Component Developments in Europe for Mechanically Pumped Loop Systems (MPLs) for Cooling Applications in Space

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The objective of this paper is to give an overview of the potential of one- and two-phase Mechanically Pumped Loops (MPLs) in scientific and commercial space cooling systems. It first presents the benefits and drawbacks compared to conventional thermal control systems. Then in more detail the principle of single-phase MPL's and two-phase MPL's is discussed and an insight is given in the potential working fluids available for MPL's and the possibilities of dynamic loop modelling.
Further an overview is given of the loop components with the emphasis on European component developments such as pumps, valves (active, passive), accumulators, and heat exchangers. The paper ends with an outlook on potential MPL applications.

Nomenclature

ρ	=	Fluid density (kg/m^3)
μ	=	Dynamic viscosity (N/m^2 s or kg/(ms))
σ	=	Surface tension (N/m)
c_p	=	Specific heat capacity (J/(kg K))
d	=	Inner diameter tube or axial groove tube (m)
f	=	Friction factor(-)
h_{lv}	=	Specific latent heat of vaporization (J/kg)
h	=	Specific enthalpy (J/kg)
L	=	Length of tube or axial groove (m)
$\dot{m}$	=	Mass flow (kg/s)
N	=	Number of axial grooves or parallel channels (-)
P	=	heat input (W)
p	=	pressure (N/m^2)
Re	=	Reynolds number (-)
v	=	Fluid velocity (m/s)
x	=	vapour quality or vapour mass fraction (-)
2Φ–MPL	=	Two-Phase Mechanically Pumped Loop
AMS02	=	Alpha Magnetic Spectrometer experiment (www.ams02.org)
ATV	=	Automated Transfer Vehicle
AU	=	Astronomical Unit (average distance from the Earth to the Sun)
CPL	=	Capillary Pumped Loop

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ESA	=	European Space Agency
EM	=	Engineering Model
GEO	=	Geostationary Earth Orbit
HCA	=	Heat Controlled Accumulator
HP	=	Heat Pipe
ISS	=	International Space Station
JPL	=	Jet Propulsion Laboratory
LEO	=	Low Earth Orbit
LHP	=	Loop Heat Pipe
LIDAR	=	Light Detection And Ranging
LSI	=	Large System Integrator
MIR	=	Russian Space Station (1986-2001)
MPFL	=	Mechanically Pumped Fluid Loop
MPL	=	Mechanically Pumped Loop
MPLM	=	Multi-Purpose Logistics Module
MPMP	=	Multi-Parallel-Micro-Pump
NASA	=	National Aeronautics and Space Administration of the USA
NASDA	=	National Space Development Agency of Japan
NLR	=	Netherlands Aerospace Centre
NSO	=	Netherlands Space Office
OHP	=	Oscillating Heat Pipe
P/L	=	Payload
RT	=	Real Technologie AG
SAR	=	Synthetic Aperture Radar
TAS	=	Thales Alenia Space
TTCS	=	Tracker Thermal Control System

I. Introduction

Because of the growing size and complexity of satellite platforms and the growing power demand conventional thermal control systems with Heat Pipes (HP) and Loop Heat Pipes (LHP) networks get to their limit. Therefore Large System Integrators (LSI) in Europe showed interest in Mechanically Pumped Loops (MPLs). Recently the interest was intensified due to platform architecture changes with a centralised PayLoad (P/L) section and a satellite bus around it. Because of the large distance between dissipative elements and radiator MPL's becomes a feasible alternative to heat pipe structures with multiple connections.

Also increasing power densities lead to more interest in mechanically pumped loop systems. With power densities over 16 W/cm^2 ordinary LHP´s are no longer suitable and therefore a small MPL is one of the options to serve dedicated high heat flux pay-loads.

Another market demand for MPL's comes from payloads requiring tight temperature control. Two-phase Mechanically Pumped Loops (2Φ-MPL's) can create temperatures stability ranging from ±0.2 K to ± 1 mK which are of interest for active antenna's or optical pay-loads requiring high temperature stability.

Recently also a new potential application of 2Φ–MPL's has been introduced by JPL[12]. This concerns solar-powered science missions to the outer planets (3AU and beyond). A 2Φ–MPL can re-distribute waste heat to locations where the heat is needed. The reduction in heater power has tremendous mass savings and makes non-nuclear deep space missions feasible.

II. Comparison two-phase MPL´s and conventional two-phase systems

The benefits and drawbacks of 2Φ-MPL's compared to conventional two-phase systems used in space systems are condensed in the two tables below. In Table 1 a guideline is given for system engineers which type of two-phase heat transport system would fit best for their type of platform and pay-load[6]. Platforms are divided in land-based platforms, airborne platforms and spacecraft. The main selection driver between platforms is the gravity dependence. For space platforms heat pipes, LHP's, CPL's are preferred with 2Φ-MPL's recommended for accurate temperature control. This is consistent with the current practice in satellite design.

	Land and Marine-based	Airborne platforms	Spacecraft
Heat pipes	gravity assisted only	limited length	excellent
Thermosyphons	gravity assisted only	not possible	not possible
LHP's and CPL's	specific benifits are not used	good	excellent
OHP's	relative low performance	good in confined locations	in specific cases
2Φ-MPL's	accurate T-control	accurate T-control	accurate T-control
Vapour chambers	as heat spreader	as heat spreader	as heat spreader

= excellent = in specific conditions = not preferred = not possible

Table 1: Two-phase system platform design guideline

To indicate for which pay-loads the different two-phase systems are best suitable a rough division in pay-loads is made. The pay-loads are divided based on their lay-out of heat sources. A centralised pay-load is a pay-load with a concentrated heat source like linear motors or LIDARs. A distributed pay-load has a large number of widespread heat sources like active antennas or SAR radar applications. Finally a third type of pay-load is defined with confined access, like the Tracker System on the AMS02 experiment[3]. This leads to the preference of different two-phase heat transport systems for each type pay-load presented in Table 2.

	Centralised pay-load	Distributed pay-load	Pay-load with confined access
Heat pipes	limited heat flux	in case of enough access	not preferred
Thermosyphons	good	not preferred	not preferred
LHP's and CPL's	good	not preferred	not possible
OHP's	not preferred	not preferred	good but limited in length
2Φ-MPL's	not preferred	excellent but adds mass	excellent
Vapour chambers	as heat spreader	not preferred	not possible

= excellent = in specific conditions = not preferred = not possible

Table 2: Two-phase system payload design guideline

This table predicts that 2-Φ MPL's are of interest for satellite applications with distributed pay-loads and limited access, and pay-loads with accurate temperature control. The advantages have to outweigh the additional mass and the drawback of an active pump in the system.
For centralised pay-loads LHP's and CPL's still can do the job as long as the heat flux is not extremely high (>16 W/cm^2).
The above tables can be used by system engineers to verify which two-phase systems are suitable for their P/L´s.

III. Working principles of Mechanically Pumped Loops

Two different types of MPL's can be identified; a single-phase MPL and a two-phase MPL. The working principle of both systems is explained in the next sections.

A. Single phase MPL

Figure 1 shows a schematic drawing of a single-phase Mechanically Pumped Loop (1Φ-MPL). The pump provides cold liquid to the payload section, where it absorbs the heat. The power that can be absorbed by the cold liquid can be calculated with:

$$P_{\text{in}} = \dot{m} c_p \Delta T \qquad (1)$$

Where ΔT is the increase of the liquid temperature that is allowed, which is typically 20 to 30°C. The heated liquid then flows to the bypass valve, where it is either directed to the heat sink (i.e. the radiator heat exchanger), or the heat sink is bypassed and the flow can go directly to the pump. This bypass valve can therefore be used to control the temperature in the payload section. An accumulator is required in the system to allow for density changes in the fluid as a result of temperature variations. The accumulator is a vessel which is partly filled with liquid, and partly filled with N2 gas. For space applications, the liquid and gas are usually separated from each other by a metal bellows (see section V.B) to prevent absorption of the gas in the liquid.

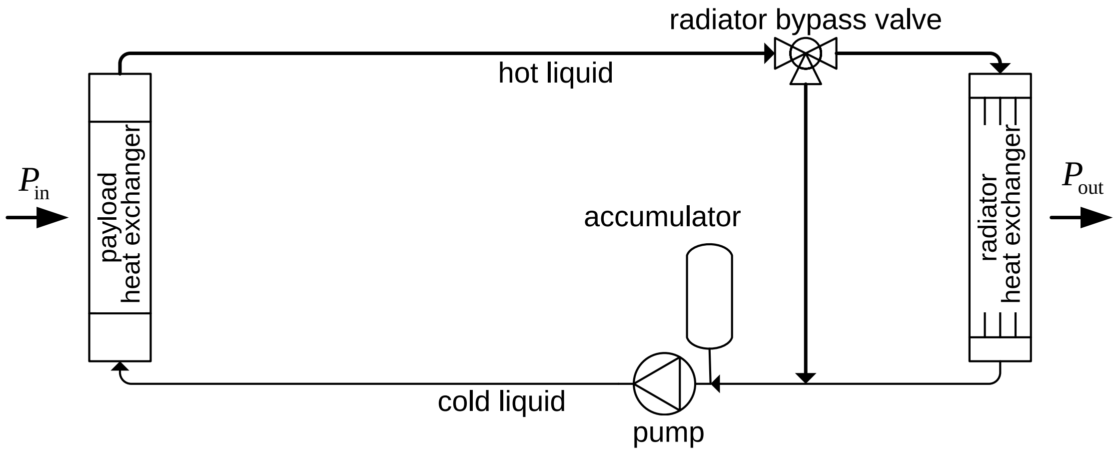

Figure 1 Schematic drawing of a 1Φ-MPL with radiator bypass valve. The valve can be used to control the temperature in the system by bypassing the radiator.

B. Two-phase MPL

In a Two-phase Mechanically Pumped Loop (2Φ-MPL), a pump is used to circulate a working fluid. Downstream of the pump, the fluid first flows to an evaporator, where liquid is evaporated, while heat from the payload is being absorbed. The power that can be absorbed by the liquid can be calculated with:

$$P_{\text{in}} = \dot{m} h_{lv} \Delta x \tag{2}$$

Where Δx is the increase in the vapor mass fraction, which is typically 0.5 to 0.8. The vapor then flows to a condenser where it is condensed back into liquid. The subcooled liquid from the condenser can have a very low temperature. In most applications, a heat exchanger is applied in which heat from the vapor/liquid is used to warm the cold liquid to near saturation temperature. This saves power budget in cold orbits. A schematic drawing of a 2Φ-MPFL with heat exchanger is shown in Figure 2. An accumulator is required in the system to allow for density changes of the fluid as a result of evaporation and condensation. Furthermore, the saturation pressure (and thereby the saturation temperature) in the system is controlled by the accumulator. When the accumulator is accurately controlled also the P/L evaporator is accurately controlled.

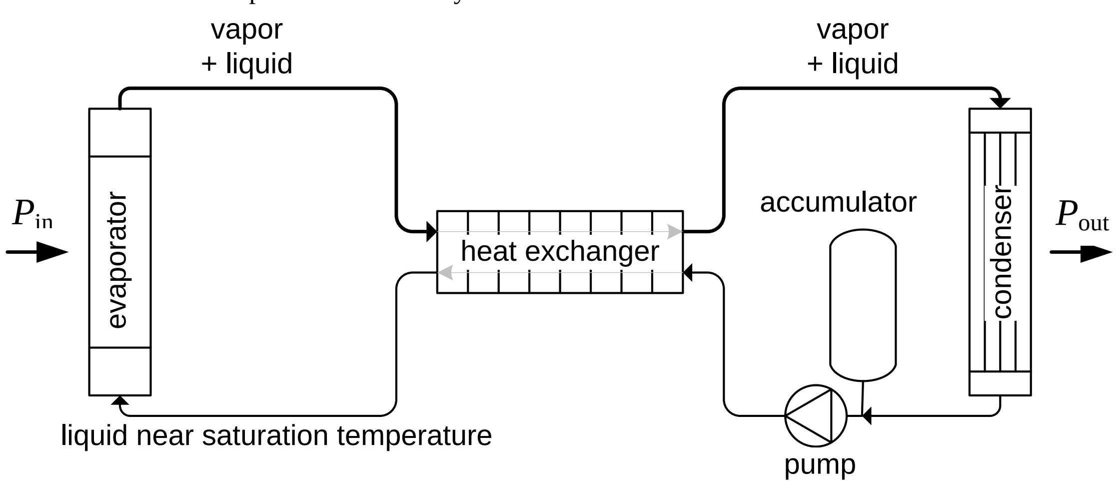

Figure 2 Schematic drawing of a 2Φ-MPFL with heat exchanger. The heat exchanger warms the subcooled liquid leaving the condenser to saturation temperature

C. Comparison between single- and two-phase MPL

One of the advantages of a two-phase system is that heat input only results in a change of the vapor mass fraction and the temperature of the liquid/vapor mixture is the same in the entire system (assuming that the pressure drop is small). The temperature drop between P/L and radiator is therefore in the range of 0.1-1 °C. This in contrast to a single-phase cooling system where heat input results in a temperature increase of the liquid (see previous section). Furthermore, the required mass flow for a two-phase pumped system is much smaller than for a single-phase cooling system, because the heat of evaporation $hl_v\Delta x$ of a fluid is much larger than the specific heat capacity of a fluid times the allowed temperature gradient (i.e. $c_p\Delta T$). This results in a much smaller tubing diameter for a two-phase system than for a single-phase pumped loop. This is one of the reasons why, a two-phase pumped system was selected for the thermal control system of the tracker instrument of the Alpha Magnetic Spectrometer[3] (AMS02). The advantage of a single-phase system is that the design is simpler, e.g. because gravity-effects do not play any role. This in contrast to a 2Φ-MPL where unwanted flow separation of the liquid and vapor can occur in e.g. evaporators and tubing. Furthermore, the accumulator size is smaller for a single-phase MPL's as the accumulator does only have to cope with the expansion of liquid. For 2Φ-MPL´s the accumulator is sized on the maximum vapour fraction in the loop during hot operation and the minimum liquid content of the loop during cold start-up.

IV. Development and applications of European pumped loop systems

Although several studies, breadboard models and some flight experiments were performed in the 1980's and 1990's in the USA (NASA) and Japan (NASDA), the application of MPL's in space systems is mainly limited to MPL's on space stations [7,8] (ISS and MIR) and MPL's dedicated to large military satellites or deep space missions by NASA. Currently only one single-phase MPL is operational on a Russian built GEO satellite. ESA started the first developments for MPL's for satellites around 2000 in the framework of the ESA ARTES Alphabus development for large telecommunication platforms. The ESA Mechanically Pumped Fluid Loop (MPFL) development aimed to develop a 3-6 kW single-phase MPL with Thales Alenia Space and Airbus Defence & Space involved for platform requirements. The project was led by Moog Bradford Engineering with Real Technology A.G. as subcontractor for pump and accumulator development and NLR as subcontractor for system engineering and system testing[4].

The ESA MPFL knowledge has been the base for the current 2Φ- MPL of development for the Thermal Control of Telecommunication Satellites led by Thales Alenia Space (TAS) with Kharkov Aviation Institute as main partner with 2Φ- MPL heritage. This large (7-20 kW) 2Φ-MPL system is being developed to thermally control the TAS Neosat large telecommunication platforms[9]. It is also foreseen to be used for thermal control of high power active antennas.

The latest 2Φ-MPL actually launched is the Tracker Thermal Control System developed by NLR for the Alpha Magnetic Spectrometer (AMS02, see Figure 2 for a photo). AMS02 is a large (8500 kg, 2 billion dollar) particle detector that has been launched with the space shuttle in May 2011[3]. This 150 Watt CO_2 –based heat transport system has been developed to keep the Tracker instrument temperature stable within ± 3 K and transport the heat from a widely distributed P/L at the heart of the AMS02 experiment to two dedicated radiators.

With the 2Φ-MPL knowledge gained in the TTCS development and MPFL development NLR started to design 2Φ-accumulators for various sized of MPL's. NLR is involved in the development of the Heat Controlled Accumulator for the TAS 2Φ-MPL with Moog Bradford as partner for accumulator manufacturing.

Other ESA studies focussed on smaller loops like the development by OHB System (D) and the Technische Universitat Darmstadt on the feasibility and use of a mechanically pumped two phase loop with methanol as working fluid. Several MPL component developments were initiated by ESA in the recent past. A brief overview is given in section VI.

V. 2Φ-MPL system design and development considerations

Single-phase MPL's are straightforward in design and system modelling. Heat is transported by sensible heat collected at the dissipative P/L and radiated to deep space. The P/L temperature can be controlled/increased by introducing a valve so part of the flow can by-pass the cold radiator. Alternatively auxiliary heaters can be used in order to delete the active valve.

A 2Φ-MPFL is usually applied when a uniform system temperature is required. This can be achieved controlling the accumulator temperature as the accumulator is the largest two-phase volume in the system and therefore dictates the saturation temperature in the whole loop. Changes in P/L heat load only change the vapour fraction in the loop and not directly the temperature. However, when the heat load on the evaporator of a 2Φ-MPFL changes, liquid will flow into or out of the accumulator. As a result, the pressure in the accumulator will change, and therefore the system saturation temperature. The accumulator can be controlled by heating/cooling the accumulator in order to return to the desired temperature. In principle, the accumulator can maintain exactly the desired temperature in the system when the accumulator heating and cooling capacity is very large or when the accumulator is very big. In practice however, the cooling capacity and accumulator size are limited and the system temperature will vary.

Therefore accurate dynamic modelling of a 2Φ-MPL is important to calculate how much the temperature will vary[10]. Also the MPL itself can be optimised to reduce pressure variations in the accumulator.

To reduce the accumulator changes it is beneficial to reduce the length of the two-phase transport lines between evaporator and condenser. This directly reduces the volume changes in the accumulator and therefore the pressure variation. Locating the highest power P/L elements at the end of the evaporator has a similar effect. Apart from better pressure control these measures also reduce the accumulator size and therefore minimize the mass of the MPL. Better 2Φ-MPL understanding led to component design optimisations and increase of robustness of the 2Φ-MPL systems.

Despite this technical progress and advantages of MPLs the telecommunication satellite market remains hesitative applying new cooling technologies. This is related to the following concerns with respect to pumped driven systems:

1. Working fluid impact on integration and assembly safety procedures
2. Pump life time concerns for 10 years of continuous operation.
3. Micro-meteoroid impact on (radiator) tubing (single point of failure)
4. Accumulator sizing related to application
5. Lack of in-orbit demonstration

Step by step these concerns are being tackled by development of robust MPL designs and robust components. In section VI these component developments are described.

VI. Components of pumped loop systems

A typical layout of a component assembly is depicted in

Figure 3 and Figure 4 as developed for ESA MPFL[8]

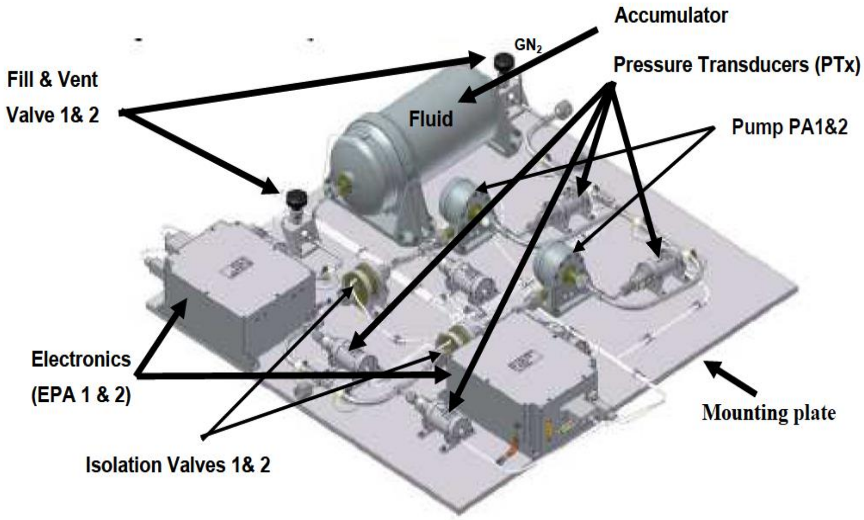

Figure 3 MPFL Pump Packages Assembly (835 x 740 x160 mm)

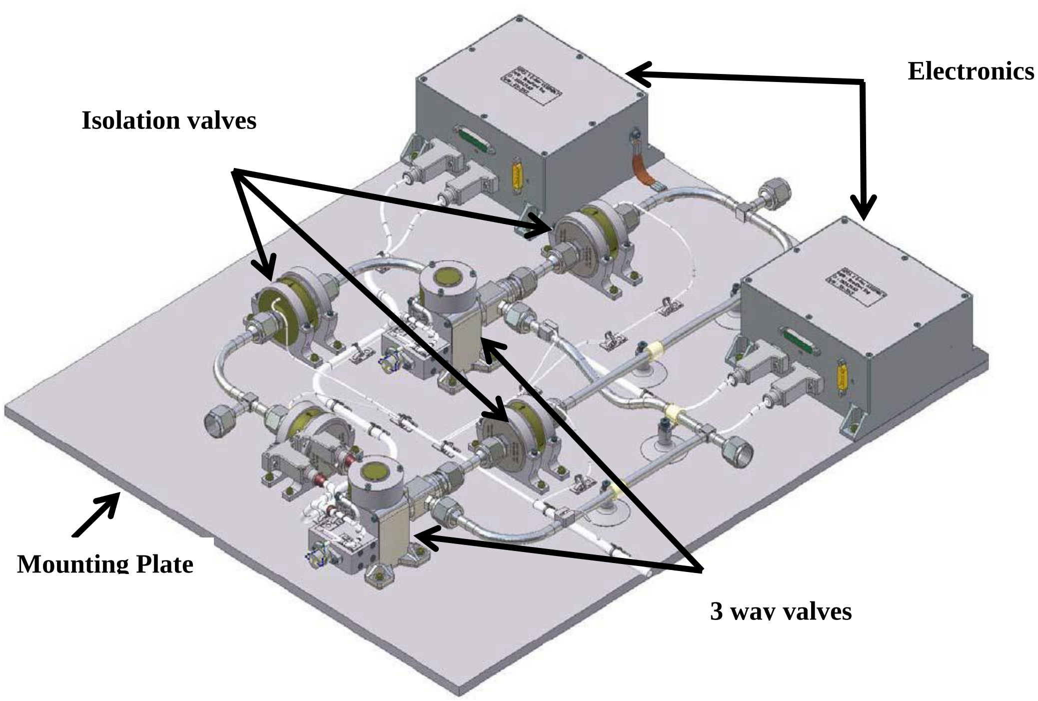

Figure 4 MPFL Bypass Assembly (715x600x90 mm)

In the figures it should be noticed that the electronics boxes take a significant part of the volume and mass. This demonstrates the importance of minimisation of active MPL's components in order to stay competitive with alternative thermal control options.

The following MPL components under development or available in Europe will be briefly highlighted:

- **Fluids selection**
- **Pumps**
- **Accumulators**
- **Valves**
- **Heat Exchangers**

A. Fluid selection

The selection of a suitable fluid is one of the first and most important steps for the design of a thermal control system. A fluid selection tool has been developed to find the best fluids for a certain application[1,6]. This tool uses a 'figure of Merit' to select the most suitable fluids from the REFPROP[7] database. With this systematic approach, fluids can be selected which would have been overlooked without the use of the figure of Merit. Furthermore, the tool offers a large saving in costs and time since the tedious process of finding and analysing possibly suitable fluids can now be carried out with a single push on a button. As an example, the selection of CO_2 for the thermal control system of AMS02 is discussed; An important requirement for the thermal control system of AMS02 was that the tubing inside the instrument must have a small diameter. However, a small diameter of the tubing results in a large pressure drop, and the available pump only has a limited pressure head. For this reason, an important characteristic of the working fluid for the AMS02 instrument is a small pressure drop for a certain heat transport and geometry. The pressure drop in the liquid and vapour tubes can be calculated with

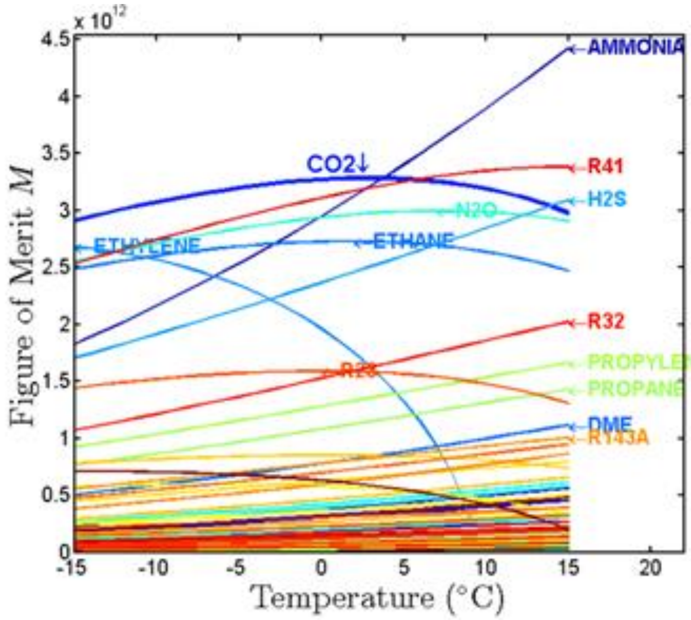

Figure 5: Figure of Merit for a two-phase pumped loop, where the main selection criterium is a low pressure drop

$$\Delta p_l = f_l \frac{L}{d} \frac{\rho_l v_l^2}{2} \text{ with } v_l = \frac{\dot{m}}{\rho_l \pi d^2 / 4} \text{ and } \dot{m} = \frac{P}{h_{lv} N} \quad \textbf{(3)}$$

Where the subscript *l* is replaced by *v* for the vapour tubes. The flow in the tubes is turbulent, and the friction factor can be approximated with the Blasius correlation for turbulent flow in smooth-walled tubes:

$$f_l = \frac{0.3164}{\mathrm{Re}_l^{0.25}} \quad \textbf{(4)}$$

In order to find a fluid with a small pressure drop, Eq. (3) and Eq. (4) are rearranged to:

$$\Delta p \propto \overbrace{\left(\frac{\mu_l^{1/4}}{\rho_l h_{lv}^{\;7/4}} + \frac{\mu_v^{1/4}}{\rho_v h_{lv}^{\;7/4}} \right)}^{\text{fluid dependant}} \overbrace{\frac{L}{d^{19/4}}}^{\text{geometry dependant}} \overbrace{P^{7/4}}^{\text{Heat input}} \qquad \textbf{(5)}$$

The figure of Merit for the two-phase loop is the inverse of the fluid dependent part of the pressure drop in Eq. (5):

$$M = \frac{1}{\mu_l^{1/4} \big/ (\rho_l h_{lv}^{\;7/4}) + \mu_v^{1/4} \big/ (\rho_v h_{lv}^{\;7/4})} \quad \textit{figure of Merit based on low pressure drop} \qquad \textbf{(6)}$$

Figure 5 shows the figure of Merit for a two-phase loop. CO_2 (R744) has the highest figure of Merit over a large part of the operating range. However, there are a number of fluids with a similar figure of Merit, for example, ammonia (R717), N_2O (R744a), R41 (Fluoromethane), and ethane (R170). Most of these fluids are not commonly used in cooling systems (except ammonia) and would not have been found without the use of the figure of Merit. After a detailed fluid trade-off, CO_2 was chosen as the most suitable fluid for the thermal control system of AMS02, because of its low toxicity, inflammability, excellent radiation hardness, and excellent material compatibility. Furthermore, the ratio between the liquid and vapor density for CO_2 is relatively low, and this ensures a 'smooth' evaporation process and allows for the use of parallel evaporators[8]. Other criteria for a two-phase pumped cooling system are also possible, for example a low electrical power consumption of the pump.

A. Pumps

The most important component of an MPL is the pump. A pump failure directly results in MPL system failure and a reliable pump is therefore of vital importance. In Europe the main space pump developments are performed by Real Technologie A.G. in Switzerland which develops high reliable centrifugal pumps with hydrodynamic bearings from ceramic materials. The newest development is the NACPA II pump as depicted in Figure 6.

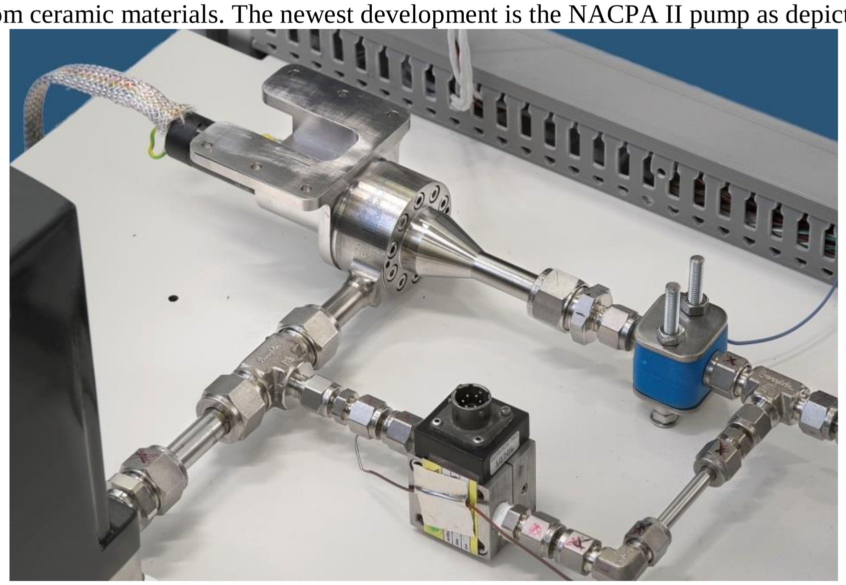

Figure 6: NACPA II Centrifugal pump (Courtesy Real Technology A.G.)

The pump flow of the RT pump range from 50 L/hr to 400 L/min and 8 to 1 bar pressure head. Recently Real Technologie developed also a dual stage centrifugal pump to match the pump head required for the 2Φ-MPL for the Neosat platform of Thales Alenia Space.

Recently NLR developed a dedicated pump for small MPL's the so-called Micro-Parallel Micro-Pump (MPMP). The concept intends to solve this pump reliability problem and reduce the mass to make the introduction of small pumped loops in space possible. This is done using a large set (15-100) of parallel micro-pumps build in one unit with only electronics for on/off control. With this new concept one pump failure is no problem and even multiple pump failures will cause only graceful degradation. New micro-pump developments for the medical sector combined with rapid manufacturing techniques made the development of such multiple sets of pumps possible. A pump prototype is shown in Figure 7. The pump flow ranges 24 ml/min for a 6 pump unit to 400 ml/min for a 100 pump unit with a pressure head of 250 mbar.

Figure 7:Multi-parallel micro pump prototype as developed by NLR

The application of the MPMP is limited to small loops because of the limited pressure head.

B. Accumulators

Second most important component in an MPL is the accumulator controlling the system pressure and allowing the fluid thermal expansion. For single-phase MPL's traditionally a bellows accumulator is used with on one side of the bellows the MPL working fluid and on the other side a pressurised gas like gaseous nitrogen. A flexible diaphragm membrane stack bellows is developed by Real Technology for MPFL and shown in Figure 8.

Figure 8: Detailed of the welded bellows accumulator by Real Technologie A.G.

For 2Φ-MPL's a heat controlled accumulator is used for the pressure and saturation temperature control in the loop. NLR was involved with the concept design of the two-phase accumulator for TTCS and is currently involved in the development of the Heat Controlled Accumulator (HCA) for the 2Φ-MPL for the Neosat platform of Thales Alenia Space. The Engineering Model Accumulator is shown in Figure 9. The HCA size can vary between 10 and 40 litre depending on the application. Apart from stable operation in space the HCA is capable of supplying only liquid to the MPL-loop in all horizontal and gravity assisted orientations on earth providing flexibility for terrestrial satellite testing. For smaller accumulators the HCA is even capable of supplying liquid to the MPL in all orientations.

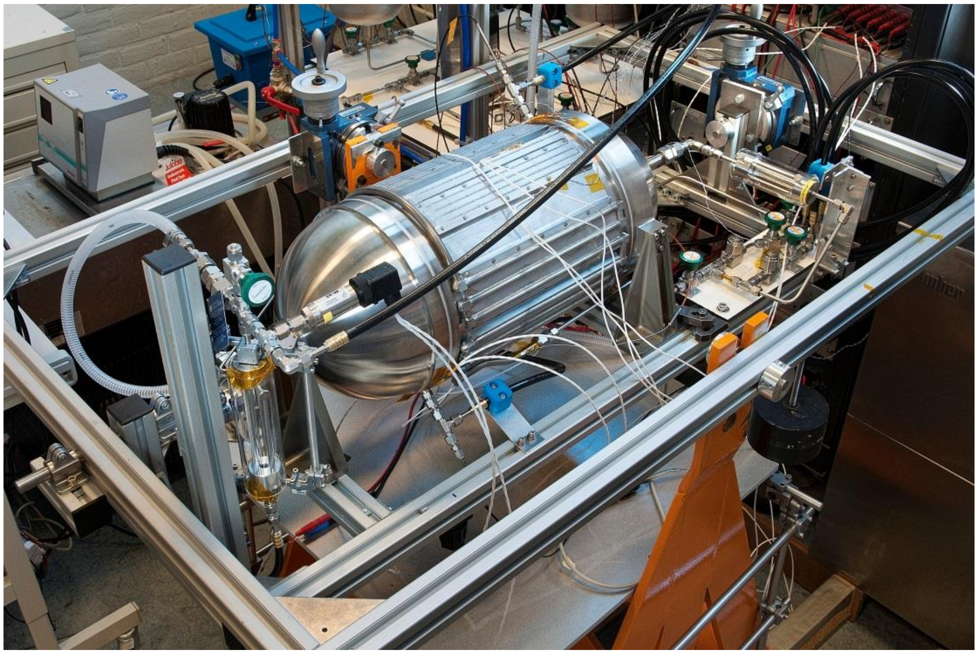

Figure 9: Heat Controlled Accumulator EM during testing at NLR

Based on the HCA technology for a 2Φ-MPL NLR intends to develop a 2Φ HCA for single-phase MPL's. Such an accumulator uses the saturation pressure of a working fluid to keep system pressurised. The pressure in the system is controlled by the temperature of the accumulator which must be kept high enough to ensure that the saturation pressure in the accumulator is higher than the minimal required pressure in the loop. This temperature depends on the working fluid. For Galden ZT85, as used in the MPFL loop, the saturation temperature must be kept above 140 °C to pressurise the system to 3.5 bar. For other common fluids (e.g. ammonia, freon-11, or freon-21) with much lower boiling points lower accumulator temperatures of less than 100°C are required. Only a small amount of heater power is needed to keep the accumulator above the specified temperature. First design iterations show a mass reduction of 35% compared to a bellows accumulator.

C. Valves

There are two main types of valves developed in Europe for pumped loop systems which are either motorized or passive. An example is the motorized 3-way Valve that has been developed by ESA in cooperation with Moog Bradford for MPFL[8] based on the heritage of numerous space programs (Columbus, ATV, SOHO, MPLM). The 3-way Valve (Figure 10) consists of a stepper motor with reduction gear box that moves the spindle up and down. The use of bellows avoids the use of dynamic seals and allows 15 year life time.

Figure 10 Motorized 3-Way Valve (MPFL)

An example of a passive valve currently developed for ESA in cooperation by Thales Alenia Space for the Exomars Rover is integrated in a LHP and used as heat switch[9]. See Figure 11 below. The switching function is achieved through a valve thermally coupled to the evaporator body. The bellow is moved by pressure difference between the argon and the propylene and opens or closes the paths to the condenser and to bypass line.

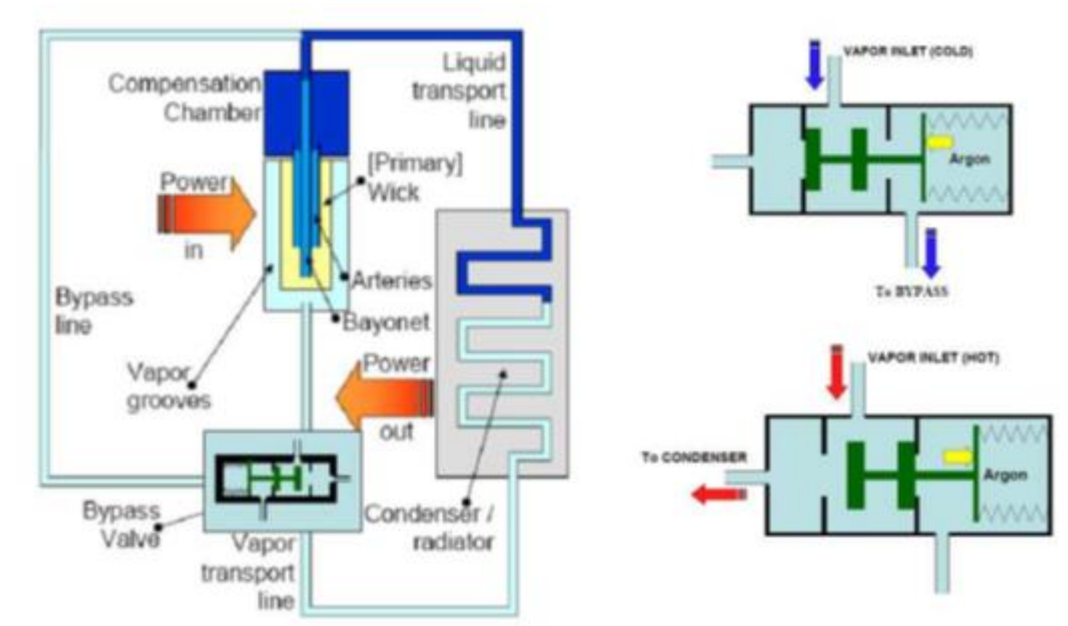

Figure 11 Passive bypass valve used as heat switch for a LHP (Exomars Rover)

NLR, and among others Moog UK are currently developing a passive bypass valve for single and two phase systems based on fluid expansion similar to commercial thermostat designs in the framework of an ESA study. The first Engineering Model is shown in Figure 12.

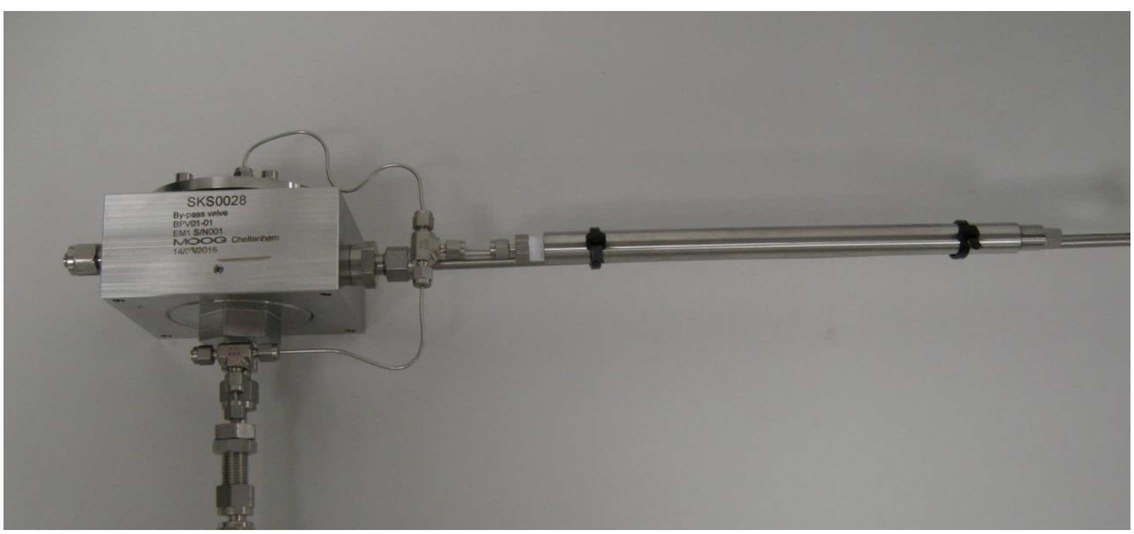

Figure 12: Engineering Model Passive Bypass Valve (Courtesy Moog-UK)

D. Heat Exchangers

To reduce the power consumption of 2Φ –MPL's in cold orbits it is important to implement a heat exchanger to re-use the P/L heat to warm-up the sub-cooled working fluid prior to entering the evaporator. The pre-heater power can then be reduced with 65%[11]. For the TTCS development in 2004 with its extreme Maximum Design Pressure of 240 bar a dedicated design was still needed as shown in Figure 13.

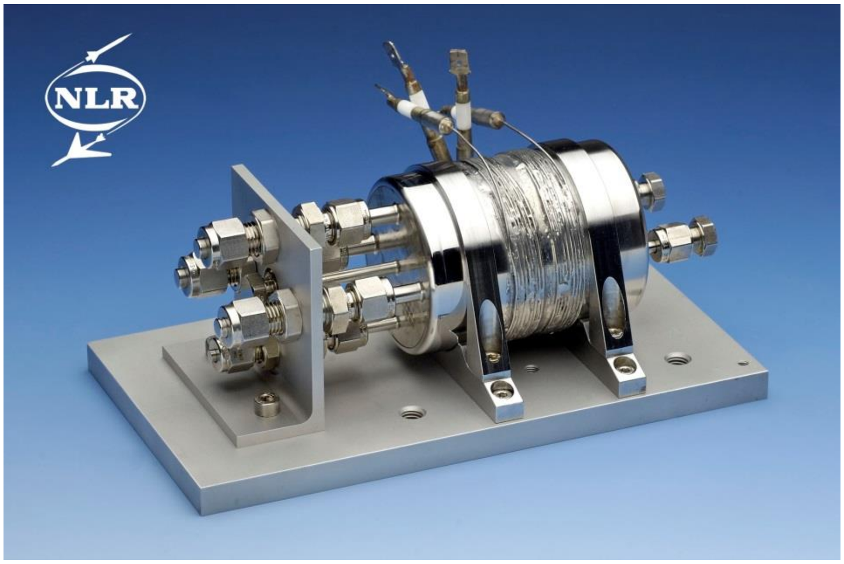

Figure 13: TTCS Plate heat exchanger between two-phase evaporator outlet and single-phase inlet flow

Recently it is possible to ruggedize commercially available plate heat exchanger and use them in space. This led to large cost reductions important for the competitiveness of MPL's.

VII. Conclusions

An overview of the MPL developments in Europe is presented. Recently the interest in MPL's is increased due to architectural changes of commercial communication satellites. A 2Φ-MPL is now baseline for the Neosat platform Thales Alenia Space leading to intensified MPL component developments. The paper presents important European component developments and system design aspects.

It is expected that the intensified European developments will lead to the introduction of MPL's in communication satellites but also in satellite applications with high heat fluxes and/or tight temperature control demands like active antennas and LIDAR.

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