Pump Assisted Heat Pipe

By

Yoshiro MIYAZAKI and Shigeto OSHIMA

(February 5, 1987)

Summary: A laboratory model of a pump assisted heat pipe has been fablicated and tested.

An arterial heat pipe with axial grooves and a gear pump with a magnetic coupling have been developed for the model.

The test has been carried out successfully.

The reasonable thermal conductance has been obtained so far as the necessary working fluid flow rate is supplied. The necessary flow rate exceeds the theoretical one and the excess flow rate increases as the heat load increases.

1. INTRODUCTION

Advanced future thermal systems for spacecrat are needed to transport large heat loads over long distances with minimal power requirements. The demand for larger capacity and higher efficiency has led to two phase heat transport systems, in which heat is transfered as a latent heat of the circulating fluid.

Motivated by the needs for two phase heat transport systems, several types of the systems have been proposed and some of them have been under development. A pump assisted heat pipe is one of the proposed systems and it appears quite promissing [1].

The present work is ateempt to asses the potential of the pump assited heat pipe experimentally.

2. PUMP ASSISTED HEAT PIPE

2.1 Conceptual Design

A pump assisted heat pipe system is shown in Fig. 1 schematically. The basic design of the system consists of a looped heat pipe and a pump. The loop consists of an evaporator section, a condenser section, a vapor transport line and a liquid return line. The pump, which is installed in the liquid return line, supplies a head to circulate the working fluid. The reservoir is also installed in the liquid return line and it controlls a pressure level and amount of the working fluid of the loop.

The laboratory model is illustrated in Fig. 2. The evaporator and the condenser are arterial heat pipes of 200 mm in length. On one end of the heat pipe, a sight glass, through which working fluid is observed, is provided. The evaporator has an electrical

---

* Toshiba Corp.

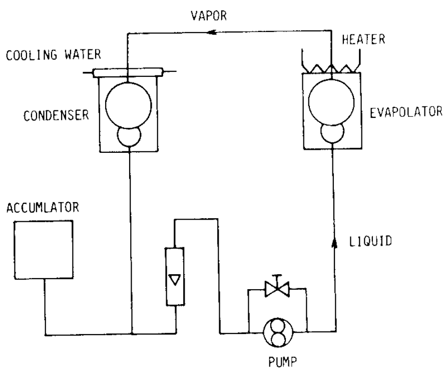

Fig. 1. Pump Assisted Heat Pipe.

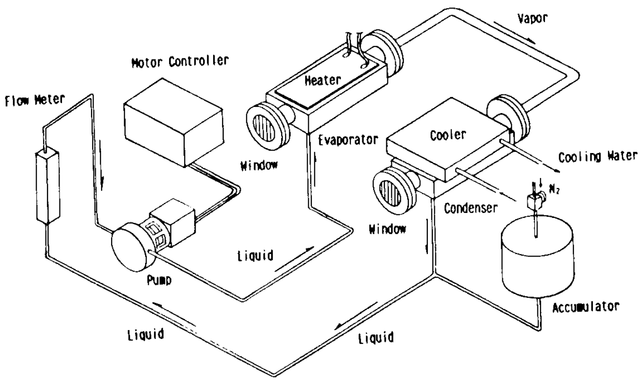

Fig. 2. Laboratory Model.

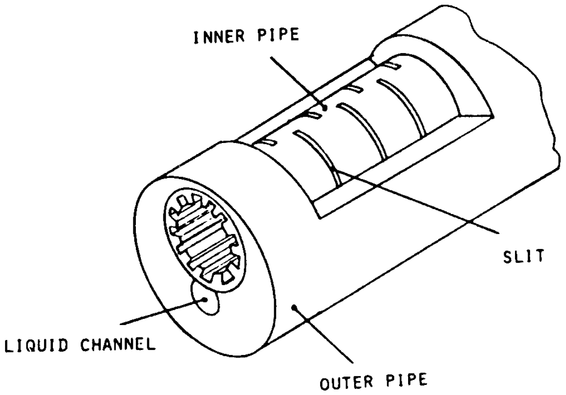

Fig. 3. Heat Pipe Construction.

heater which supplies specified heat load. In order to prevent heat leak to ambient air, the evaporator is thermally insulated. The condenser has a water cooling plate.

The evaporator and the condenser are set horizontal and the liquid channels are directioned downword. The configuration is taken in order to realize the same liquid distribution in the pipes as that under non-gravity field.

Working fluid is Freon R11.

2.2 Arterial Heat Pipe

An arterial heat pipe is used for the laboratory model as an evaporator and a condenser. It has a double pipe construction as shown in Fig. 3. The outer pipe provided with two axial channels is a container and the inner pipe is inserted into the larger channel. The inner pipe is provided with axial grooves and circumferential slits. Owing to this construction, the heat pipe has two axial channels, the larger one with a grooved wall and the smaller one with a smooth wall. The larger one is a vapor core and the smaller one is a liquid channel. The grooves communicates with the liquid channel through the slits.

This type of an arterial heat pipe has been tested for ammonia working fluid and the design concept has been confirmed [2].

According to the working fluid change from ammonia to Freon R11, some design changes have been taken.

Table 1. Specification of the Heat Pipe

Pipe Material	A-6063
Heat Pipe Length	200 mm
Liquid Channel ID	5 mm
Vapor Core ID	8 mm
Groove Width	0.25 mm
Groove Depth	0.5 mm
Groove Number	50
Slit Width	0.25 mm
Slit Pitch	33 mm

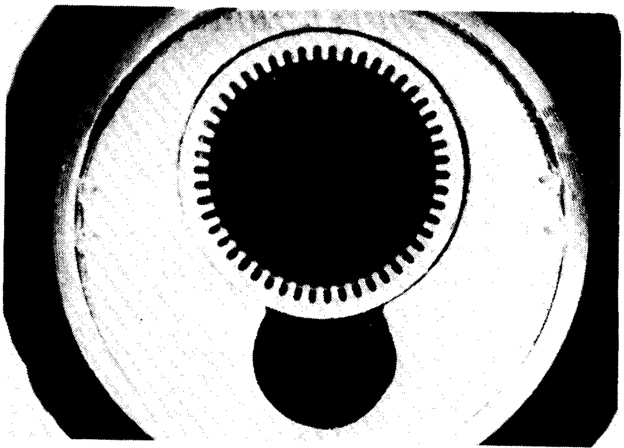

Fig. 4. Sectional View of the Heat Pipe.

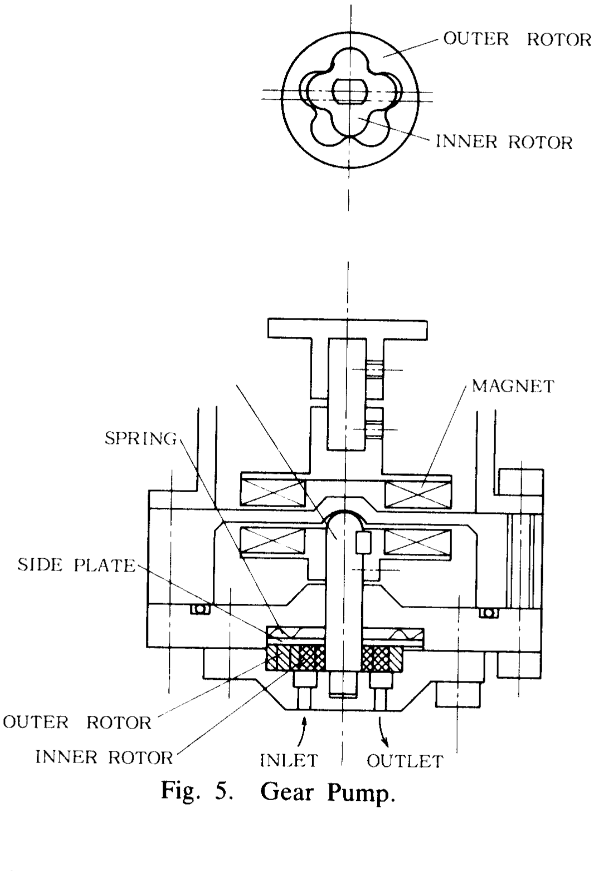

Fig. 5. Gear Pump.

Major specification for the heat pipe are shown in Table 1.

The sectional view photograph to the heat pipe is shown in Fig. 4, in which the meniscus of the liquid on the grooves is shown.

2.3 Pump

The pump for a two-phase heat transport system drives the liquid whose temperature is close to the saturation one. Therefore, good characteristics with respect to cavitation is of importance. Considering the condition, a gear pump has been chosen for the pump assisted heat pipe system. The pump developed for the

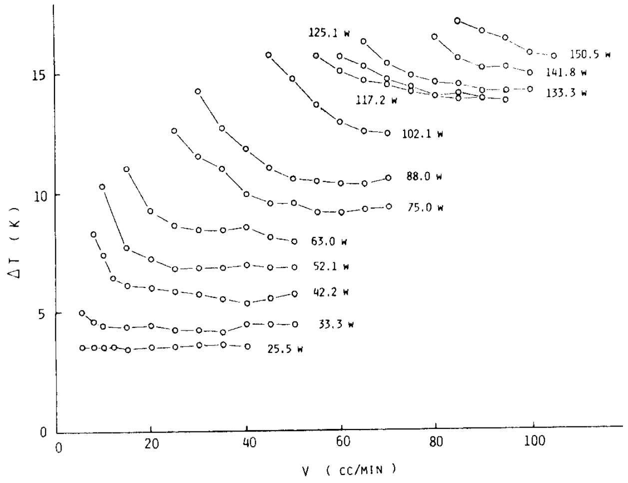

Fig. 6. Experimental Results.

laboratory model has been tested and satisfactory characteristics has been obtained [3].

Another remarkable design feature of the pump is a magnetic coupling. It gives a no penetration pump container which is suit to long-life mission.

The sectional view of the pump is shown in Fig. 5.

3. PERFORMANCE TEST

3.1 Testing Procedure

Experiments relating to the overall thermal conductance as a function of the working fluid rate have been carried out.

The test prodedure is as follows. The pecified heat load is supplied by the electrical heater. The working fluid flow rate, which is controlled by the pump revolution number, is varied from the larger to the smaller. During the test, the temperature of the pipe of the vapor line, which is controlled by the cooling water temperature, is maintained at 30°C.

3.2 Test Results

Test results are shown in Fig. 6, in which the temperature difference between the evaporator and the condenser is shown as a function of the working fluid flow rate. The minimum flow rate of each test series shows the lower limit for stable operation. Decreasing the flow rate over the limit, dry-out occurs.

For the test of 25.5 W of heat load, the temperature differnce does not varies with the flow rate. When the heat load is larger than 25.5 W, the temperature difference increases with the flow rate decrease near the lower limit of the flow rate. It suggests that partial dry-out occurs in this flow rate region and it propagates as the flow rate decreases.

Fig. 7 shows heat transfer characteristics for two extreams, one is for the lower limit

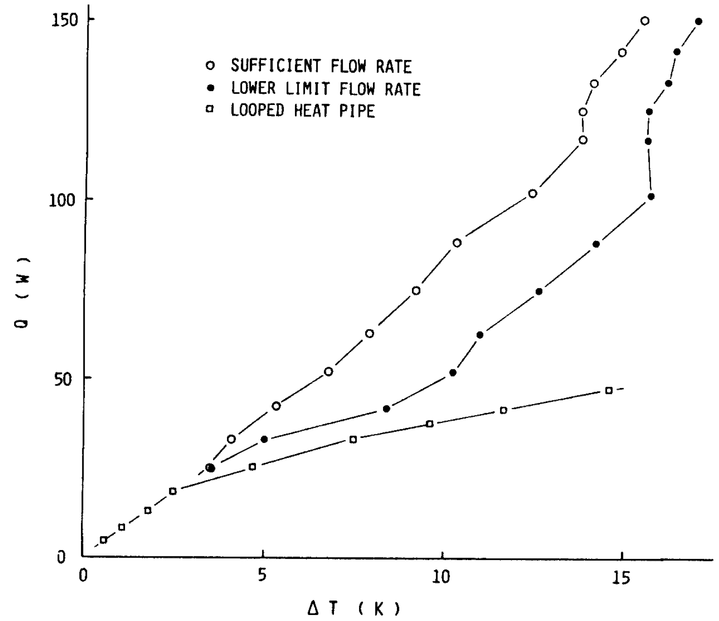

Fig. 7. Heat Transfer Characteristics.

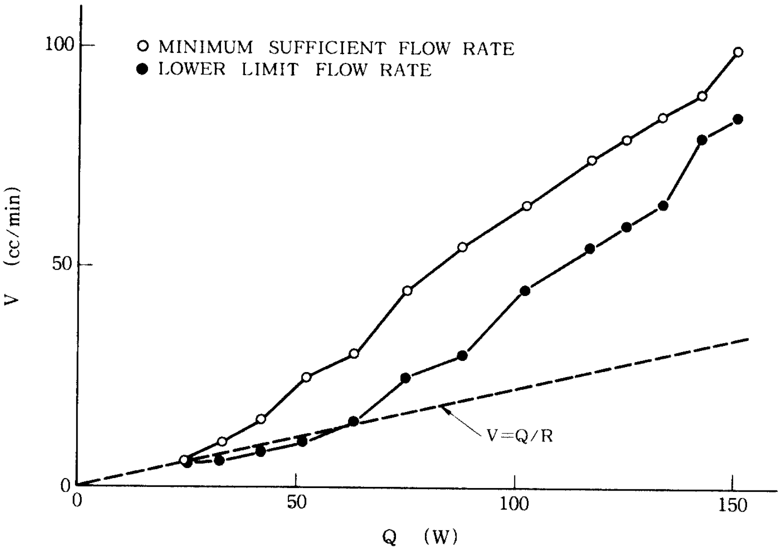

Fig. 8. Working Fluid Flow Rate Characteristics.

flow rate and the other is for the sufficient flow rate. For comparison, heat transfer characteristics for the looped heat pipe, in which the capillary pumping head circulates the working fluid, is shown in the figure. From the figure, it is seen that the feature of heat transfer varies with the heat load.

At 25.5 W of heat load, the overall thermal conductance is the same as that for the looped heat pipe under normal operation. In this heat load range, it seems that the capillary head would be sufficient for pumping up the liquid from the liquid channel to the grooves at the top of the vapor core and then the expected liquid distribution in the evaporator would be realized.

In the next heat load range above 25.5 W, overall thermal conductance remains nearly constant so far as the flow rate is sufficient. When the flow rate is not sufficient, overall thermal conductance decrease is observed. As described before, it is supposed that the decrease of the overall thermal conductance would be caused by partial dry-out.

In the higher heat load range above 100 W, another feature of heat transfer is observed. In the heat load range, boiling occurs even in the liquid channel of the evaporator and the overall thermal conductance increases.

In Fig. 8, the minimum of sufficient flow rate, above which the overall thermal conductance does not vary with the flow rate, and the lower limit flow rate, below which dry out occurs, are plotted against the heat load. A broken line in the figure shows theoretical necessary flow rate.

Up to about 25 W of heat load, the experimental necessary flow rate is nearly equal to the theoretical one. Above the heat load, the flow rate larger than the theoretical one is needed. The excess flow rate increases significantly as the heat load increases.

Although, relatively large amount of liquid flows into the vapor line in the large heat load range, anomalous loop behaviors have not been observed.

4. CONCLUSION

The laboratory model of a pump assisted heat pipe has been fabricated and tested.

Some remarkable features related to evaporative heat transfer such as partial dry-out occurrance or necessity for excess flow rate are observed.

Even with these phenomena, serious flow instabilities or controll difficulties have not been observed and the system has been operated successfully.

From the test, it is proved that the pump assisted heat pipe is a promissing candidate as advanced future thermal systems for spacecraft.

REFERENCES

[1] Hanneman, R. J.: Paper No. AIAA-79-1091, (1979).
[2] Miyazaki, Y. and Ido, Y.: ISAS Rept. SP 4 (1986), 161–165.
[3] Sakata, K., Morozumi, N, Nagatomo, S., Miyazaki, Y., Itakura, T. and Ido, Y.: Proc. 29th Space Sciences and Technology Conference (1985) (in Japanese), 202–203.