



**Technical Institute of Physics and Chemistry**  
CHINESE ACADEMY OF SCIENCES

# **Study on a miniature mixed-gases Joule-Thomson cooler driven by an oil-lubricated mini-compressor for 120 K temperature ranges**





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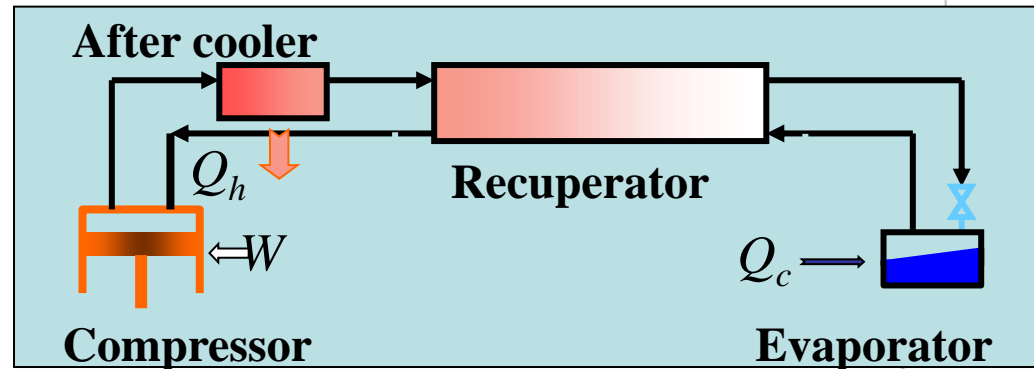
-  **Introduction**
-  **System configuration and testing facilities**
-  **Testing results**
-  **Summary**



# Introduction

## Background 1

- The Mixed-gases Joule-Thomson refrigerator (MJTR) has been widely investigated and used in many applications, especially those driven by oil-lubricated compressors.
- For many applications, the size and weight are crucial factors for the system design.
- Most efforts were made on the fabrication of the micro size recuperator.

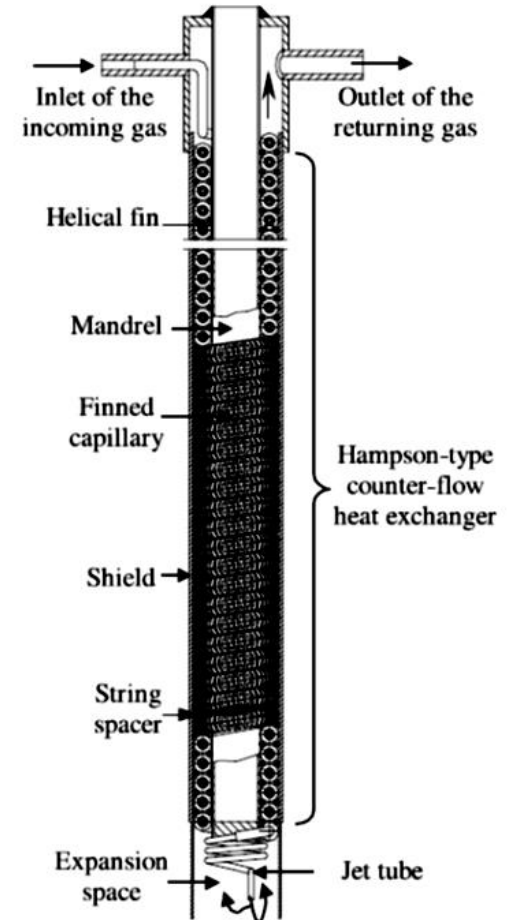
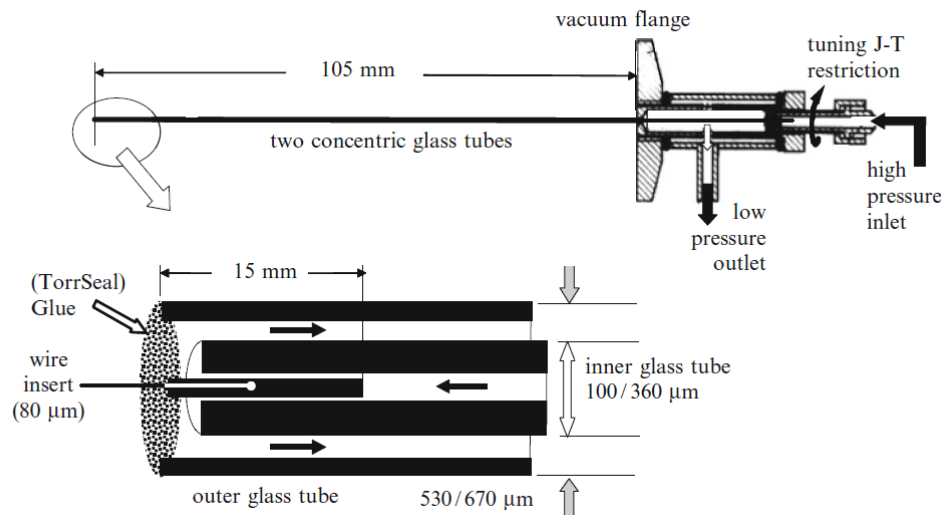


Single-stage mixed-refrigerant recuperative refrigeration cycle

# Introduction

## Background 2

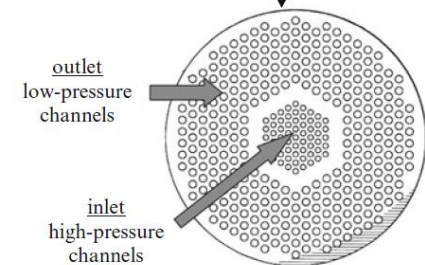
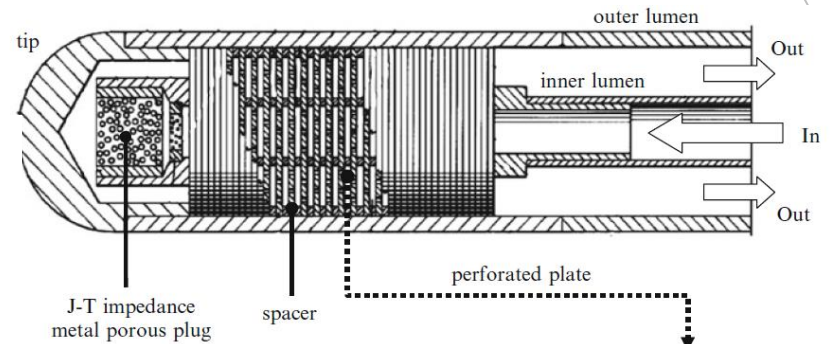
- The Linde-Hampson micro J-T cooler has been used decades with sub-millimeter flow passage sizes ranging from 100 to 1000  $\mu\text{m}$ .
- Micro size tube-in-tube J-T cooler



# Introduction

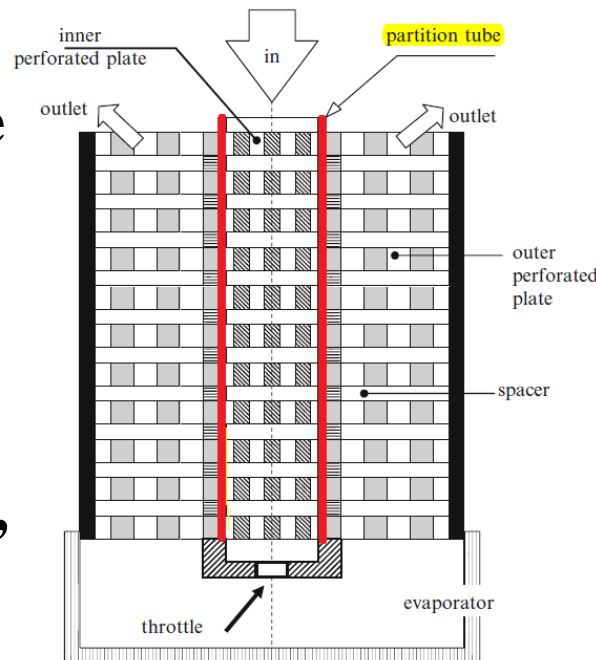
## Background 3

➤ The perforated plate micro heat exchanger show good prospects in micro J-T coolers.



**A thin steel tube**  
(Fill the perforated plate in the coaxial tubes, quite easy)

By Luo, Zhou,  
Gong, 1998



By Dobak, Radebaugh

1997

(vacuum brazing method)

# Introduction

## Background 4

**Oil-lubricated mini compressor:**

**Rotary**



**Reciprocating**



**Rotary**



**RuiYun  
Shenzhen, China**

**RuiYun**

**SECOP**

**Aspen**

**With DC power supply, all these are designed for electronic devices cooling or car refrigerator, etc...**



# Introduction

## In this work





Development and test a closed cycle J-T micro cooler operating with mixed-refrigerant using **an oil-lubricated mini-compressor**;

Fabrication and test of two kinds of recuperative heat exchangers: **tubes-in-tube type** and **plate-fin type** fabricated by the **wire-electrode cutting method**.

The focus of in this work is trying to make a micro cryocooler **with features of easiness to be fabricated and low cost**.



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# System configuration and testing facilities

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 **Miniature J-T cooler system configuration**

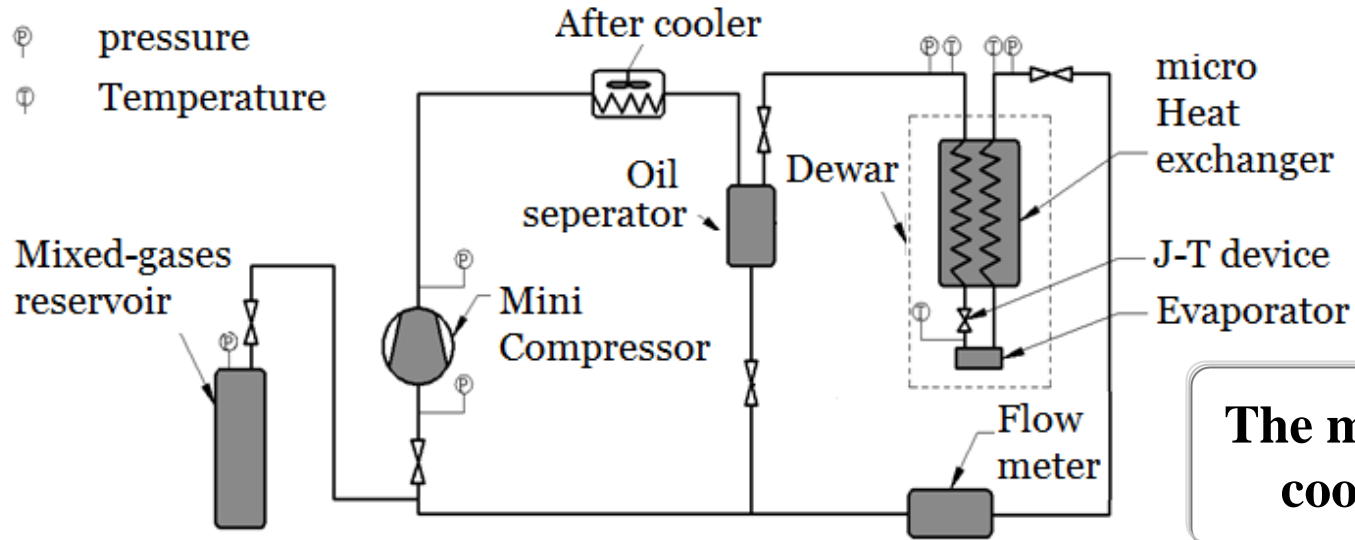
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 **Two kinds of micro heat exchangers**

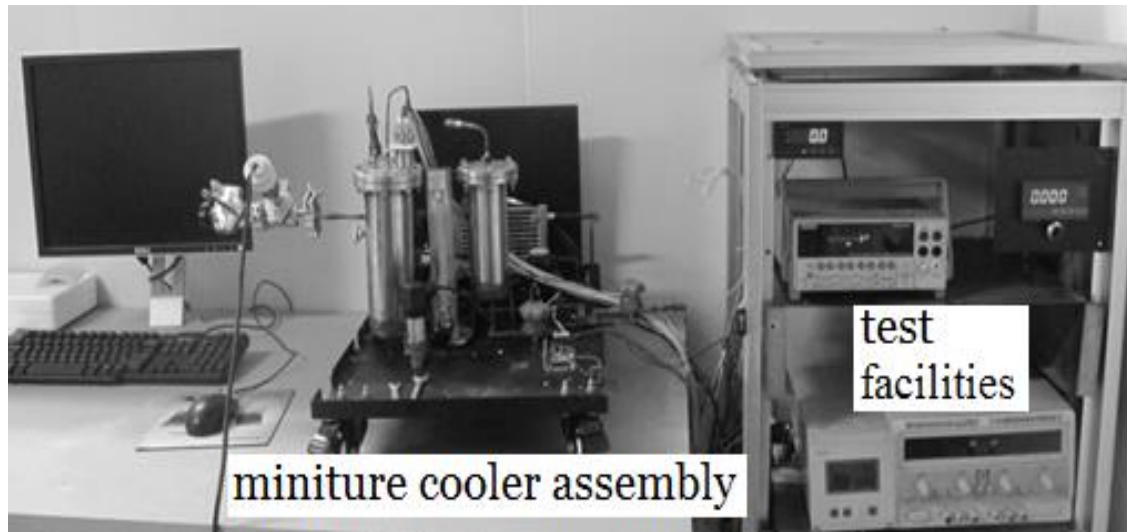
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# Miniature J-T cooler system configuration



**The miniature J-T cooler system**



**Photo of the experimental set up**



# Micro heat exchangers



**Tubes-in-tube type**

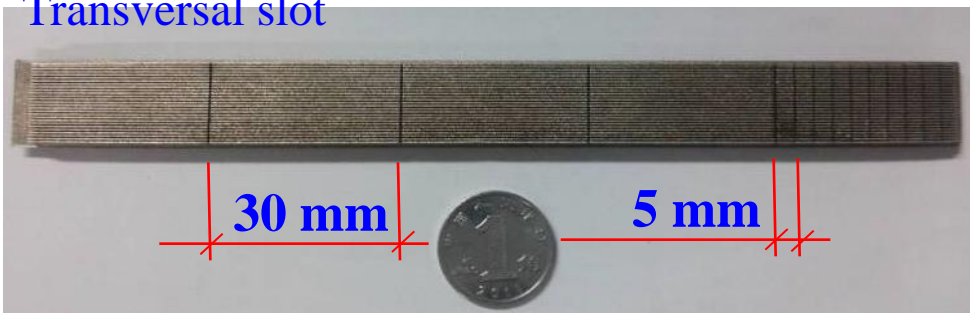
**Inner tube: ID/OD=300/500  $\mu\text{m}$**

**Number: 10**

**Outer tube: ID/OD=2/3 mm**

**Length: 800 mm**

**Transversal slot**



**Plate-fin core**

**Fin height: 3 mm for  $p_L$  passage**

**2.5 mm for  $p_H$  passage**

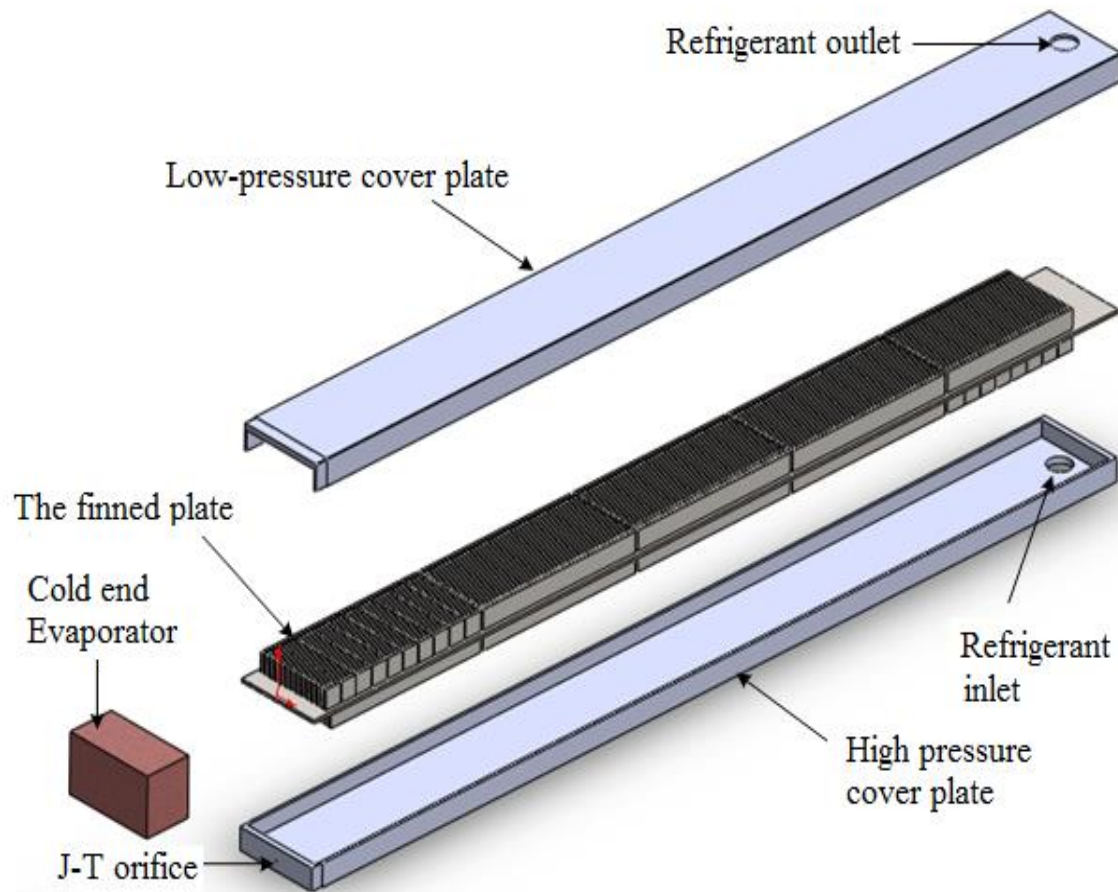
**Fin width: 0.3 mm**

**Fin Frequency: 2000/m**

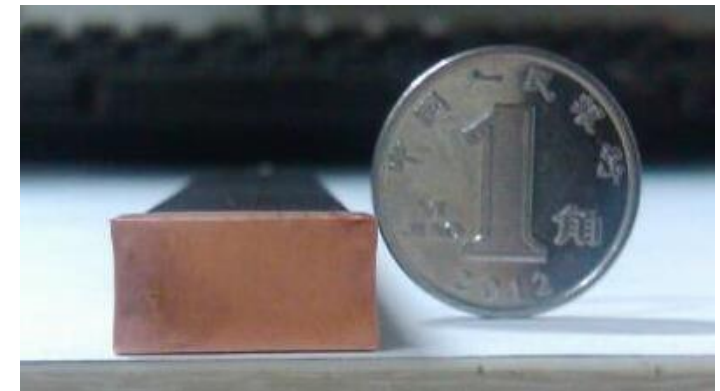
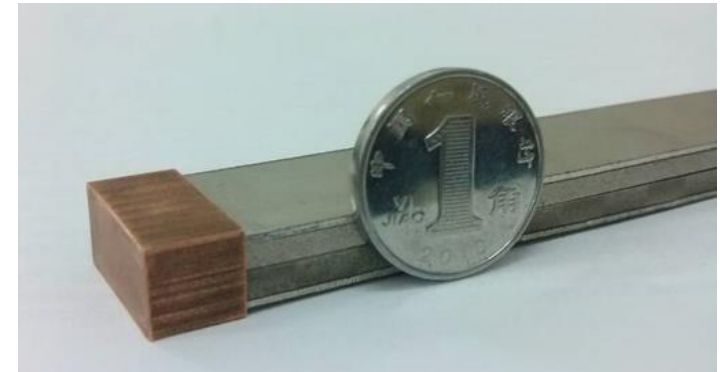
**Core length: 120 mm**



# Plate-fin heat exchanger



**Schematic of the plate-fin heat exchanger assembly**



**Photo of the plate-fin heat exchanger**

# Features of heat exchangers and mixtures

Heat Exchanger	Area (mm <sup>2</sup> )	Compactness (mm <sup>2</sup> /mm <sup>3</sup> )	Mixture	Composition (mole %)
<b>Tubes-in-tube</b>	7536 ( $p_H$ )	$1.33 \times 10^4$ ( $p_H$ )	<b>N<sub>2</sub></b>	22.78
	12560 ( $p_L$ )	$1.33 \times 10^4$ ( $p_L$ )	<b>CH<sub>4</sub></b>	32.38
<b>Plate-fin</b>	23925 ( $p_H$ )	$1.04 \times 10^4$ ( $p_H$ )	<b>C<sub>2</sub>H<sub>6</sub></b>	6.8
			<b>C<sub>3</sub>H<sub>8</sub></b>	20.9
	28275 ( $p_L$ )	$1.03 \times 10^4$ ( $p_L$ )	<b>iC<sub>4</sub>H<sub>10</sub></b>	17.2







# Measurement uncertainties

<b>Parameter</b>	<b>Apparatus</b>	<b>Range</b>	<b>Uncertainties</b>
<b>Temperature</b>	<b>PT100 type platinum resistance thermometers</b>	<b>52~300 K</b>	<b>0.1 K</b>
<b>Pressure</b>	<b>Pressure transducers (HY133, HuaYu company, China)</b>	<b>0.1~2.2 MPa</b>	<b>3.5 kPa</b>
<b>Flowrate</b>	<b>Glass floater flowmeter</b>		<b>1 %</b>
<b>Heat load and input power</b>	<b>DC power meter</b>		<b>1 %</b>

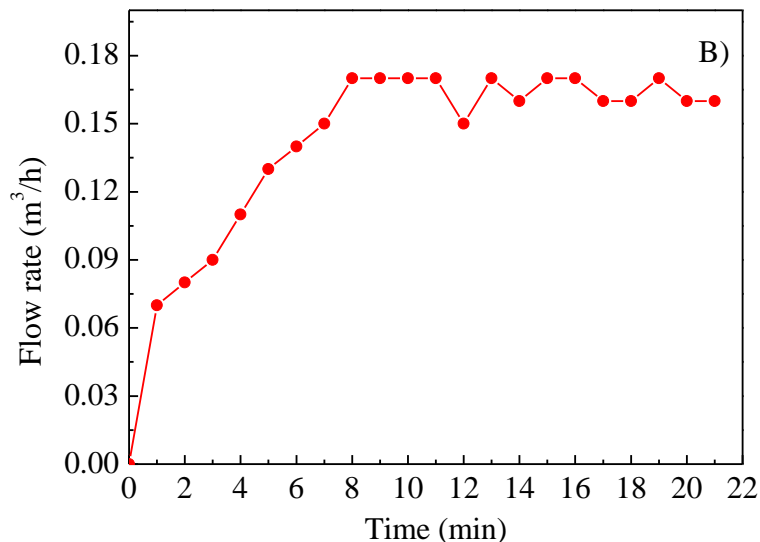
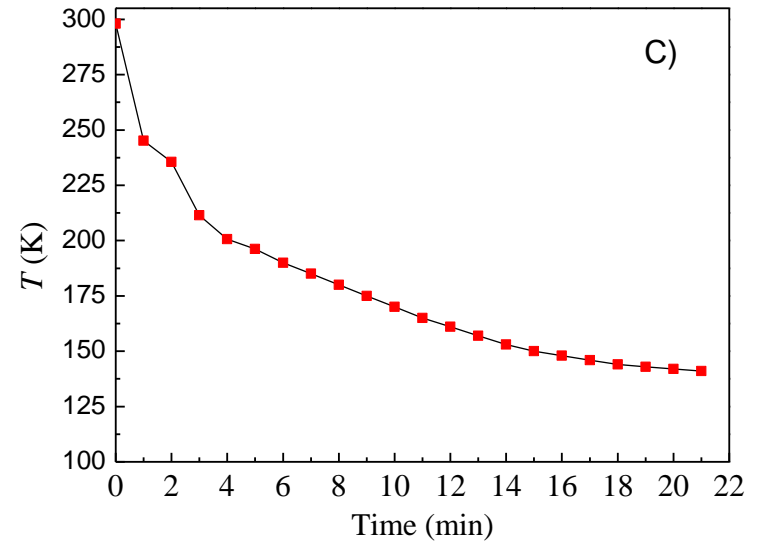
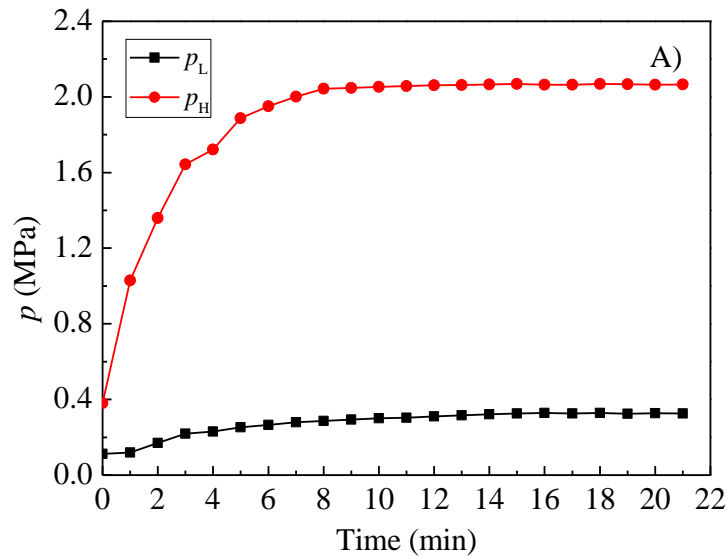


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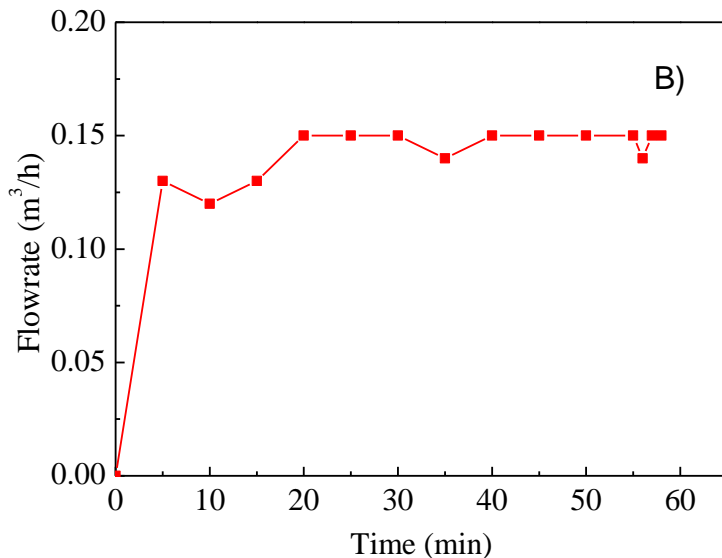
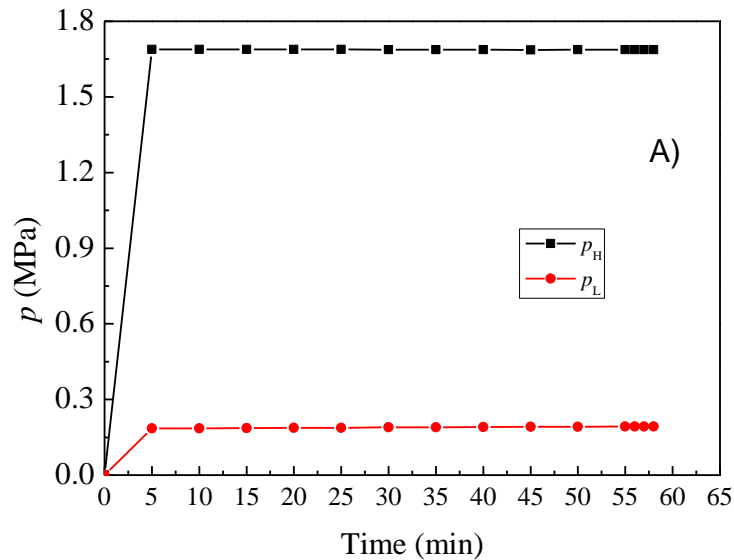
# The tubes-in-tube J-T cooler



1. A steady minimum temperature without heat load of **140 K** was reached.
2. The operating pressure ratio is around **6.5**.
3. The electric current of the **24 V DC** power source is ranging from **3.5 to 4 A**.

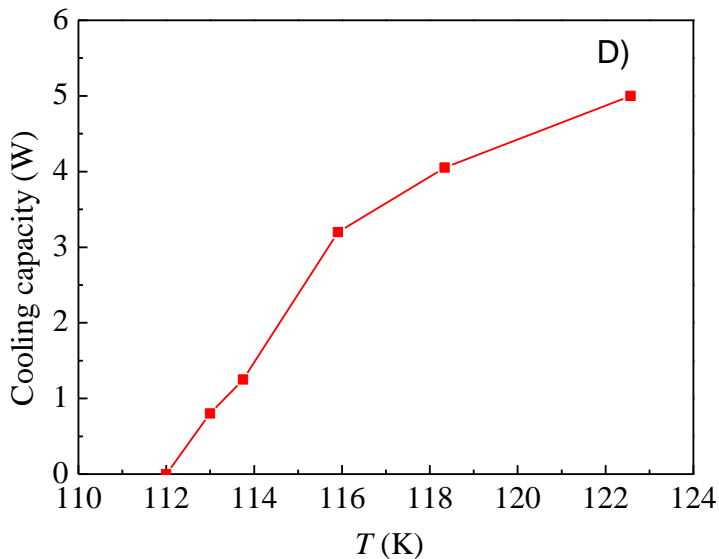
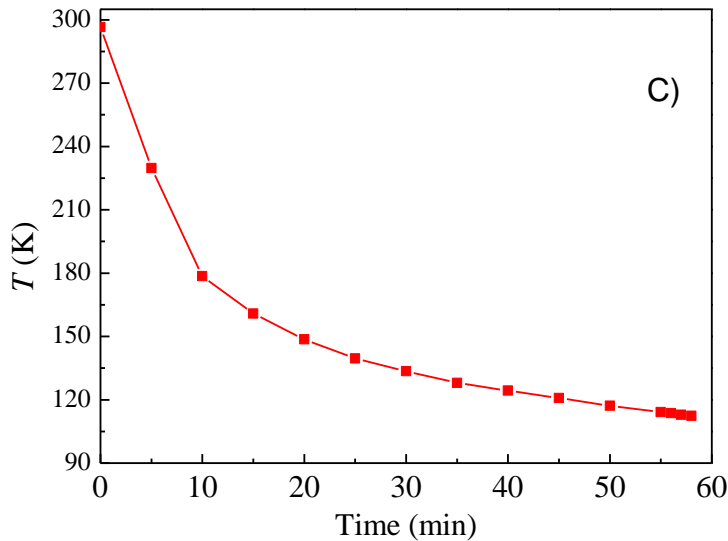


# The plate-fin micro J-T cooler



1. The operating pressures for this cooler are quite constant.
2. The pressure ratio is around **8.8**, relatively larger than that of the tubes-in-tube cooler.
3. The high pressure is around **1.7 MPa**, while the low pressure is **0.19 MPa**.
4. The flowrate is about **0.15 m<sup>3</sup>/h**, which is also a little less than that of the tubes-in-tube cooler.





# The plate-fin micro J-T cooler



1. The cooler takes about almost 1 hour to reach the lowest temperature of **112 K**.
2. We got **4 W** at **118 K**, while the DC electric current at this condition is about **4.5 A**.
3. The heat capacity of the plate-fin cooler is larger than that of the tubes-in-tube J-T cooler.
4. The cooling down speed is a little lower than that of the tubes-in-tube J-T cooler.



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# Summary

## 1

**A miniature mixed-refrigerant J-T cooler testing set up was built, in which a mini oil-lubricated rotary compressor was used.**

**Two micro J-T coolers were designed and tested. One is a tubes-in-tube J-T cooler reaching the lowest temperature of **140 K**. Another is a plate-fin J-T cooler fabricated by the wire-electrode cutting method.**



# Summary

## 2

**For the plate-fin J-T cooler, the lowest temperature without heat load temperature of 112 K, and 4 W at 118 K were obtained.**

**The results obtained in this work indicate that the miniature mixed-refrigerant J-T cooler for cryogenic temperature applications can be driven by commercialized mini compressors with good prospects.**





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**Thanks for your attention!**