Heat Load Sharing in a Capillary Pumped Loop
with Multiple Evaporators and Multiple Condensers

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Abstract

This paper describes the heat load sharing function among multiple parallel evaporators in a capillary pumped loop (CPL). In the normal mode of operation, the evaporators cool the instruments by absorbing the waste heat. When an instruments is turned off, the attached evaporator can keep it warm by receiving heat from other evaporators serving the operating instruments. This is referred to as heat load sharing. A theoretical basis of heat load sharing is given first. The fact that the wicks in the powered evaporators will develop capillary pressure to force the generated vapor to flow to cold locations where the pressure is lower leads to the conclusion that heat load sharing is an inherent function of a CPL with multiple evaporators. Heat load sharing has been verified with many CPLs in ground tests. Experimental results of the Capillary Pumped Loop 3 (CAPL 3) Flight Experiment are presented in this paper. Factors that affect the amount of heat being shared are discussed. Some constraints of heat load sharing are also addressed.

Introduction

Capillary Pumped Loops (CPLs) are versatile two-phase heat transport devices that have gained increasing acceptance for spacecraft thermal control [1]. The CPLs onboard the NASA EOS-Terra spacecraft and the Hubble Space Telescope have demonstrated excellent performance and robust operation for several years [2-4]. All CPLs currently servicing the orbiting spacecraft have a single evaporator and a single condenser.

A CPL with multiple evaporators has several additional advantages. First, it can transport a significantly larger heat load than a CPL with a single evaporator. Second, it can be used to isothermalize a payload having a large thermal footprint. Third, it can serve as a thermal bus for multiple instruments that require similar operating temperatures. Fourth, the loop is self-regulating and requires no flow control devices because each evaporator will draw as much liquid as needed, according to the applied heat load, so that the exiting fluid will have vapor quality of one.

An inherent operating feature in a CPL with multiple evaporators is heat sharing among the evaporators. When some instruments are turned off, the attached evaporators can draw heat from other evaporators serving the operating instruments, thus warming the non-operating instruments. This will save the supplemental heater power. The amount of heat that is shared among the evaporators is governed by mass, momentum and energy conservation laws for the entire system, and is affected by the total system heat load, temperatures of the condenser sinks, and the environment surrounding the non-operating instruments. The ability for multiple evaporators to share heat loads has been demonstrated in several CPLs in ground tests and in the CAPL3 Flight Experiment.

In the following sections, the theoretical background for the CPL heat load sharing operation will be discussed first. The performance characteristics will be illustrated by using a pressure drop diagram in the loop. This will be followed by a discussion of the test results in the CAPL 3 Flight Experiment. Some constraints in CPL heat sharing will also be addressed.

Theoretical Background

The following discussion applies to the general case of a CPL consisting of N_E evaporators and N_C condensers. However, for simplicity, the schematic a CPL having only two evaporators and two condensers is shown in Figure 1. A flow regulator consisting of a capillary wick is usually installed at the exit of each condenser to prevent vapor from flowing out of the condenser. When a heat load $Q_{IN}^{(i)}$ is applied to the ith evaporator, part of the heat, $Q_{SC}^{(i)}$, is used to raise the incoming liquid from a subcooled state to the saturation state, and the remaining heat, $Q_E^{(i)}$, is used to vaporize liquid to generate a mass flow rate of $m_e^{(i)}$. The vapor flow from each evaporator then merges to form a total mass rate of m_t that flows to the condenser section. Thus,

$$Q_{IN}^{(i)} = Q_E^{(i)} + Q_{SC}^{(i)} \qquad i = 1 \ to \ N_E \qquad (1)$$

$$Q_E^{(i)} = m_e^{(i)}\lambda \qquad i = 1 \ to \ N_E \qquad (2)$$

$$m_t = \sum_{i=1}^{N_e} m_e^{(i)} \qquad (3)$$

where λ is the latent heat of vaporization of the working fluid. Note that the evaporators are passive and self-regulating in that each evaporator, based on the applied heat load $Q_{IN}^{(i)}$, will draw a liquid flow of $m_e^{(i)}$ so that equations (1) and (2) are satisfied and the vapor will exit the evaporator with a quality of unity. The total mass rate of m_t will be distributed among the N_C condensers. The ith condenser will receive a mass rate of $m_c^{(i)}$ with an associated latent heat of $m_c^{(i)}$ λ, and the vapor will be completely condensed over a length of $L_{c,2\phi}^{(i)}$. Thus,

$$m_t = \sum_{i=1}^{N_C} m_c^{(i)} \qquad (4)$$

$$m_c^{(i)}\lambda = 2\pi D_c^{(i)} L_{c,2\phi}^{(i)} h_{c,2\phi}(T_{sat} - T_{c,wall}^{(i)}) \qquad i = 1 \ to \ Nc \qquad (5)$$

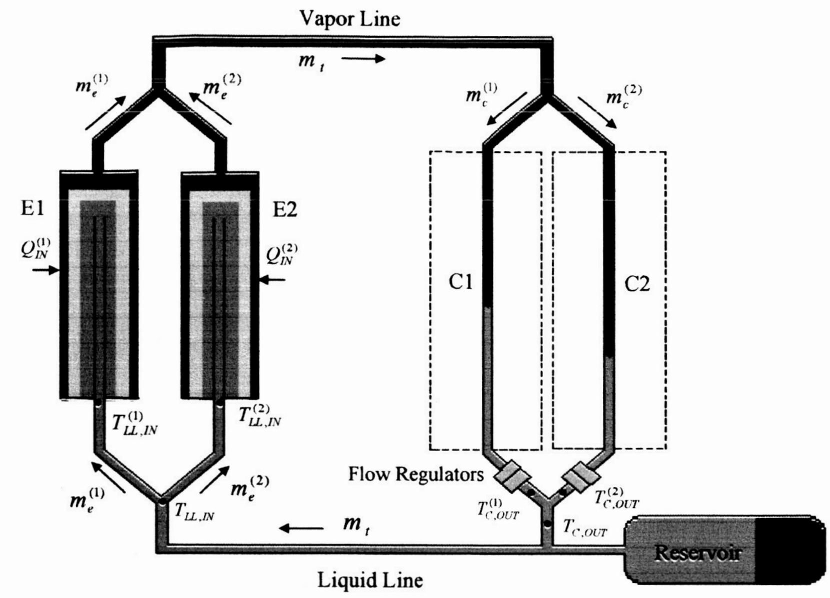

Figure 1 Schematic of a CPL with Multiple Evaporators and Condensers

where $D_c^{(i)}$ is the diameter of the ith condenser and $L_{c,2\phi}^{(i)}$ is the length required to dissipate the latent heat, $h_{c,2\phi}$ is the condensation heat transfer coefficient, T_{sat} is the loop saturation temperature, and $T_{c,wall}^{(i)}$ is the condenser wall temperature. The liquid will then be subcooled over the remaining length of the condenser. If a condenser is fully utilized for vapor condensation, the vapor will be stopped by the flow regulator and the excess vapor will be diverted to other condensers, resulting in a flow re-distribution among all condensers. The liquid flow exiting each condenser then merges into a total liquid flow with a mass rate of m_t. The pressure drop in the ith condenser is the sum of the pressure drops in the two-phase region (over the length $L_{c,2\phi}^{(i)}$) and the liquid phase region, and the hydraulic pressure head due to gravity. Thus,

$$\Delta P_c^{(i)} = \Delta P_{c,2\phi}^{(i)} + \Delta P_{c,1\phi}^{(i)} + \rho_l g \Delta h_L^{(i)} = f(m_c^{(i)},\ L_{c,2\phi}^{(i)}) \qquad i = 1\ to\ N_C \tag{6a}$$

$$\Delta P_c^{(k)} = \Delta P_{c,2\phi}^{(k)} + \Delta P_{FR}^{(k)} \qquad \text{Condenser k is fully utilized} \tag{6b}$$

where $\Delta P_c^{(i)}$ is the pressure drop over the ith condenser, ρ_l is the liquid density, $\Delta h_L^{(i)}$ is the end-to-end elevation of the ith condenser, $\Delta P_{FR}^{(k)}$ is the capillary pressure exerted by the flow regulator in the kth condenser. However, there can be only one pressure drop over the condenser section. Hence,

$$\Delta P_c^{(i)} \equiv \Delta P_c \qquad i = 1\ to\ N_C \tag{7}$$

where ΔP_c is the pressure drop over the entire condenser section.

There are a total of 2N +1 unknowns ($m_c^{(i)}$, $L_{c,2\phi}^{(i)}$ and ΔP_c), and 2N +1 equations in (4), (5), and (6). In essence, the conservation laws of mass, momentum and energy yield a set of mass flow rates through the condensers, a set of lengths over which vapor is condensed, and a pressure drop across the condenser section. A flow schematic and associated pressure drop diagram in the condenser section are shown in Figures 2(a) and 2(b). In Figure 2(a), all condensers contain two-phase and subcooled regions, where in Figure 2(b), one of the condensers is fully utilized and a pressure difference is sustained by the wick inside the flow regulator.

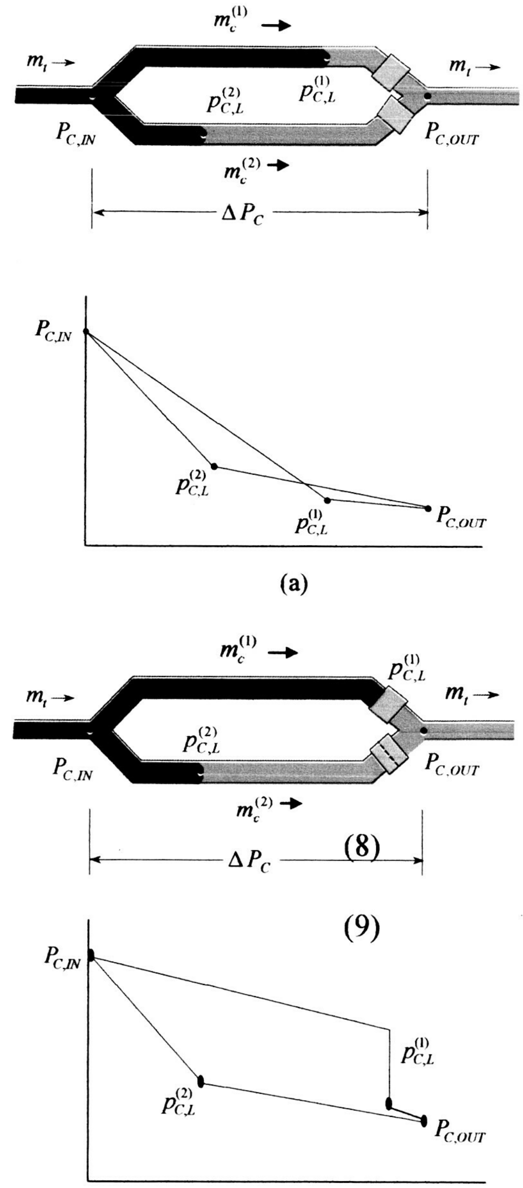

Figure 2 Flow distribution and Pressure Drops in Condenser Section

The fluid will exit each condenser with a temperature of $T_{c,out}^{(i)}$, which is a function of the flow rate through that condenser, the length of the two-phase region, and the condenser wall temperature. The exiting flows then merge and mix to yield a single temperature $T_{c,out}$. Thus,

$$T_{c,out}^{(i)} = f(m_c^{(i)},\ L_{c,2\phi}^{(i)},\ T_{c,wall}^{(i)}) \qquad i = 1 \ to \ N_C \qquad (8)$$

$$T_{c,out} = \frac{1}{m_t}\sum_{i=1}^{N_c} m_c^{(i)} T_{c,out}^{(i)} \qquad (9)$$

The liquid exchanges heat with the surrounding as it flows along the liquid return line. When it reaches the evaporator section, its temperature reaches $T_{LL,IN}$, which is a function of the total mass flow rate m_t, diameter and length of the liquid transport line, temperature of the surrounding, and mode of heat transfer. The mass flow then splits among all evaporators, and each individual liquid flow further exchanges heat with its surrounding along the liquid inlet line. At the inlet of the evaporator, each liquid flow has a temperature of $T_{LL,IN}^{(i)}$. The governing equation can be written as follows:

$$T_{LL,IN} = f\left(T_{c,out}, m_t, L_{LL}, D_{LL}, T_{amb}\right) \qquad (10)$$

$$T_{LL,IN}^{(i)} = f\left(T_{LL,IN}, m_c^{(i)}, L_{LL}^{(i)}, D_{LL}^{(i)}, T_{amb}^{(i)}\right) \qquad i = 1 \ to \ N_E \qquad (11)$$

$$Q_{SC}^{(i)} = m_e^{(i)} C_P \left(T_{sat} - T_{LL,IN}^{(i)}\right) \qquad i = 1 \ to \ N_E \qquad (12)$$

where C_p is the specific heat of the liquid. As each fluid flow completes its path, each evaporator is subjected to a total pressure drop which is the sum of pressure drops in the evaporator, vapor transport line, condenser section, liquid transport line, and the individual wick. The total pressure drop must not exceed the capillary pressure rise that the wick can develop. Thus,

$$\Delta P_{cap}^{(i)} = \frac{2\sigma \cos\theta}{r_p^{(i)}} \qquad i = 1 \text{ to } N_E \qquad (13)$$

$$\Delta P_{tot}^{(i)} \leq \Delta P_{cap}^{(i)} \qquad i = 1 \text{ to } N_E \qquad (14)$$

where $r_p^{(i)}$ is the pore radius of the i[th] wick, $\Delta P_{cap}^{(i)}$ is the capillary pressure rise developed by the i[th] wick, σ is the surface tension force, and θ is the contact angle. Equations (1) to (14) describe the operation of a CPL with multiple evaporators and multiple condensers. A pressure drop diagram of the loop under normal operation where each evaporator receives an applied heat load is shown in Figure 3.

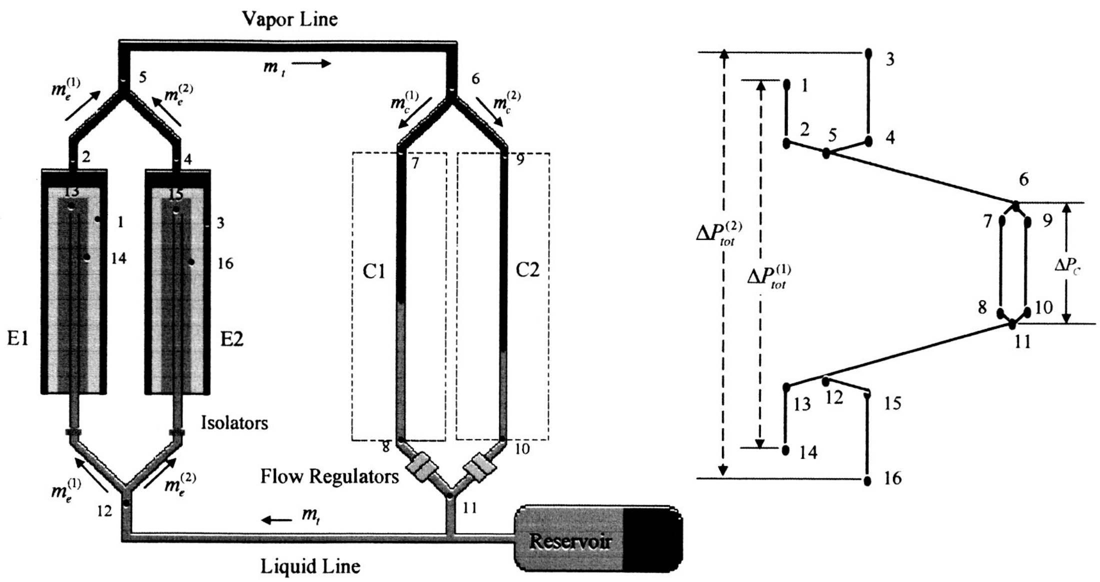

Figure 3. Pressure Drop Diagram of CPL under Normal Operation

In the heat load sharing mode, the evaporator attached to a non-operating instrument works as a condenser, and its wick works as a flow regulator. The operating principles of heat load sharing can be explained by referring to Figure 4, where E2 receives an applied heat load and E1 is sharing the heat load. The vapor generated in E2 will flow to locations where the temperatures are low, i.e. the condensers and E1. In essence, a single pressure drop of $\Delta P_{EV} = P5 - P12$ exists among all "condensers", which share the total heat load according to the conservation laws of mass, momentum, and energy, as previously illustrated in Figure 2. Thus, heat load sharing is an inherent function of a CPL with multiple parallel evaporators. Note that at least one of the instruments must be operational and supply heat to the system during the heat load sharing operation. Also note that equations (13) and (14) still apply in heat load sharing mode of operation.

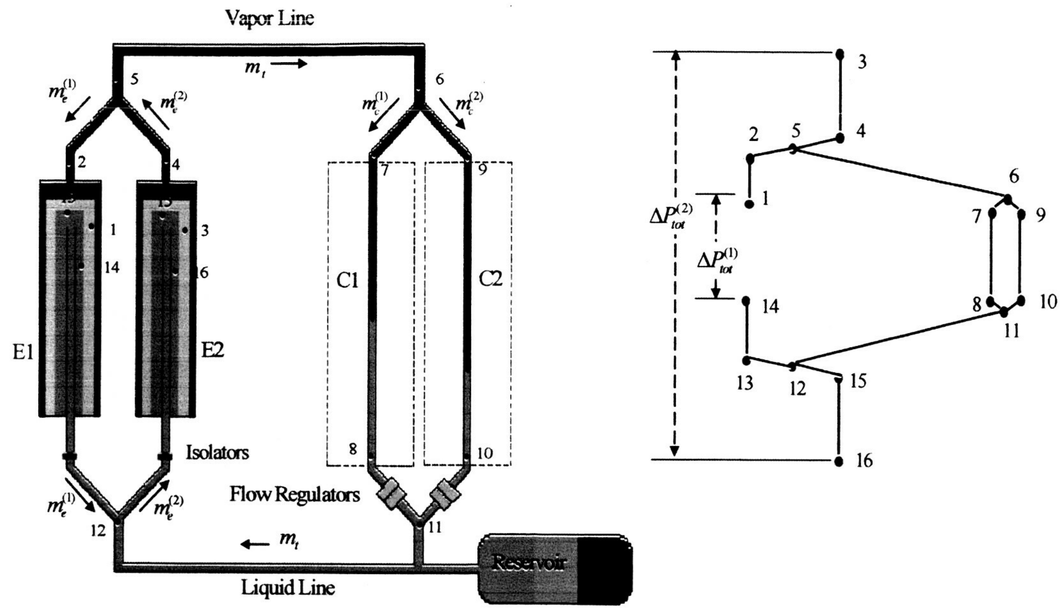

Figure 4 Pressure Drop Diagram in a CPL Under Heat Sharing Mode

The amount of heat that is shared by a condensing evaporator is a function of the system heat load and the sink temperatures of all "condensers". The evaporator sharing the heat will resume its normal operation automatically when the attached instrument is turned on again. When the condensing evaporator is fully utilized, the liquid exiting the evaporator will be close to the saturation temperature. This may affect the operation of evaporators located downstream of this condensing evaporator due to reduced subcooling of the returning liquid.

Figures 4 shows that some heat will always flow to the condenser section regardless of how much heat is applied to the evaporators, i.e. the condensing evaporator can not share 100 percent of the applied heat load. To increase the heat that can be shared by the condensing evaporator, a back pressure regulator (BPR) consisting of a capillary wick can be installed on the vapor line. Figure 5 shows that the condensing evaporator will share 100 percent of the applied heat load when the pressure drop $\Delta P_{EV} = P_5 - P_{12}$ is smaller than the capillary pressure of the wick in the BPR. Vapor will flow to the condensers only if ΔP_{EV} is greater than the capillary pressure across the BPR.

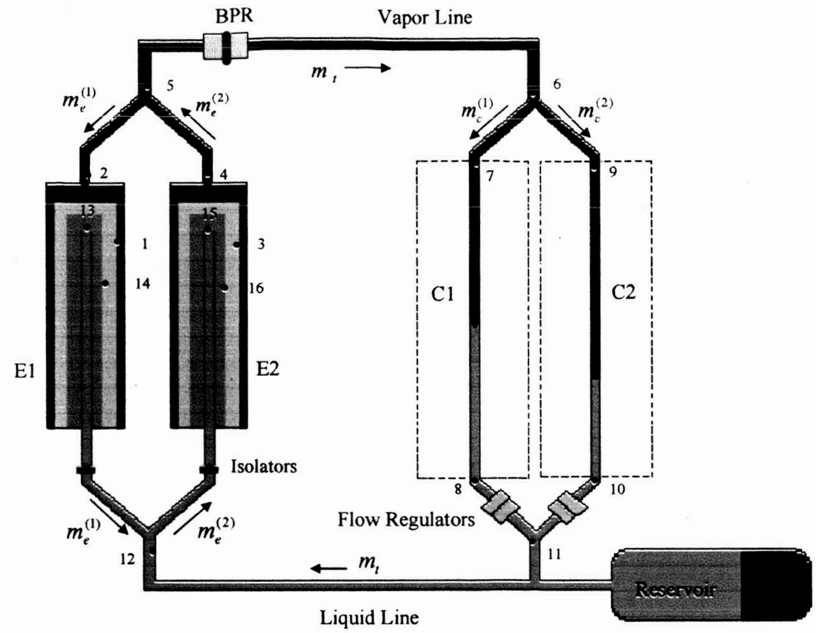

Figure 5. A CPL with a Back Pressure Regulator on the Vapor Line

The reservoir in the CPL can maintain a constant saturation temperature for the loop operation. However, temperatures of the instruments will deviate from the saturation temperature due to the heat transfer requirement. When an instrument is turned on, the instrument will be at a higher temperature than the saturation temperature, i.e. $\Delta T_1 = Q_E/G_{evap}$, where Q_E is the heat dissipation of the instrument and G_{evap} is the overall thermal conductance associated with the evaporation process. Conversely, when the instrument is turned off, the instrument temperature will be lower than the saturation temperature, i.e. $\Delta T_2 = Q_{shared}/G_{cond}$, where Q_{shared} is the heat being shared by the instrument and G_{cond} is the overall thermal conductance associated with vapor condensation process. Thus, a temperature difference of $\Delta T = \Delta T_1 + \Delta T_2$ can be expected between the "on" and "off" states of the instrument.

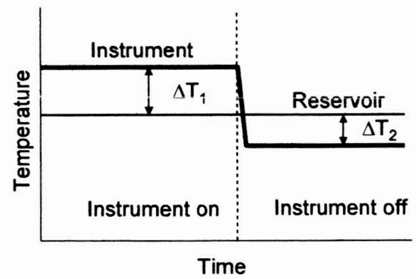

Figure 6 Temperature Drop between Operating and Non-Operating Instruments

Description of the CPL in CAPL3 Flight Experiment

Details of the CAPL 3 flight Experiment can be found in the literature [5, 6]. This section describes the CPL and other parts pertinent to the heat load sharing operation. The CPL contained a capillary starter pump and four capillary evaporators – two evaporators in one cold plate and two individual evaporators. The vapor line and liquid line were made of stainless steel tubing. The vapor line contained a back-pressure regulator. The condenser section consisted of eight parallel direct-condensation tubes, and each condenser tube has a flow regulator at the exit. The system was charged with anhydrous ammonia such that the CPL (except the reservoir) could be fully flooded with liquid ammonia prior to start-up of the system. One of the evaporators (Evaporator 3) was connected to a variable conductance heat pipe (VCHP), which in turn was connected to the radiator. This allowed Evaporator 3 to be exposed to a much colder environment than other evaporators during heat load sharing tests. Instrumentation consisted of 180 thermistors, an absolute pressure transducer, and three differential pressure transducers, which monitored the pressure drop across the evaporator section, across the reservoir line, and across the back-pressure regulator in the vapor line. Heat rejection was accomplished via a radiator panel which measured 1.57 m x 2.54 m (62 inches x 100 inches). A schematic of the CPL with some thermister locations is shown in Figure 7.

CAPL 3 Schematic

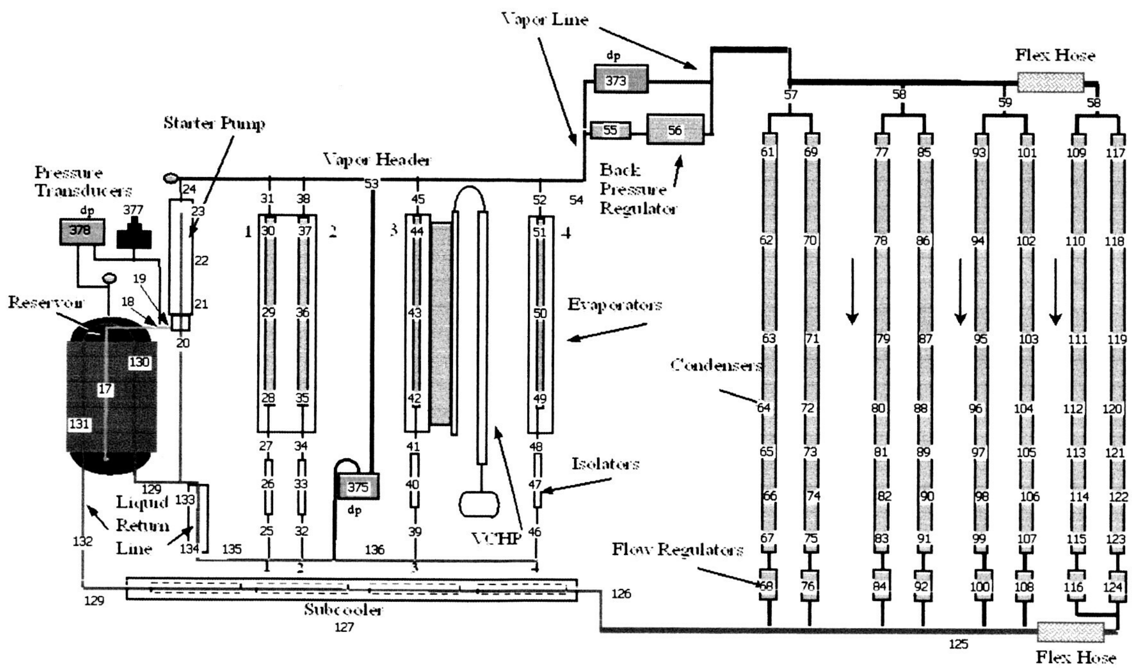

Figure 7 CAPL 3 Schematic

Heat Sharing Tests During CAPL 3 Flight Mission

The VCHP shown in Figure 7 connected the evaporator E3 to the radiator. By varying the VCHP reservoir temperature, the heat transport by the VCHP from E3 to the radiator also varied. This was used to simulate various thermal links between the instrument and the spacecraft environment. During the normal operation when a heat load was applied to E3, the VCHP reservoir temperature was set higher than the CPL reservoir saturation temperature, and the VCHP became non-operational.

When the VCHP was non-operating, the heat leak from E3 through the VCHP was by conduction only and was very small. Three heat load sharing tests were conducted under this condition. In the first test, the nominal heat load to each evaporator was alternated between 100W and 0W as shown in Table 1. The evaporators receiving 0W would share heat from other evaporators receiving 100W. Figure 8 shows temperatures of evaporators and inlets. Throughout the tests, all evaporators were able to maintain their temperature near the CPL saturation temperature of 303K. Note that the evaporator receiving 100W would draw subcooled liquid and its inlet temperature was between 260K and 270K. The evaporator sharing heat would work in a condenser mode and its inlet temperature will reach a steady state near the CPL saturation temperature. Also note that each evaporator automatically switched its operation between the evaporator mode and the condenser mode depending on whether or not a heat load was applied to that evaporator. This test was repeated once and similar results were obtained.

Table 1. Nominal Heat Loads for Heat Sharing Test

Step	E1 Power (W)	E2 Power (W)	E3 Power (W)	E4 Power (W)	Total Power (W)
1	100	100	100	100	400
2	100	100	100	0	300
3	100	100	0	100	300
4	100	0	100	100	300
5	0	100	100	100	300
6	100	100	0	0	200
7	100	0	100	0	200
8	100	0	0	100	200
9	0	100	100	0	200
10	0	100	0	100	200
11	0	0	100	100	200
12	100	100	100	100	400

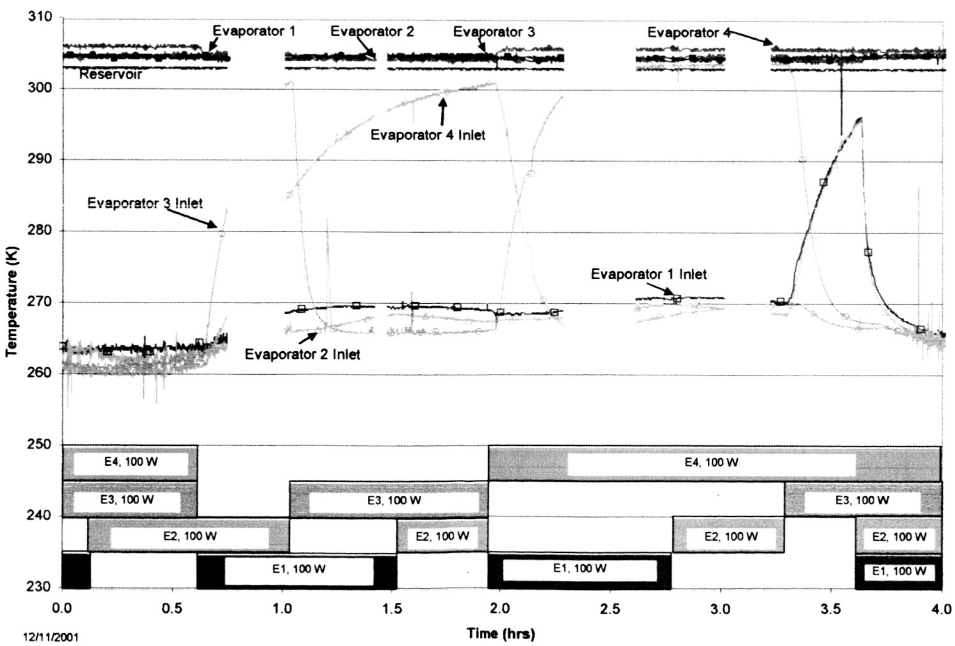

Figure 8 Heat Sharing with a Non-Operating VCHP

When the VCHP is non-operational, all evaporators were exposed to the spacecraft interior environment. The condensing evaporators, having a very limited heat dissipating capability, would be fully open for vapor condensation, and all evaporators could be maintained at close to the CPL saturation temperature. To illustrate this point, another heat load sharing test with a non-operating VCHP was conducted at a CPL reservoir temperature of 293K and with much lower heat loads. The nominal heat load to each evaporator was alternated among 0W, 25W and 50W as shown in Table 2. A portion of the test results is shown in Figure 9. All evaporators were maintained at close to the CPL saturation temperature of 293K as expected. The inlet temperature was subcooled when the evaporator received an applied heat load, and was rising toward the saturation temperature when the evaporator shared heat from other evaporators.

Table 2. Nominal Heat Loads for Heat Sharing Test

Step	E1 Power (W)	E2 Power (W)	E3 Power (W)	E4 Power (W)	Total Power (W)
1	25	25	25	25	100
2	50	25	25	0	100
3	50	25	0	25	100
4	50	0	25	25	100
5	25	50	25	0	100
6	25	50	0	25	100
7	0	50	25	25	100
8	25	25	50	0	100
9	25	0	50	25	100
10	0	25	50	25	100
11	25	25	0	50	100
12	25	0	25	50	100
13	0	25	25	50	100
14	50	50	0	0	100
15	50	0	50	0	100
16	50	0	0	50	100
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18	0	50	0	50	100
19	0	0	50	50	100
20	25	25	25	25	100

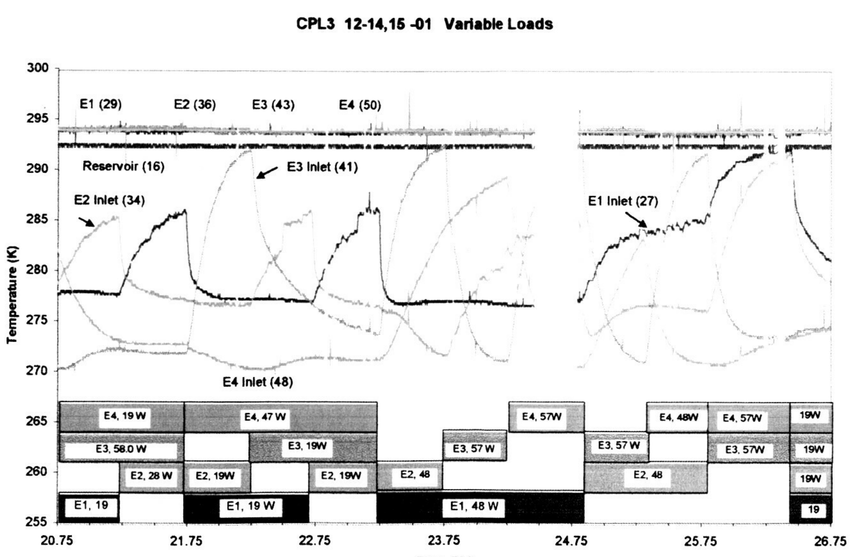

Figure 9 Heat Sharing with a Non-Operating VCHP

When the VCHP is operational, evaporator E3 was exposed to the cold radiator environment. During the heat load sharing operation, the heat load received by E3 might not be sufficient to keep the entire evaporator isothermal, i.e. a portion of E3 could be filled with liquid. In the following test, heat loads were applied to E1 and E2 only and the CPL reservoir was set at 303K. E4 was exposed to the spacecraft interior environment while E3 was exposed to the radiator via the VCHP whose reservoir was initially set at 283K. With 50W/evaporator to E1 and E2, E4 was maintained at 303K over the entire length of the evaporator, and saturated liquid flowed out of the E4 inlet. On the other hand, the heat shared by E3 was not enough to keep the entire evaporator at the saturation temperature. Thus a portion of E3 was subcooled as shown in Figure 10. This portion became more subcooled as the applied power to E1 and E2 reduced to 25W/evaporator. The VCHP reservoir set point was then increased gradually. As the VCHP operating temperature increased, E3 temperature become more and more uniform. The entire E3 was at 303K when the VCHP reservoir was above 305K. Note that E4 was maintained at 303K throughout the test.

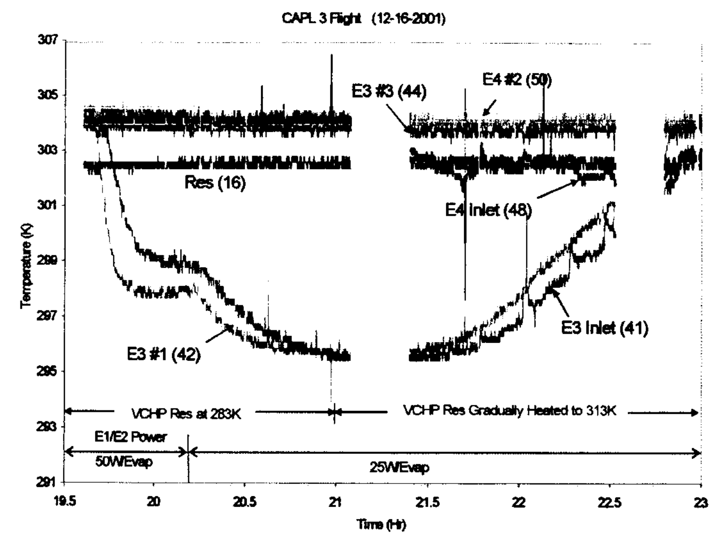

Figure 10 Heat Sharing by Two Evaporators with Different Sink Temperatures

Figures 11 and 12 show temperatures of the CPL during another test where the VCHP was operational. The CPL saturation temperature was set at 303K. Initially all four evaporators received 150W each. At 22:40, the E3 power was removed, and E3 worked in a condenser mode. The VCHP reservoir heater power was also removed at the same time, allowing the VCHP reservoir temperature to continue to decrease. The VCHP had a heat transport capability of about 90W. Thus, E3 was fully open for vapor condensation at 150W/evaporator and 75W/evaporator to E1, E2 and E4, as evidenced by the fact that saturated liquid was leaving the E3 inlet. During this period, a significant portion of the applied heat was dissipated by the condensers as shown in Figure 12 that vapor reached the condenser inlets. Note that when the evaporator heat load was reduced from 150W/evaporator to 75W/evaporator, the liquid line temperature (TC135) increased slightly. The E1 and E2 inlet temperatures closely followed TC135. However, E4 inlet temperature was about 15K and 30K higher than the E1 inlet temperature at 150W/evaporator and 75W/evaporator, respectively. Because E4 is at the downstream of E3, cold liquid returning from the condenser was mixed with saturated liquid from E3 before it was fed to E4.

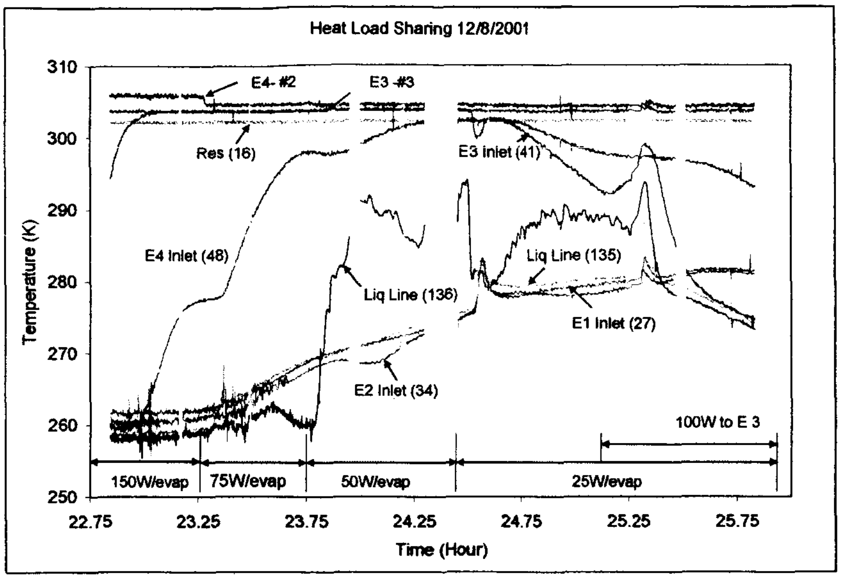

Figure 11 Heat Load sharing with an Operating VCHP (Varying System Heat Load)

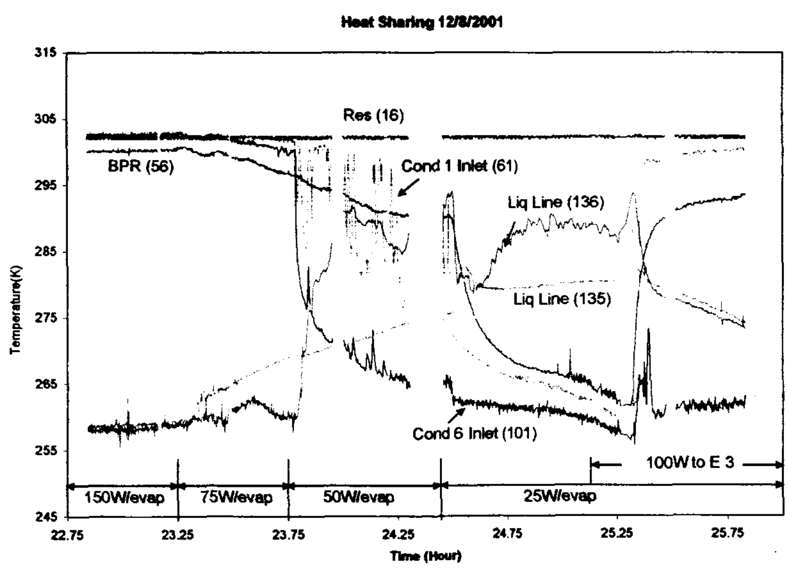

Figure 12 Heat Load Sharing with an Operating VCHP (Varying sytem Heat Load)

As the applied power decreased to 50W/evaporator, much less heat was dissipated by the condensers. The vapor front just barely reached the condenser inlet as shown in Figure 12. TC135 rose to 275K, and E1 and E2 inlet temperatures continued to follow TC135 closely. E4 practically drew all the saturated liquid from E3, and its inlet was at the saturation temperature of 303K. When the applied power further decreased to 25W/evaporator, all the heat was dissipated by E3. Figure 12 indicated that the BPR was filled with subcooled liquid and the condenser was completely flooded with liquid The VCHP was running at 283K and could transport more than 60W. Thus, E3 vapor grooves were partially filled with liquid and its temperature was no longer uniform. Subcooled liquid leaving E3 was fed into the other three evaporators. As the E3 inlet temperature continued to drop, so did the temperatures at the inlets of the other three evaporators.

Test was continued by applying 100W to E3 and simultaneously raising the VCHP reservoir temperature to 305K to shut down the VCHP operation. The E3 changed its operation to the normal evaporator mode. All applied heat load was dissipated by the condenser, and subcooled liquid was supplied to all evaporators. The temperatures of all evaporator inlets reach a steady temperature of 270K in subsequent step where a heat load of 50W/evaporator was applied to all evaporators (not shown in the figures).

When the evaporator inlet temperature is close to the saturation temperature, the evaporator was prone to deprime due to possible liquid flashing at the inlet. Past experience in ground testing of CPLs indicated that the evaporator could operate with saturated liquid at the inlet as long as no sudden change was imposed. Examples of a sudden change of the operating condition include rapid and steep change in the condenser sink temperature and/or a sudden decrease of the applied power. Both conditions could result in a sudden movement of hot liquid from the reservoir to the condenser via the liquid line, and could also create a sudden suction action that leads to evaporator deprime. During CAPL 3 flight experiment, the condensers were nearly closed in all heat load sharing tests due to the cold environment and the relatively low applied power. Thus, changing the applied heat load did not lead to rapid fluid movement in the loop.

Past flight operation of CPLs indicated that the acceleration induced by the spacecraft maneuver could lead to liquid sloshing in the reservoir, which in turn could cause mixing of warm and cold fluid inside the reservoir and result in a sudden drop of the saturation temperature – the so-called reservoir cold shock [2, 3, 7, 8]. The reservoir cold shock has two adverse effects. First, the saturation temperature could drop below the evaporator inlet temperature, lead to liquid flashing and eventual evaporator deprime. This is particularly problematic during the heat load sharing operation when the evaporator inlet temperature could be close to the saturation temperature. Second, reservoir cold shock could lead to rapid fluid movement inside the loop, resulting in the pressure drop higher than the capillary limit of the wick and a deprime of the evaporator.

In the CAPL 3 flight experiment, there were several orbital maneuver rocket burns during some of the heat load sharing tests that eventually led to the drprime of E4. Figure 13 depicts the loop temperature in one of these tests. The CPL reservoir was set at 303K, and E3 was sharing heat loads which were applied to E1, E2 and E4. The VCHP reservoir was set at 283K. During the period that the applied heat load was 75W/evaporator, a series of orbital maneuver burns occurred that lasted for a total of 45 seconds. The CPL reservoir temperature dropped by 3.5K and some rapid vapor/liquid movements occurred in the condenser section and the transport lines as indicated by the sudden rise and fall of temperatures shown in Figure 14. The pressure drop across the evaporator section jumped to 3000Pa, exceeding the capillary limit of E4. E4 deprimed about 10 minutes later. The fact that E4 inlet temperature was already higher than that of E1 and E2 inlet and that E4 happened to have the weakest wick helped explain why E4 deprimed and E1/E2 did not.

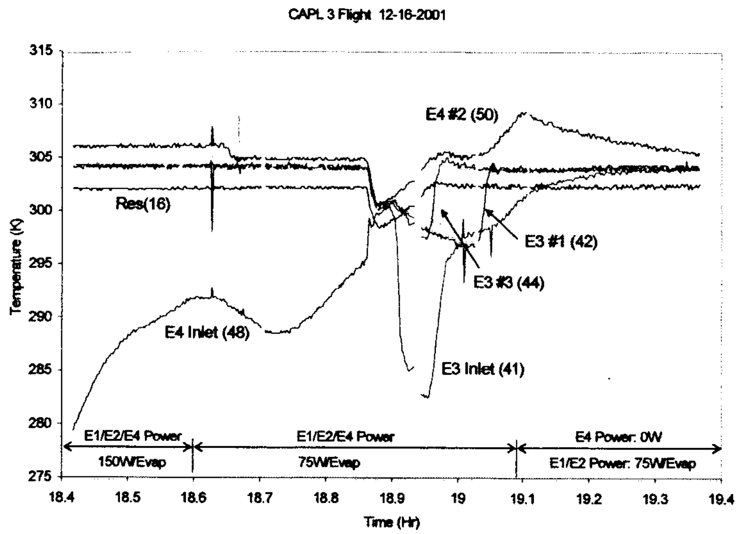

Figure 13 Effect of Spacecraft Maneuver on CPL Heat Load Sharing Operation

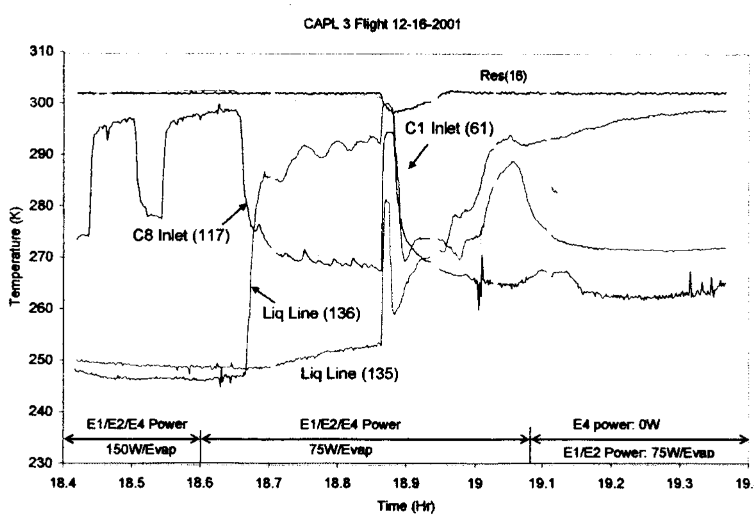

Figure 14 Effect of Spacecraft Maneuver on CPL Heat Load Sharing Operation

Summary and Concluding Remarks

Heat load sharing among evaporators is an inherent and useful feature provided by a CPL with multiple evaporators. It allows the evaporators attached to non-operating instruments to receive heat from other evaporators serving the operating instrument, thus eliminating or reducing the supplemental heat power that is required to maintain the non-operating instrument within the allowable temperature range. The amount of heat that can be shared by an evaporator is governed by the conservation laws of mass, momentum and energy in the entire loop, and is a function of the system heat load, and sink temperatures of the condensers and the evaporators sharing the heat load.

The CAPL 3 flight Experiment has successfully demonstrated the heat load sharing operation of a CPL with four evaporators and eight condensers in a micro-gravity environment. Tests performed included variable heat load distributions among all evaporators, variable condenser sink temperatures and variable thermal conditions surrounding the evaporators sharing the heat load. In particular, one of the evaporators was exposed to the cold radiator environment via a VCHP to investigate some extreme conditions for heat load sharing.

CAPL 3 flight experiment also incorporated a back pressure regulator on the vapor line to demonstrate 100 percent heat load sharing. Although 100 percent heat sharing was successfully demonstrated, it also revealed that the loop was prone to deprime because the inlet of the operating evaporators was close to the saturation temperature and could cause liquid flashing. This was particularly true when spacecraft maneuvers took place and caused liquid sloshing in the reservoir.

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