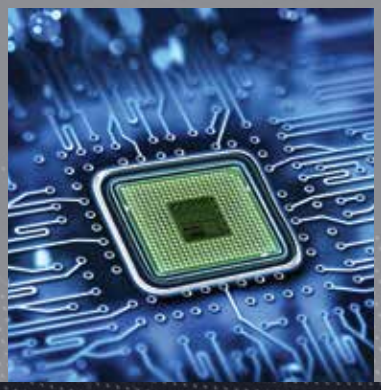
ADVANCED COOLING TECHNOLOGIES

The Thermal Management Experts

DYNAMIC
Measurement & Control Solutions, LLC

SOLUTIONS OVERVIEW



DESIGN | ANALYSIS | MANUFACTURING | TESTING

Dynamic Measurement & Control Solutions www.dynamicrep.com sales@dynamicrep.com 408-780-9190

THERMAL MANAGEMENT EXPERTS

> "The technical interchange between teams was excellent. I believe it enabled the larger team (ACT & our company) to achieve more than either acting alone."
>
> – ENGINEER, MAJOR MILITARY SUPPLIER

ADVANCED COOLING TECHNOLOGIES, INC. IS A PREMIER THERMAL MANAGEMENT SOLUTIONS COMPANY

We serve our customers' thermal management and energy recovery needs in diverse markets including Defense, Aerospace, HVAC, Medical Devices, Enclosure Cooling, and Calibration Equipment.

Our diverse Product portfolio allows us the maximum ability to meet our customers' performance, cost and reliability requirements. ACT is the only U.S. manufacturer that routinely ships Heat Pipe products for terrestrial, spacecraft and high temperature applications. Our Heat Exchanger products are deployed all over the world to improve the energy efficiencies of building HVAC systems and industrial processes. Our PCM Heat Sink products ensure the reliable operation of some of the most mission critical equipment in the world.

As one of the "Best Places to Work in Pennsylvania", ACT is strongly committed to our customers, employees, and community. Innovation, Teamwork and Customer Care are our core values that drive the continuing growth of our company.

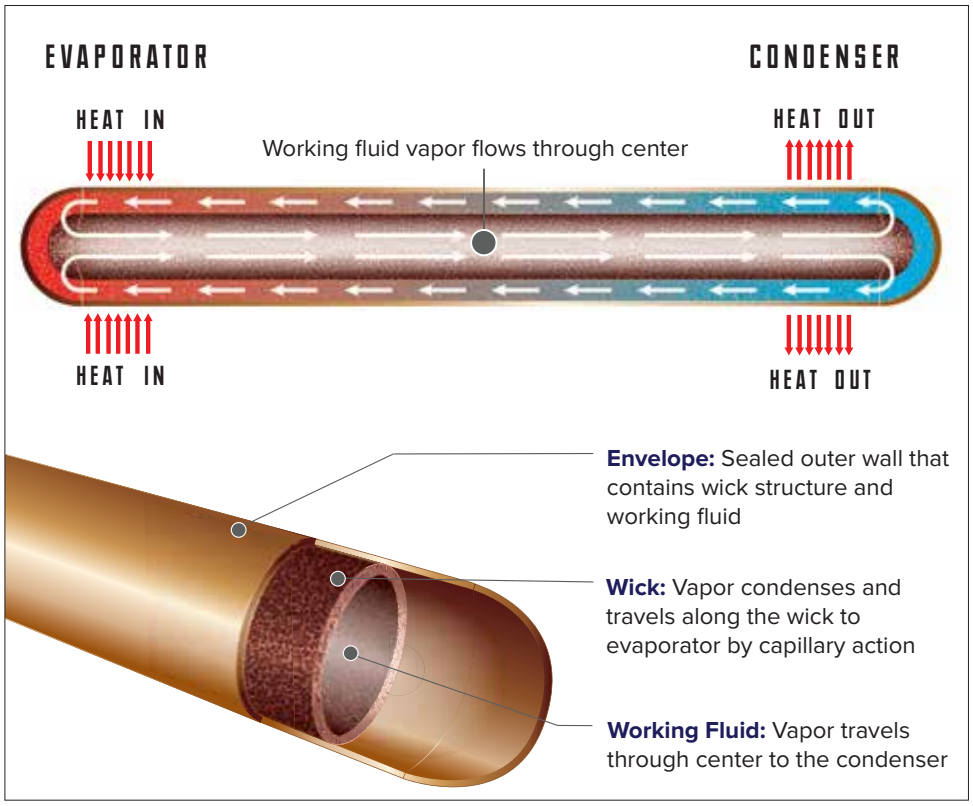
QUALITY AND CONTINUOUS IMPROVEMENT ARE BASIC ACT OPERATING PRINCIPLES

The overarching goal of ACT is to provide a superior standard of service to our customers through responsiveness, competitive pricing and most importantly, the quality of our products and services. One element demonstrating our commitment to quality was the achievement of ISO 9001:2008 international quality certification in December 2005 and the receipt of AS9100 aerospace certification in December 2006. Our certifications are audited and renewed each year by Intertek.

It is ACT's commitment to achieve the highest quality standard in the industry, providing our customers with superior products and solutions.

PRODUCTS: HEAT PIPES

HEAT PIPES are one of the most efficient ways to move heat from one point to another. First developed by Los Alamos National Laboratory for high temperature energy conversion systems in the 1960s, heat pipes are used today in a variety of applications from satellite thermal control to microprocessor cooling to industrial waste heat recovery.



BENEFITS OF HEAT PIPES

- **High Effective Thermal Conductivity.** Transfer heat over long distances, with minimal temperature drop (i.e. near isothermal operation).
- **Passive Operation.** No moving parts or mechanical or electrical energy input for operation, resulting in long term reliability and system simplicity.
- **Lower Costs.** Cost of ownership is inherently low because of the high reliability and system simplicity.

HEAT PIPE ASSEMBLIES Copper-water heat pipes typically operate in the temperature range of 20 to 150°C. ACT manufactures copper-water heat pipes in two basic geometries: Tubular Heat Pipes and Planar Heat Pipes (or Vapor Chambers). These heat pipes are often combined with other components to form heat transfer assemblies. ACT's copper-water heat pipes are designed to survive numerous freeze/thaw cycles without degradation as required for many outdoor applications.

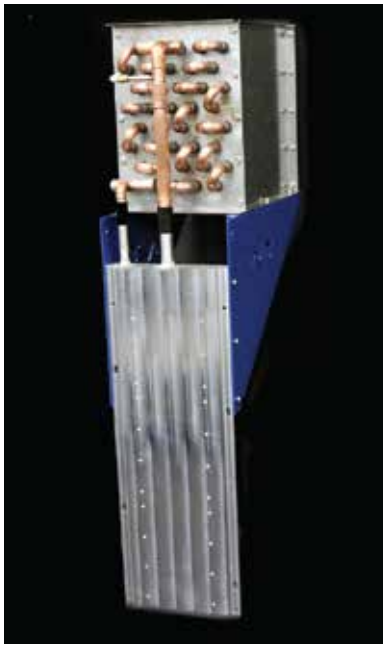
ACT's Copper-Water Heat Pipes and High Conductivity (HiK™) Plates have space flight heritage.

PRODUCTS: HEAT PIPES

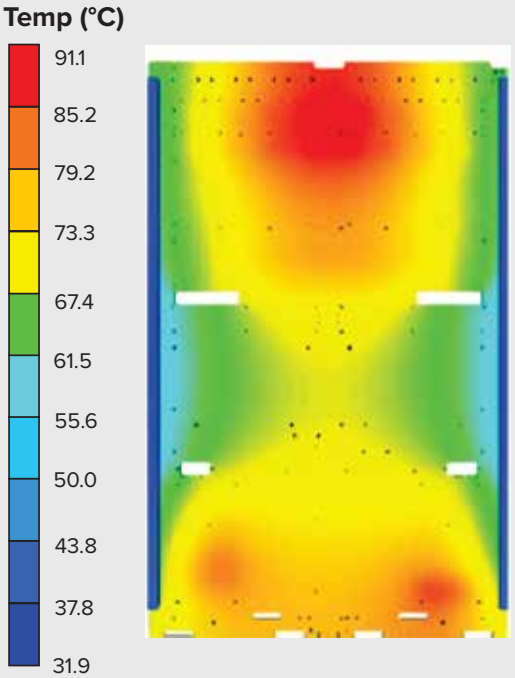
VAPOR CHAMBERS are planar heat pipes used for cooling high heat flux electronics. A vapor chamber can accept heat from one or more sources and transfer the heat to an integral air-cooled heat sink or water cooled edge rails.

HiK™ PLATES are heat spreaders with embedded heat pipes. They are particularly useful for cooling of multiple high power components, by collecting and moving heat from these discrete heat sources to a liquid cooled edge or an air cooled heat sink with minimal temperature gradients.

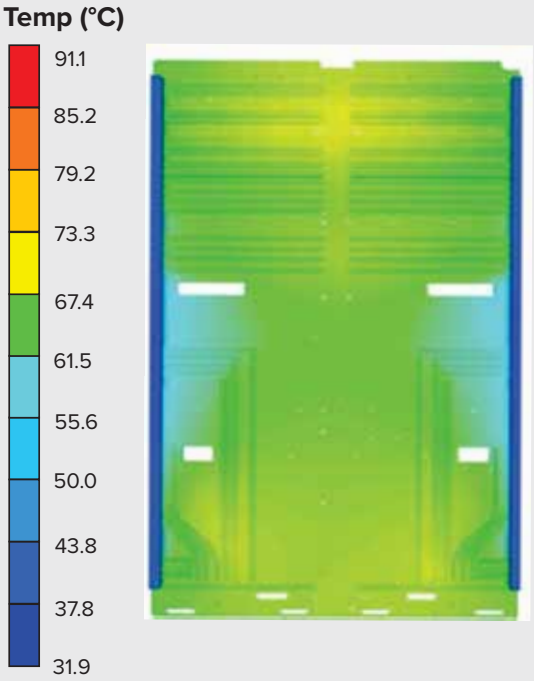
HIGH PERFORMANCE POWER ELECTRONICS COOLERS



use loop thermosyphon technology to move large amounts of waste heat. Heat generated by power electronics causes liquid within the loop thermosyphon evaporator to evaporate. The resulting vapor travels in the vapor line to the condenser that is cooled by airflow. The condensed liquid then returns to the evaporator through a separate liquid line, completing the two-phase loop. This results in an extremely high performance cooler that requires no moving parts or external power for its operation.



(a) Temperature Profile of an edge cooled aluminum plate with various high powered electronic components



(b) Temperature Profile of a HiK™ Plate that has the same components as Figure A above.

The conventional aluminum plate's highest temperature of 90.3° C was reduced to 69.1° C when the HiK™ aluminum plate was substituted.

PRODUCTS: HEAT PIPES FOR AEROSPACE

CONSTANT CONDUCTANCE HEAT PIPES (CCHPS) use miniature grooves as the wick structure and ammonia or other low freezing temperature fluids as the working fluid to efficiently transfer heat in a microgravity and cold environment. The materials and processes used to manufacture these heat pipes are certified and qualified to the highest aerospace quality requirements. To date, ACT's CCHPs have been operating onboard satellites and other spacecraft for millions of hours.

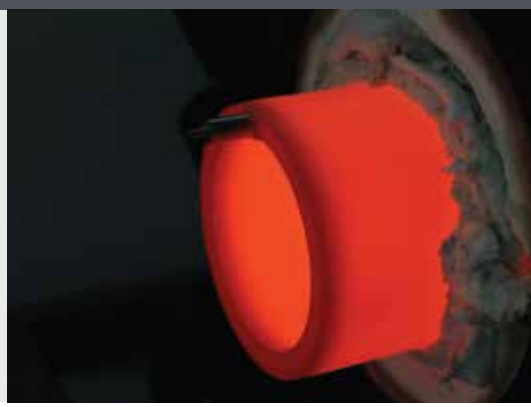
VARIABLE CONDUCTANCE HEAT PIPES (VCHPS) are similar to the CCHPs in wick structure and working fluid selection, but with a predetermined amount of non condensible gas (NCG) added into the heat pipe. The NCG expands or shrinks in volume according to the pressure (and temperature) of the working fluid vapor inside the heat pipe, therefore blocking or opening condenser area for heat dissipation. The result is a passively controlled, relatively constant payload temperature even when the condenser (radiator) temperature goes through large temperature variations.

LOOP HEAT PIPES use micron pore size wicks in their evaporators to provide capillary pumping for the two-phase fluid circulation. In a typical space environment (micro gravity), a loop heat pipe can passively transport a large amount of heat (several kW) over a distance of many meters. Most spacecraft loop heat pipes use ammonia as the working fluid, while some loop heat pipes use ethane and other cryogenic fluids for lower temperature applications. Some advanced loop heat pipes have sophisticated control features to maintain the temperatures of sensitive payloads despite large variations of the environmental temperature.

"ACT worked closely with the ITT team to successfully manufacture and deliver complex heat pipes for integration at ITT. At the end of the program, ACT received an outstanding supplier award from ITT. According to ITT, "ACT was a critical supplier for what will be an important national asset", referring to the GOES-R satellite. Since then, ACT has delivered similar CCHPs for the GOES-S, T and U satellites."

-ITT/HARRIS CORPORATION CASE STUDY

PRODUCTS: HIGH TEMPERATURE HEAT PIPES



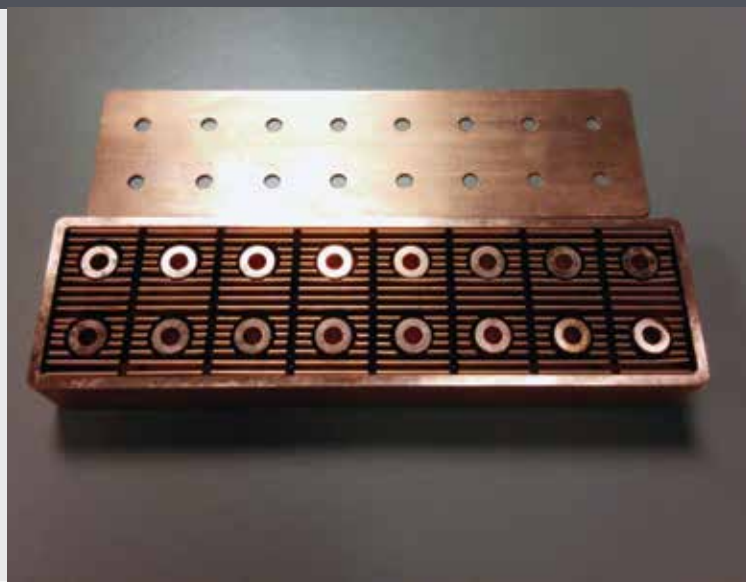
ISOTHERMAL FURNACE LINERS (IFLS) An IFL is a unique, annular heat pipe that is inserted into a tubular furnace to provide a work zone that is highly stable and uniform in temperature. Most IFLs can achieve a temperature uniformity of within 0.1°C. This eliminates the need for multiple heat zones and sophisticated controls, substantially reducing equipment and maintenance costs. In some cases, IFLs have been used to extend the usable work zone beyond the original furnace heater length, thus increasing productivity. ACT offers standard and custom IFLs for operation from -60°C to 1,100°C.

HEAT PIPE BLACKBODY CAVITY A Heat Pipe Blackbody Cavity is an annular heat pipe with a hemispherical end cap that forms an isothermal blackbody cavity. The temperature uniformity within the cavity is typically within 0.1°C. Materials of construction are typically Aluminum, Stainless Steel, Monel, Inconel or Haynes, depending on the operating temperature. Other materials or coatings are also possible. The heat pipe's inner and outer surfaces are typically oxidized to provide high emissivity.

PRESSURE CONTROLLED HEAT PIPE FURNACES A typical PCHP furnace consists of four major components that can be physically detached from each other: annular heat pipe, tube furnace, control cabinet with electronics and pressure monitoring system, and a computer. Unlike a conventional heat pipe that is hermetically sealed, the vapor space of the annular heat pipe in the PCHP furnace is connected to a helium gas reservoir. The control system for the helium pressure consists of a pressure transducer, a helium supply and a vacuum pump. The pressure is maintained constant by admitting or removing helium. ACT's PCHP Furnaces have demonstrated less than 5mK temperature stability over 2+ hour time periods.

PRODUCTS: THERMAL STORAGE

PHASE CHANGE MATERIAL (PCM) HEAT SINKS PCM Heat Sinks can absorb heat with minimal temperature rise during the PCM's solid to liquid phase transition. The latent heat of the phase change is at least an order of magnitude higher than the sensible heat that can be stored by either the single phase solid or liquid. PCM heat sinks are particularly useful for pulsed power applications where the PCM prevents overheating by providing temporary heat storage during the transient peaks of heat generation. Some advanced PCM heat sinks have heat pipes integrated into the structure for enhanced heat transfer.

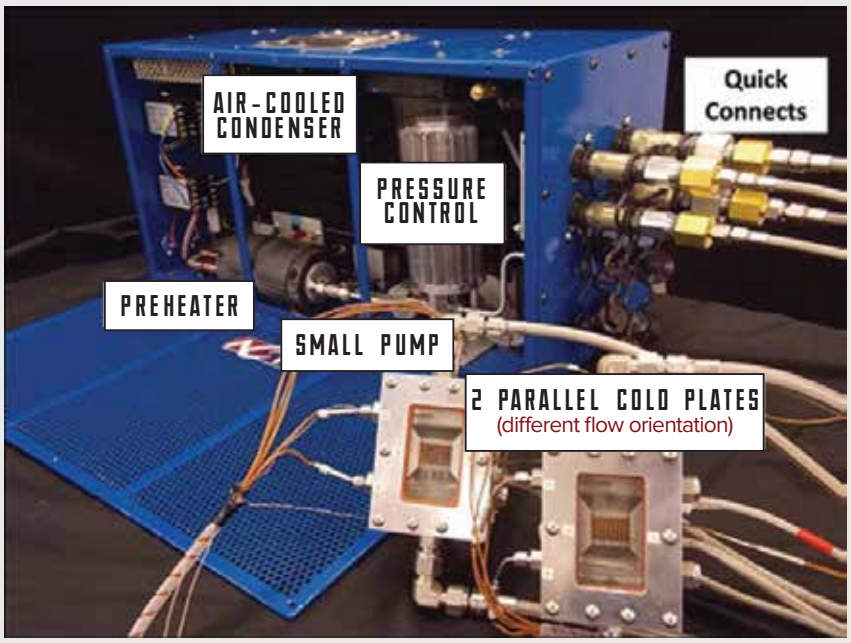


PRODUCTS: PUMPED COOLING

PUMPED LIQUID COOLING A typical pumped liquid cooling loop consists of a pump, a cold plate, a heat exchanger/sink and liquid lines. In many cases, reservoirs and valves are used to control the fluid volume and flow rate. The pump circulates the fluid in the loop, which picks up the heat in the cold plate and dissipates the heat through the heat exchanger. Compared to capillary driven (passive) two-phase devices such as heat pipes and loop heat pipes, pumped liquid loops can provide more robust operation against gravity or acceleration.

PUMPED TWO-PHASE COOLING (P2P)

Pumped two-phase (P2P) systems transfer heat by the evaporation and condensation of a portion or all of the working fluid. Typically, a liquid near saturation is pumped into the cold plate (evaporator), where it starts to boil, cooling the electronics and storing the energy in the latent heat of the fluid. The two phase (liquid and vapor) fluid then flows to the condenser, where the heat is removed, condensing the vapor, so that a single phase (liquid) exits the condenser, and the cycle repeats. Compared to a pumped liquid (single phase) cooling system, a P2P system is typically more compact and lighter, consumes less power, and provides more isothermal cooling of multiple, discrete heat sources (an important requirement for many optoelectronics devices).



> "Allowing us to have direct communication with your senior level, technically savvy engineers was immensely helpful at early stages of a project where a customer is not fully certain about a variety of technical specifications."
>
> – INNOVATIONS COMPANY

PRODUCTS: HEAT EXCHANGERS

HVAC HEAT PIPE HEAT EXCHANGERS ACT's Wrap-Around Heat Exchangers and Air-to-Air Heat Exchangers provide effective and affordable energy recovery during the hot summer and cold winter months as well as throughout the year. Compared to other HVAC energy recovery technologies, the heat pipe heat exchangers have no moving parts, require no external energy for their operation, and maintain zero cross-contamination between the air streams (in cases of Air-to-Air Heat Exchangers).

SEALED ENCLOSURE COOLERS ACT's UL certified Enclosure Coolers effectively dissipate heat from sealed electrical and electronics enclosures operating in indoor, outdoor and other types of environments. Our products incorporate many advanced technological and manufacturing innovations, resulting in significantly improved performance/cost and performance/volume ratios.

PRODUCTS: CONTINUED

CUSTOM THERMAL, FLUID AND MECHANICAL SYSTEMS ACT designs and manufactures custom thermal, fluid, and mechanical systems for customers in diverse industries. Examples of custom systems designed and built by ACT in the past several years include Single Phase and Two Phase Thermal/Fluid Systems, Directed Energy Weapon cooling and thermal storage systems, Flammability and Thermal/Compressibility Test Rigs, Avionics Box Experimental Simulators, and Temperature Calibration Systems.

ISOTHERMAL CARD EDGE (ICE)-LOK™ ACT's ICE-Lok™ is a thermally enhanced wedgelock for conduction cooled embedded computing systems. Compared to a conventional wedgelock, an ICE-Lok™ provides additional heat transfer paths between the card and the chassis and bypasses the thermally inefficient clamping mechanism. The form factors are seamlessly compatible with standard VITA systems, allowing for longer life and higher reliability for critical components without costly board or chassis redesigns.

INNOVATIONS IN ACTION

RESEARCH AND DEVELOPMENT HAS BEEN A CORE COMPETENCY OF ACT SINCE ITS INCEPTION, and continues to lead our product and market diversification effort. Examples of our Innovations include:

ADVANCED COATINGS Coatings available for corrosion/erosion resistance *(see ANCER™ below),* boiling enhancement, wettability control, and Plasma-Enhanced CVD coatings for nanoparticles.

APPLIED NANOSCALE CORROSION EROSION RESISTANT (ANCER™) COATINGS allow for greater life when high purity de-ionized water is used in copper microchannel systems. The coatings reduce erosion and corrosion by more than two orders of magnitude, while allowing for reduced pH and dissolved oxygen control, significantly reducing operating costs. ACT uses electrochemical techniques to evaluate the effectiveness of various passivation techniques.

PHASE SEPARATION Momentum-driven Vortex Phase Separators provide gravity-independent separation and inventory management of liquids, gases, and solids.

ADVANCED HEAT EXCHANGERS ACT offers Advanced Heat Exchangers for applications including pulsed power systems, passive temperature control of chemical reactant streams, and direct contact heat transfer.

ADVANCED MULTI-SCALE MODELING AND RESEARCH
These offerings include ablation materials (atomic), Boltzmann transport models for semiconductors (gate level), and damage and corrosion fatigue models.

COMBUSTION AND SYNFUELS ACT's offerings include fuel reforming for fuel cells, nano-catalysts for low temperature methanol combustion, and solar power for synfuels and coal gasification.

ADVANCED HEAT PIPES Standard heat pipes act as thermal superconductors, transmitting heat with minimal temperature drop in both directions. By adding small amounts of Non-Condensable Gas (NCG) and modifying the heat pipe design, it is possible to create many heat pipe variations. Other advanced heat pipes include high heat flux vapor chambers (>1,000 W/cm^2), as well as heat pipes with new working fluids and envelopes for the temperature range between 150 and 450°C.

TECHNICAL SERVICES

ACT IS FULLY COMMITTED TO SERVING OUR CUSTOMERS BY PROVIDING THE SERVICES THEY TRULY NEED. We offer a broad range of high quality technical services. In all cases, we maintain strict confidentiality to protect our customers' valuable information.

THERMAL MANAGEMENT CONSULTING

ACT's thermal engineering experts have helped guide clients in diverse industries to cost effective thermal solutions. Using our extensive product development and manufacturing experience, we offer feasibility studies to generate and evaluate potential thermal management solutions. We also offer trade studies to determine which of the potential thermal solutions offers the best performance and value. We can help you save time and avoid costly delays by identifying the correct thermal solution.

DESIGN AND ANALYSIS

ACT's engineering staff is fully competent in CFD and heat transfer analysis. We use commercial software and can also create or modify computational codes as required. Examples of our analytical capabilities span all scales: Atomic (Ab Initio, Molecular Dynamics), Microscopic (Boltzmann Transport Equation, Phase Field Modeling), and Macroscopic (CFD, FEA). ACT has developed custom codes for multi-phase systems, thermal storage devices, and chemical reaction mechanisms.

PROTOTYPING

We offer custom thermal management component and system prototyping. Examples of our high quality, fast turnaround prototyping services include heat pipes, vapor chambers, assemblies with thermoelectric coolers or laser devices, phase change materials, thermal storage heat sinks and heat exchangers, and pumped liquid and two phase systems.

MANUFACTURING

ACT's in-house volume manufacturing operations are certified to ISO9001 and AS 9100 quality standards. The heat pipe manufacturing line produces >250,000 heat pipes annually which are then integrated into a variety thermal management devices for military, aerospace, and commercial applications. In fact, ACT is the only U.S. manufacturer that manufactures heat pipe products for both terrestrial and spacecraft applications.

PRODUCT TESTING

Our laboratory includes a host of testing and characterization equipment from standard data acquisition systems to high temperature and high heat flux testing metrology equipment. Our experienced quality-conscious technicians ensure all testing is performed in accordance with industry standards.

ONLINE TOOLS

HEAT PIPE CALCULATOR This program will give a performance curve of a copper-water heat pipe with the given input values. This curve is a guide for ACT's standard heat pipes; custom solutions are readily available to meet a large variety of design specific requirements.

THERMAL STORAGE CALCULATOR This program can be used to determine the approximate size and mass of a Phase Change Material (PCM) heat sink required for thermal storage applications.

HVAC ONLINE SELECTION TOOLS will assist the HVAC design engineer in the proper selection of an Air-to-Air Heat Pipe Heat Exchanger (AAHX) or a Wrap-Around Heat Pipe Heat Exchanger (WAHX) and provide energy savings estimates. The tool provides the designer with the capability to perform a preliminary design selection and to evaluate and rate the AAHX or WAHX performance at various design conditions. It is also intended as a tool to communicate engineering requirements to ACT for additional evaluation.

ENCLOSURE COOLING ONLINE SELECTION TOOL This program will assist the Enclosure Cooler design engineer in the proper selection of an enclosure cooler. The tool will select the best Enclosure Cooler products based on user inputs, allowing for easy online purchase.

ENCLOSURE COOLING ONLINE ORDERING ACT offers online ordering for it's line of Enclosure Cooling products. Choose your product and preferred options and conveniently pay online.

WEBINARS Our library of webinars cover a wide variety of thermal management topics and discuss industry trends, the latest technology, and more.

HEAT PIPE RESOURCES PAGE contains the most extensive information on heat pipes and related technology available anywhere on the web, including Fundamentals, Limits, Wicks, Working Fluids and Envelopes, Different Kinds of Heat Pipes, and Advanced Developments.