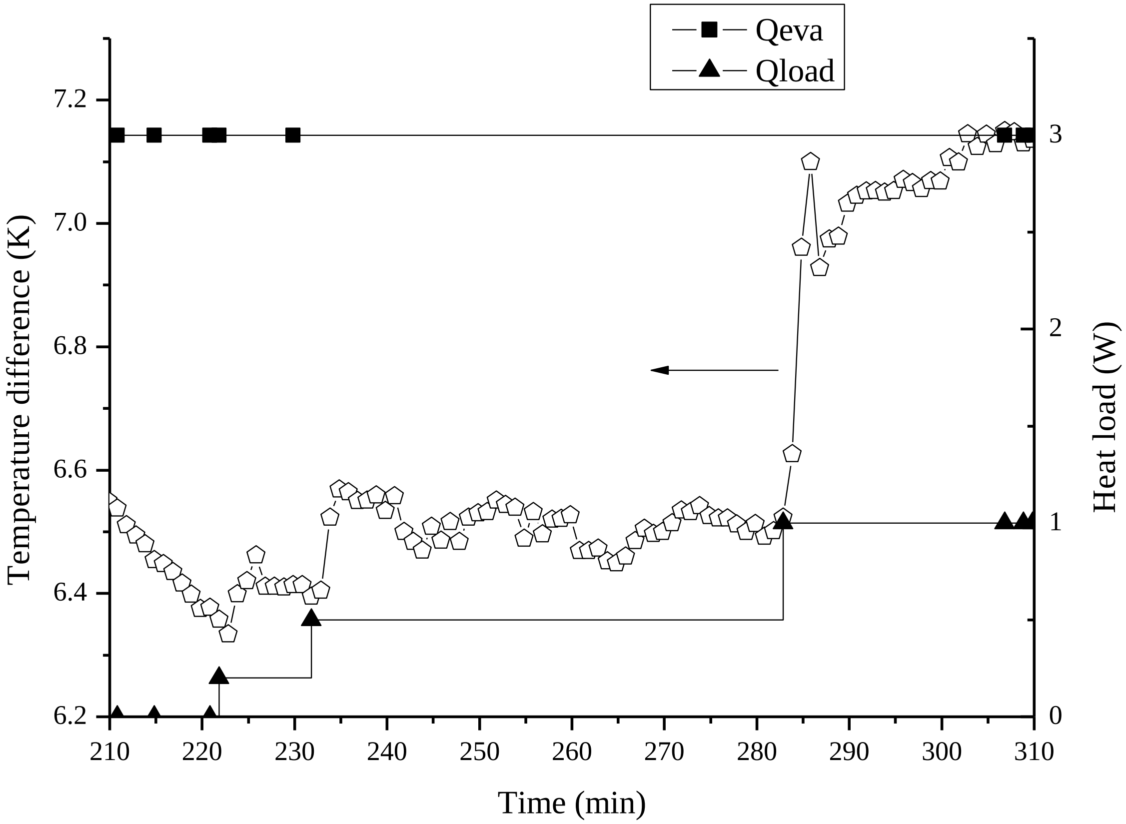




Temperature sensors arrangement

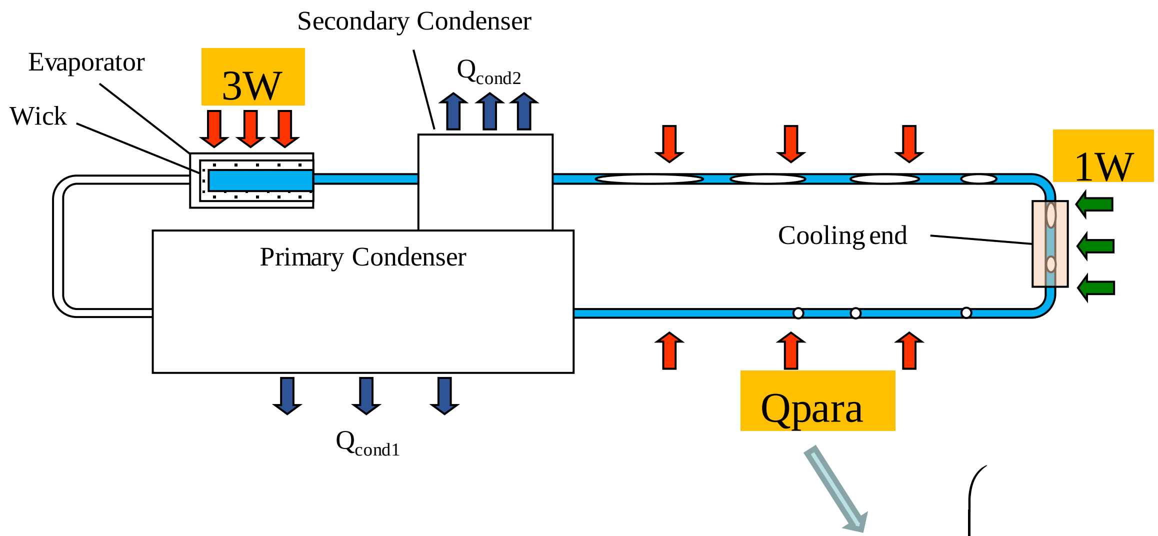
Cooling down process

➢ Loading process



Loading process

➢ Heat transfer efficiency calculation

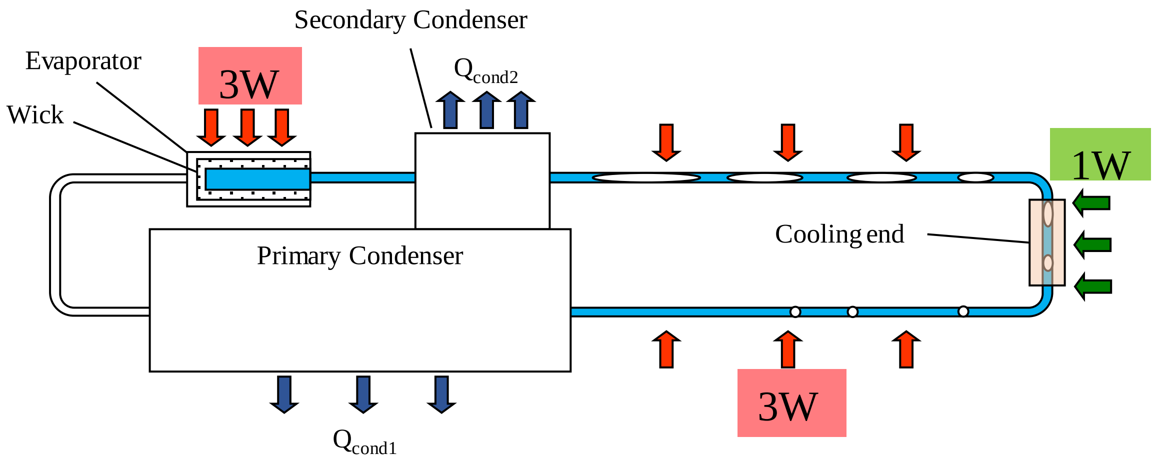


$$Q_{para} = \left(\frac{1}{\frac{1}{\varepsilon_{vp}} + \frac{1}{\varepsilon_{op}}} \right) A_{op} \left(T_{vp}^{\ 4} - T_{op}^{\ 4} \right)$$

~ 3W

$$\eta = \frac{Q_{load}}{Q_{eva} + Q_{load} + Q_{para}} = \frac{1}{3+1+3} \approx 14\% \ ☹$$

➢ Heat transfer efficiency calculation



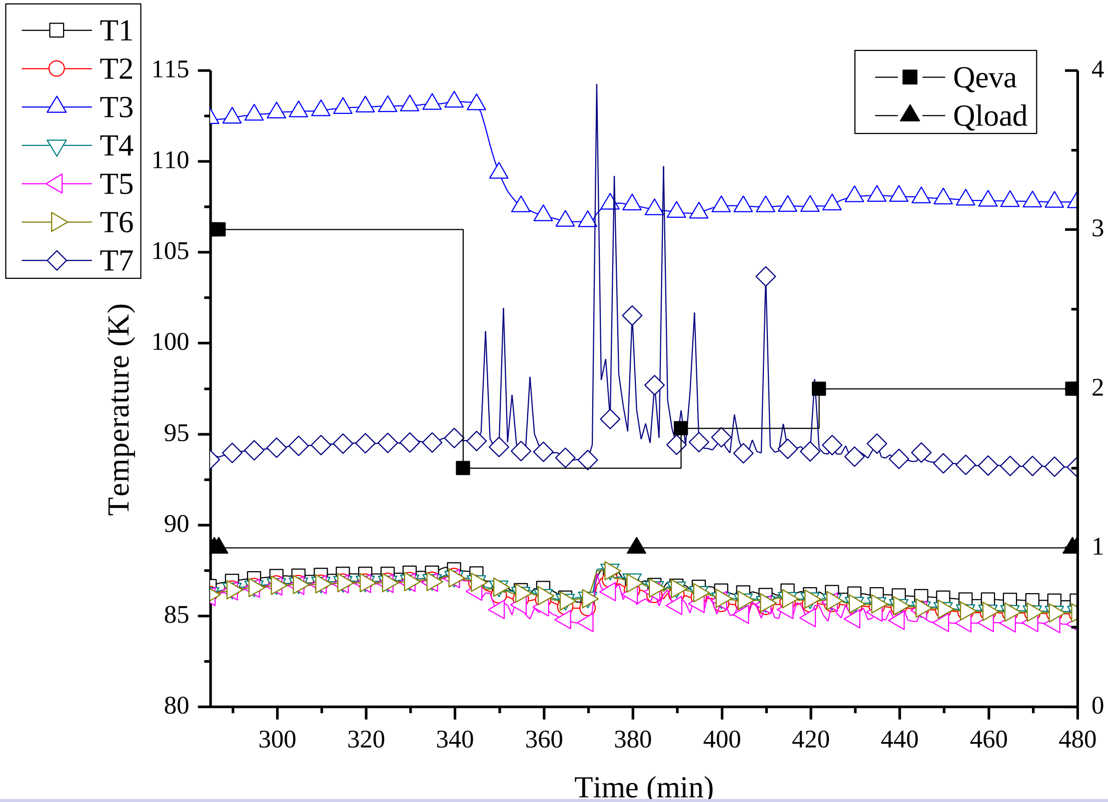
$$\eta = \frac{Q_{load}}{Q_{eva} + Q_{load} + Q_{para}} = \frac{1}{3+1+3} \approx 14\%$$ ☹

Two possible ways of increasing efficiency：

(1) decreasing evaporator heat load through loop pressure optimization;

(2) decreasing parasitic heat load through surface treatment

➢ Effect of evaporator heat load on stability



Cooling end temperature oscillates with a small Q_{eva} (< 2 W)

Therefore the most effective way is to decrease parasitic heat load!

➢ Conclusion

A CRHD prototype is designed, fabricated and tested , aiming at solving the problem of space/ground remote cooling and narrow space cooling at about 80 K. The fabricated CRHD prototype is capable of cooling power transfer over 2 m with a 5 mm in diameter pipe and a15 mm long cooling end.

- The CRHD prototype has a heat transfer efficiency of about 14%, which is to say, it can transfer 1 W of cooling power at about 80 K over 2 m at a cost of another 6 W of cooling power;
- Further improvement of the efficiency is expected through reducing the radiation heat load from the vacuum shell to the CRHD.

Thanks !

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