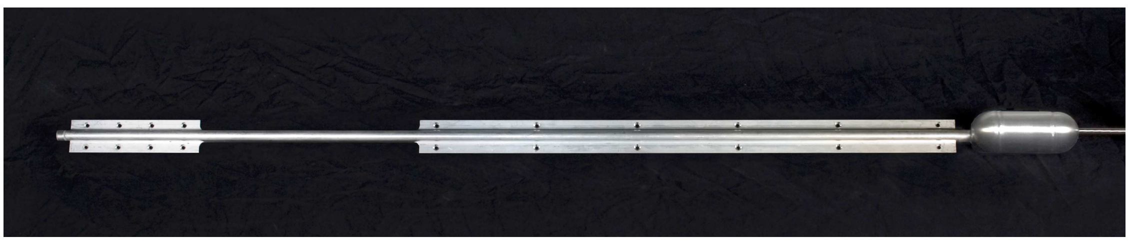
AXIAL GROOVE VARIABLE CONDUCTANCE HEAT PIPES

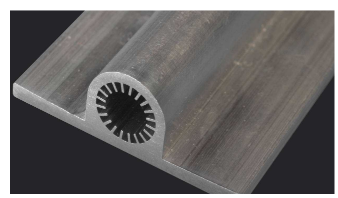
Variable conductance heat pipes (VCHPs) are used to achieve temperature control. This is accomplished by blocking a fraction of the condenser with a small amount of non-condensable gas. When the heat load or the condenser temperature increases, the heat pipe temperature tends to rise. The increased vapor pressure compresses the non-condensable gas, exposing more condenser area and as a result increases the heat pipe conductance. The opposite happens when the heat load or the condenser temperature decreases. The variation of the conductance keeps the heat pipe operating temperature nearly constant over a wide range of heat inputs and condenser thermal environments. A modest level of control is achieved with an uncontrolled, passive reservoir; precision control is achievable with a temperature controlled reservoir. Axial groove capillary wick structures are often utilized because of the relative ease of manufacturing (aluminum extrusions) and their demonstrated heritage in spacecraft and instrument thermal control applications. Common working fluids include: ammonia, propylene, and ethane.



Aluminum/Ammonia VCHP with non-condensable gas reservoir

Applications:

- Passive Thermal Control of Spacecraft Electronics
  - Over varying sink conditions
  - Over a wide range of thermal loads
- Minimizing Power Requirements for Survival Heaters

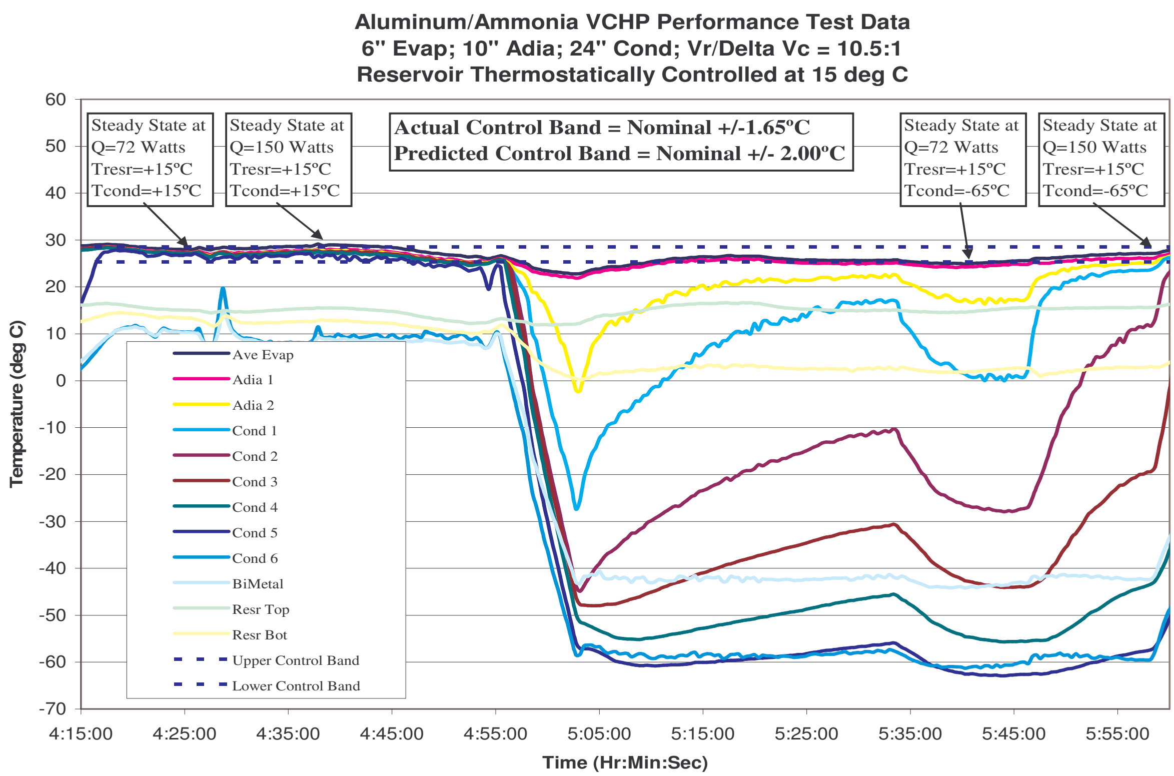


Precision axial groove extrusion with integral flange

ACT fabricates Variable Conductance Heat Pipes (VCHPs) to exact aerospace requirements. These devices are manufactured under ACT's AS9100-B Quality System. The materials used for manufacturing (extrusions and working fluids) are certified and qualified to meet the demanding level of aerospace quality. Each aluminum extrusion is fully characterized to determine thermal and pressure containment capabilities as functions of operating temperature and fluid charge. The welding processes are performed by welders certified to AWS 17.1 Specification for Fusion Welding for Aerospace Applications.

ACT has heat pipe models to simulate each design application. These models are used to assist with the selection of the right extrusion for each application. The capillary limit of the heat pipe is determined by taking into account the exact extruded groove geometry. The optimum fluid charge is determined for the specific application and the effect of excess fluid charge is determined for both 0-G and 1-G operations. ACT has specialized VCHP prediction models that are used to select the reservoir size and evaluate various control techniques such as: Cold Reservoir (passive, no temperature control), Reservoir Temperature Controlled (thermostatically held at specific set point), Optimum Reservoir Temperature Controlled (active temperature control of reservoir – variable set point), and Non-Wicked Hot Reservoir (reservoir temperature coupled to vapor temperature).

The graph below shows the thermal performance of a reservoir temperature controlled VCHP that ACT built and tested for a spacecraft application. The evaporator section of the VCHP was controlled to +/-1.65ºC as the input power was varied from 72 Watts to 150 Watts and as the sink temperature ranged from +15ºC to -65ºC. The control band achieved was in good agreement with the analytical prediction of +/-2ºC.



Actual Performance Data for an Aluminum/Ammonia VCHP
Tested From Q=72 Watts, Tcond = +15ºC to Q=150 Watts, Tcond= -65ºC

ACT has specialized equipment required to manufacture VCHPs to achieve aerospace quality. This includes: dedicated cleaning baths for chemically cleaning raw extrusions, triple distillation apparatus for working fluid purification, state-of-the-art helium mass spectrometer leak detector, dedicated charging, processing, and non-condensable gas venting stations, and specialized test setups for testing and characterization at various temperatures.