

# Methods of filling the heat pipes

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**Abstract.** The paper deals with individual methods of filling heat pipes methods (filling by evaporation of the working fluid, filling by vacuuming of working fluid, freezing of working fluid – vacuuming). The second part of the paper is devoted to the comparison of the power of heat pipes after filling by individual methods.

## 1 Filling of heat pipes

The heat pipe may be filled in several ways to compare the extent to which the way the heat pipe function is affected. In all filling methods, distilled water is used as the working fluid, due to its availability and good thermophysical properties. For each filling method, the tube will be filled three times [1].

### 1.1 Filling by evaporation of the working fluid

This method of filling is followed by the total weight of the heat pipe.

- Check the weight of the heat pipe in the empty state, calculating the total volume according to the relationship (1), and determining the required quantity of the working fluid from it. Usually it is 15 % to 25 % of the total volume [2].

$$V = \pi \cdot r^2 \cdot v \tag{1}$$

- Fill the tubes with a syringe at a higher value than required.
- Verify weight after filling. The difference in weight before and after is the amount of working medium in the tube.

Fill of heat pipe:

Required quantity of working fluid

16.25 ml – 25 %

The tube placed on the weight is filled to:

24 ml – 37 %  $\leftrightarrow$   $m_{37\%} = 532.4$  g

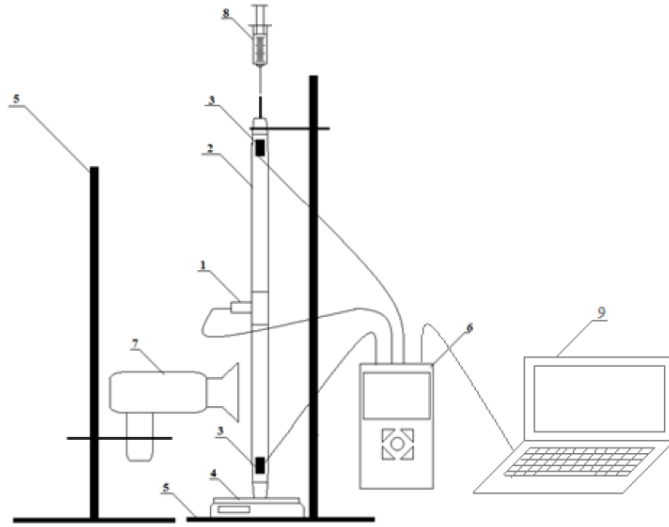
Weight of heat pipe after filled to 25 %

$V = V_{37\%} - V_{25\%} = 25 - 16.25 = 7.75$  ml  $\leftrightarrow$   $m_0 = 7.75$  g

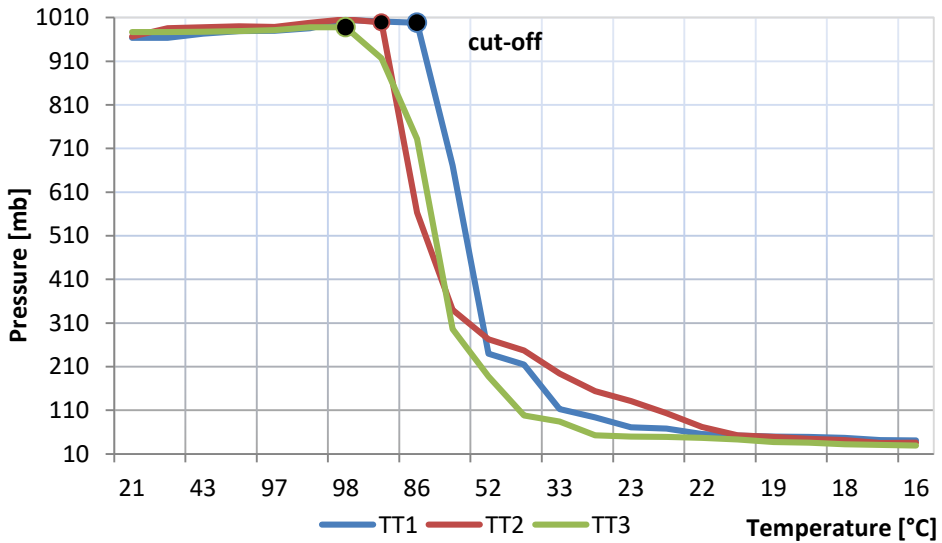
$m_{25\%} = m_{37\%} - m_0 = 532.4 - 7.75 = 524.65$

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**Fig. 1.** Evaporation filling scheme 1) ALMEMO pressure sensor, 2) heat pipe, 3) temperature sensor, 4) weight KERN KB, 5) stand, 6) data logger ALMEMO 2890-9, 7) hot air gun, 8) Syringe, 9) PC.



**Fig. 2.** Pressure in heat pipe during filling.

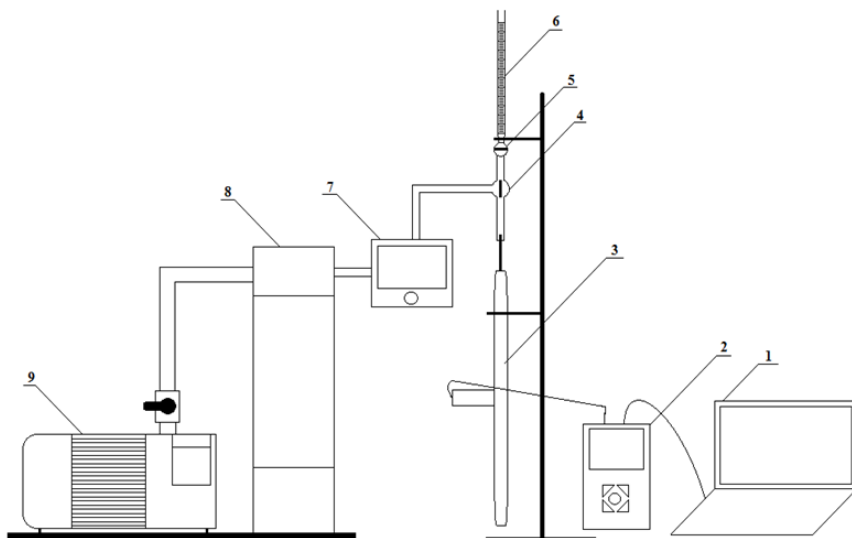
During filling TT1, the pressure dropped to 41 mb, TT2 to 32 mb and TT3 dropped to 21 mb. The evaporation and subsequent closing times vary depending on the amount of working medium in the tube, the heating intensity and the room conditions.

## 1.2 Filling by vacuuming of working fluid

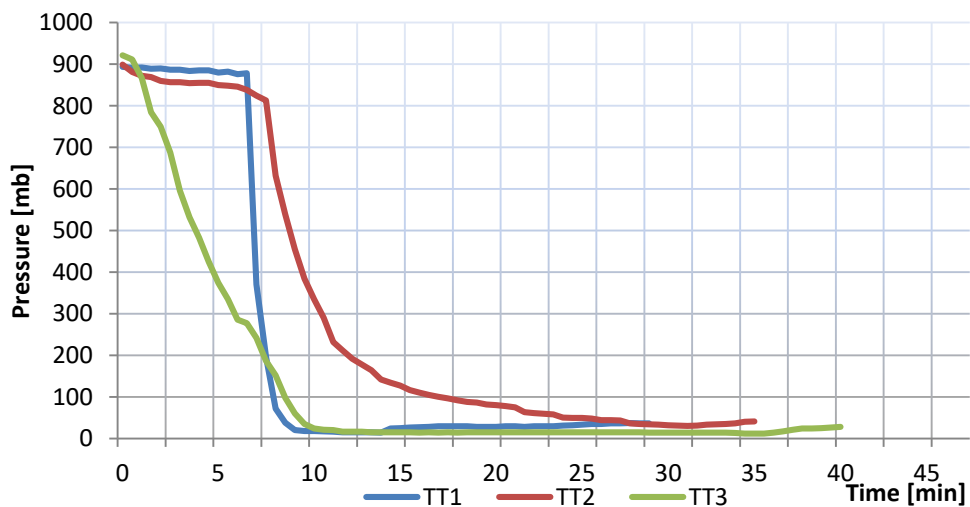
This method is based on the principle of extracting air from the heat pipe by rotary vacuum pump via the container with liquid nitrogen [2].

### Fill of heat pipe:

- The heat pipe is connected via a three-way valve to the metering vessel with the working fluid and the pump. The exchanger is connected to a container with liquid nitrogen to which a pressure meter is attached.
- The three-way valve is fully open. The pressure on the pressure gauge is monitored when it drops to a value close to 0 hPa. The three-way valve is switched so that the paths between the tube and the measuring vessel are permeable. Fill in the required amount that you calculate in the same way as in the first method.
- After filling, the filling tube is pressed and begins to start.



**Fig. 3.** Scheme of filling by vacuuming of working fluid 1.) PC, 2) data logger ALMEMO 2890-9, 3) heat pipe, 4) three Way Valve, 5) valve, 6) measuring Tank, 7) pressure gauge, 8) container with liquid nitrogen 9) vacuum pump.



**Fig. 4.** Pressure in heat pipe during filling.

The vacuuming time for each tube varied between TT1: time - 32min, pressure - 36mb, TT2: time - 36min, pressure - 42mb and TT3: time - 41mi, pressure - 28mb. Room temperature at 18 °C.

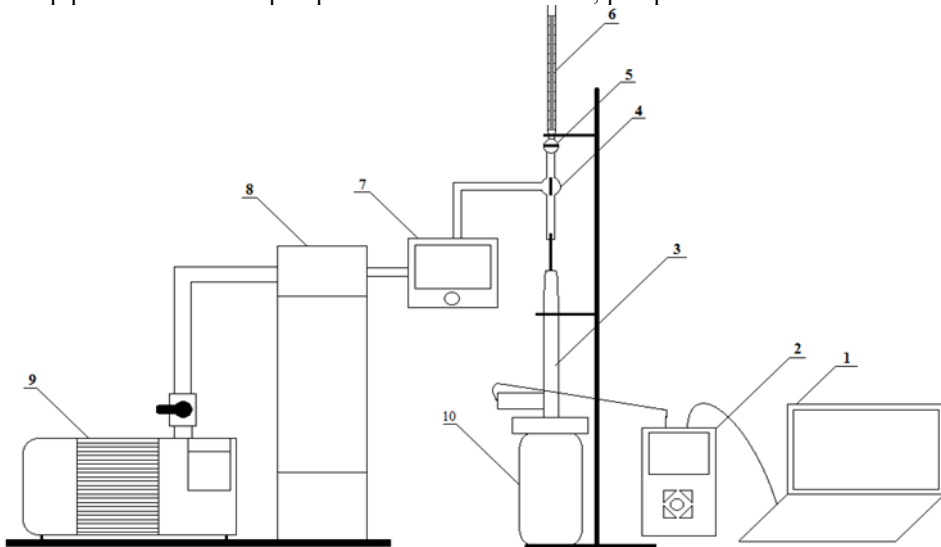
During the measurement, the vacuum pump was cleaned, exchange the starter capacitor, the overload coil and the winding of the motor were changed. Despite these measures, we did not achieve the required pressure in the tubes, the pump overheated and lost the pull during suction.

### 1.3 Freezing of working fluid - vacuuming

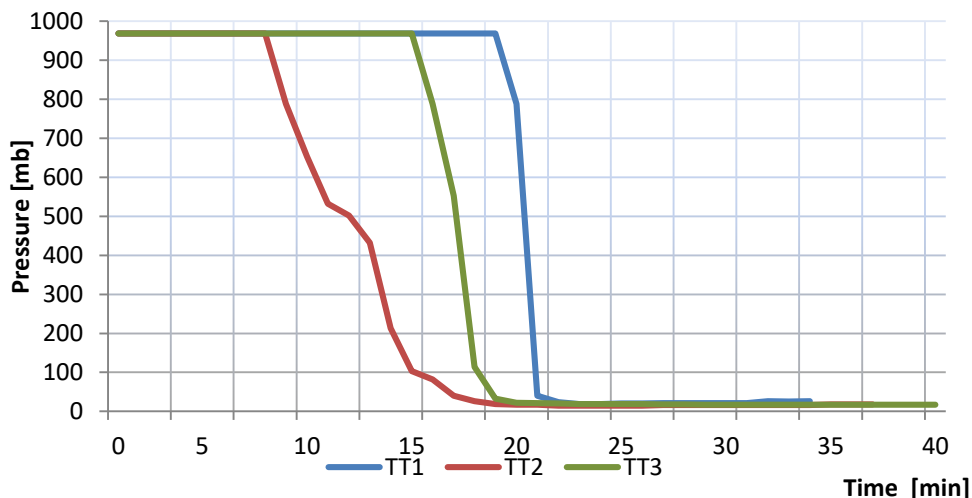
It works on a similar principle as the “filling by vacuuming of working fluid”, with the difference that the tube is filled with the exact amount of the working fluid. The working fluid is freeze and the air is pump out of the tube [2].

Fill of heat pipe:

- The tube is filled to the required amount, calculated as in the previous methods.
- Using liquid nitrogen is a cooled thermo-insulating vessel, after cooling, returns the nitrogen to the dewar vessel. Put the tube into the thermal insulator, lock it off with a 20 minute insulating plug.
- The pipe connects to the pump as in the second method, pump out the air and closed.



**Fig. 5.** Scheme of working fluid – vacuuming 1) PC, 2) data logger ALMEMO 2890-9, 3) heat pipe, 4) three-way valve, 5) valve, 6) measuring vessel, 7) Pressure gauge, 8) container with liquid nitrogen 9) vacuum pump, 10) thermo-insulating vessel.



**Fig. 6.** Pressure in heat pipe during filling.

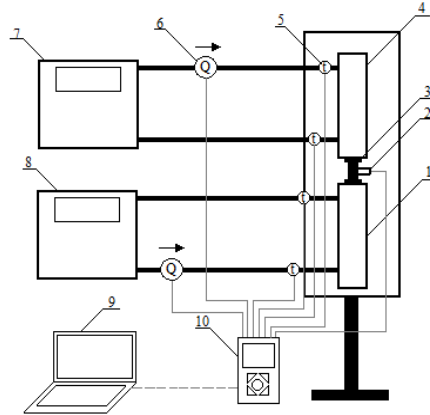
The time of filling of the suction tubes was different TT1: 32 min, pressure-26 mb, TT2: 36 min, pressure 18 mb, TT3: 40 min, 17 mb. Room temperature during filling of 19 °C.

## 2 Testing the power of different types of heat pipes

Power measurement was implemented at 0°, 15°, 30°, 60°, 90°, and it was repeated several times in order to achieve the most accurate results.

Measurement procedure:

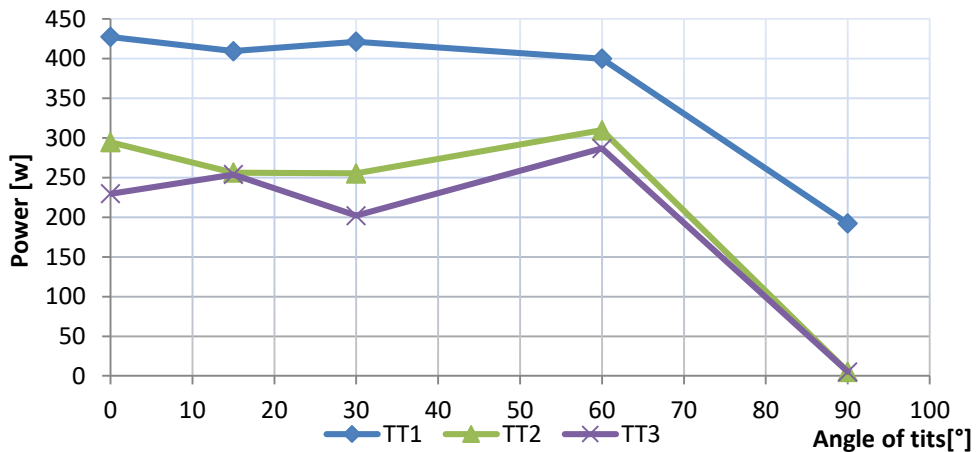
- Set operating position 0°.
- Set JULABE to 80 °C.
- Record input and output temperatures along with flow rates every 10 seconds for 20 minutes (heating and cooling).
- When the measurement is complete, the device turns off. Close the hot water supply and open the cold water inlet. Cool the system to 30 °C.
- After cooling, a new working position of 15° is set and the measurement is repeated from point 2.



**Fig. 7.** Scheme for testing power of heat pipes. 1) heating part, 2) pressure sensor ALMEMO, 3) heat pipe, 4) cooling part, 5) temperature sensor, 6) flow meter ALMEMO, 7) JULABO for cooling 20 °C water, 8) JULABO heating 80 °C water, 9) PC, 10) data logger ALMEMO 2890-9.

In the first method filling (Figure 8) heat pipe TT1 reached higher performance than heat pipe TT2 and TT3, which have about the same power range. The TT2 and TT3 were measured on a modified measuring device, while the TT1 tube on the original device. By more accurate results, the measurement device passed through the adjustment. This is also seen when comparing TT1 with TT2 and TT3. Several measurements were made on the original device to confirm that the device must be edited. Only one of these measurements was selected to indicate the problem [3].

The device has been modified to prevent flow changes due to hose wounds when adjusting work positions and to allow better temperature sensing. The treatment concerned the heating section, where hoses and valves were replaced by water-jet galvanized fittings.



**Fig. 8.** Power of heat pipes filled by first method.

The TT1, TT2 and TT3 heat pipes of the second fill method (Figure 9) had similar performance ranges. In the TT2 heat pipe, the power dropped sharply at 15° from 214 W to 136W.

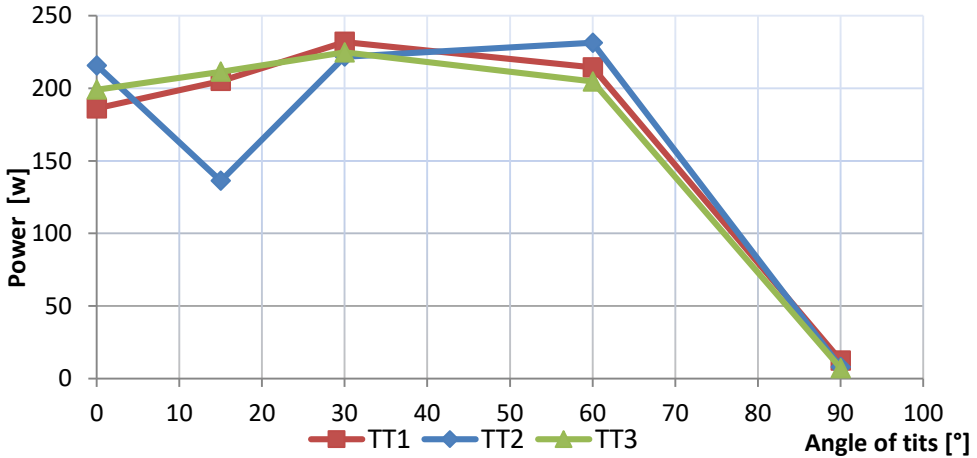


Fig. 9. Power of heat pipes filled by second method.

The TT3 heat pipe curve for the third filling method (Figure 10) has a decreasing character all the time, the performance achieved is significantly lower than that of the TT1 and TT2 heat pipes even though the best parameters have been reached during the TT3 heat pipe.

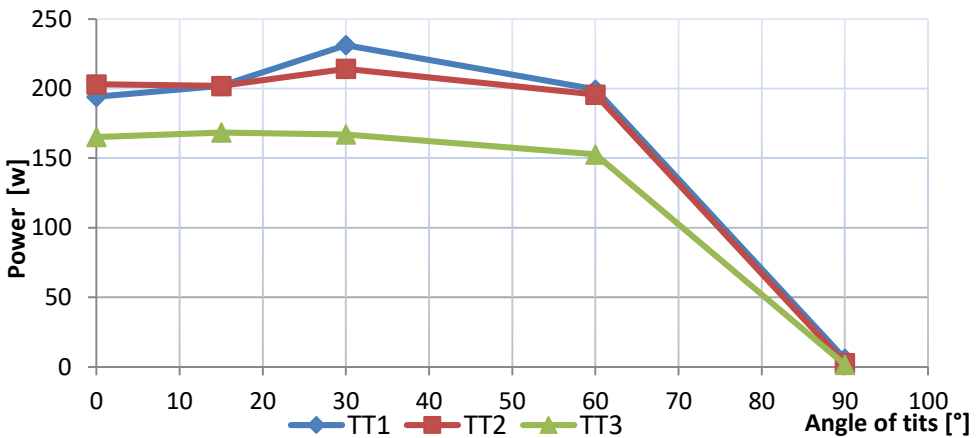


Fig. 10. Power of heat pipes filled by third method.

### 3 Evaluation of results

First method of filling (Filling by evaporation of the working fluid): The average pipe outputs are: TT1 = 413.5 W, TT2 = 279 W and TT3 = 243 W. The heat pipe TT1 was measured on the original measuring device. It points out that the measuring device has to be adjusted to achieve the most accurate results. The heat pipe TT2 had a higher power output of 36W even though the initial pressure was higher by 10 mb than heat pipe TT3.

Second method of filling (Filling by vacuuming of working fluid): In this method of filling, the average power of all three heat pipes was approximately equal to TT1 = 209.4W, TT2 = 201.3 W and TT3 = 210 W their outputs varied by an average of 5.2 W. In heat pipe TT1 and TT3, the smallest difference in power of 0.6 watts occurred with an initial pressure difference of 8 mb.

Third method of filling (Freezing of working fluid - vacuuming): In the third method of filling, the smallest performance was achieved. At heat pipe TT3, the lowest power was achieved at 163 W on average. These low power values can be caused by air bubbles created in the tube when they freeze the working fluid, which after thawing, has increased the internal pressure.

**Table 1.** Comparison of the power of heat pipes after filling by individual methods.

TT	1. filling method			2. filling method			3. filling method		
	TT1	TT2	TT3	TT1	TT2	TT3	TT1	TT2	TT3
0°	423.4	294.6	229.6	186.2	215.7	199.1	194.0	203.1	165.3
15°	409.4	256.3	253.8	205.0	136.2	211.4	202.0	201.9	168.5
30°	421.3	255.3	202.0	232.0	221.8	224.8	231.2	214.2	167.0
60°	399.9	309.7	286.6	214.4	231.4	204.7	199.4	195.6	152.7
90°	192.1	5.1	5.2	12.3	7.9	7.1	5.8	2.6	1.5

## 4 Conclusion

The filling technology also has a big influence on the heat pipe performance. Based on the different filling methods (filling by evaporation of the working fluid, filling by vacuuming of working fluid, freezing of working fluid – vacuuming) and the number of repetitions of each filling method, it was found that the best values of the transmitted power were achieved in the first filling method (filling by evaporation of the working fluid). The advantage of this method is that it is not as technologically demanding as other methods of filling. In the second filling method more accurate results would be obtained in the case of a better vacuum pump condition.

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