Mechanically Pumped Fluid Loops: Components and Systems for Space Applications

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Mechanically Pumped Fluid Loops

- Typical Mechanically Pumped Fluid Loop
- System Considerations
- Past and Present Systems
- Testing Protocol
- Performance Measurement
- Future Trends
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Typical Mechanically-Pumped Fluid Loop

ACCUMULATOR WITH LEVEL INDICATOR

PURGE/FILL OUTLET

PURGE/FILL INLET

CHECK VALVE

FILTER

MOTOR-DRIVEN PUMP

HEAT EXCHANGER OR RADIATOR

FROM HEAT LOAD

TO HEAT LOAD
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BAMS LSCU

Firescout LCS

ISR Aircraft LCS
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Liquid Cooling Systems for Space Applications

MSL Integrated Pumping Units

ISSA Satellite Refueling Demo.

AMS-2 Pump and Controller
Primary Environments which affect system design are:
- Temperature ranges
- Altitude
- Vibration / Shock

Operational Voltage(s) -
Input Power Limit -
Input VA Limit -
Power Factor Requirements -
EMI Requirements -

System Warm-Up Time -
Fluid Temperature Control -
Reliability / Life -
Noise Limits -
Built-In-Test Features -
etc.

Operational Voltage(s) -
Input Power Limit -
Input VA Limit -
Power Factor Requirements -
EMI Requirements -

Select Coolant(s)

Calculation of operational and non-operational environments

Define Cooling Requirements and Heat Transfer Method

Heat Transfer capacity / method drives the flowrate, pressure drop, heat exchanger size, etc.

Define System Fluid Volume

Required to size the accumulator

Calculate System Fluid Volume

Calculate Required Fluid Flowrate & Pressure Drop

Required to select and size the pump / motor
Requires definition of line size and hydraulic layout

Defining operational and non-operational environments

Define Operational / Non-operational Environments
Unique Requirements for Space Applications

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<tr>
<th>Challenge</th>
<th>Feature(s)</th>
<th>Benefit</th>
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<tbody>
<tr>
<td>Long-duration missions</td>
<td>• All-welded construction (no elastomeric seals)</td>
<td>High reliability</td>
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<td>• Flooded pump motors (no shaft seals)</td>
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<tr>
<td>Strict cleanliness and material compatibility</td>
<td>• CRES wetted materials</td>
<td>Reduced potential for material interactions</td>
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<tr>
<td>requirements</td>
<td>• Canned (sealed) motors</td>
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<td></td>
<td>• Carbon bearings</td>
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<tr>
<td>Wide temperature range</td>
<td>• Limited material list</td>
<td>Reduces thermal expansion issues</td>
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<td></td>
<td>• Appropriate fits/clearances</td>
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<td>Tight power budget</td>
<td>• Small motors</td>
<td>Reduced power consumption</td>
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<td></td>
<td>• Low flow rates</td>
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<td></td>
<td>• Minimize system pressure drop</td>
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<td>• Passive thermal control valves</td>
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Past and Present Systems

Integrated Pump Assemblies
- Mars Pathfinder (cruise stage)
- Mars Exploration Rover (cruise stage)
- Mars Science Laboratory (cruise stage and rover)

Pumps and Accumulators
- AMS-2 Tracker
- Satellite Refueling Demonstrator

Thermal Control Valves
- Part of Mars IPA’s
- “Smart” Loop Heat Pipes (ground demo projects)
Typical Test Sequence

- Component performance testing, lab ambient environment
- Pre- and Post-Welding performance, lab ambient environment
- Proto-flight Vibration and Shock
- Thermal Vacuum Cycling
- Performance Mapping
- Integration testing (by customer)
- Vehicle testing (by customer)
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Pump Performance

- Flow, pressure rise and power consumption
- Speed control, start-up and high/low temperature performance
- Current/Power Limiting circuitry
- Fault detection/Speed output signals

Centrifugal Pump Performance Map
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**Accumulator Performance**
- Displaceable volume
- Pressure vs. volume performance

**Thermal Control Valve Performance**
- Flow rate vs. temperature
- Flow and pressure drop performance

Accumulator Performance Test

Thermal Control Valve Performance Map
Performance Enhancements
• Higher pump efficiency through impeller changes, and multi-stage pumps
• Sensorless motor controls to eliminate position sensors
• High temperature electronics
• Controller miniaturization

Alternate Fluids
• Reduce use of ozone-depleting chemicals

Thermal Control Valves
• New system architectures

Multi-stage Pump Impellers
Summary

• Pumped-loop systems provide relatively high capacity heat transfer performance in a small package
• High reliability systems have been proven through multiple long-duration missions
• Electric power consumption can be minimized through proper system sizing
• Materials and processes well established
• Established supply base minimizes program risk
• Advances in electronics offer future improvements in size/weight/power
• Innovative architectures under development