THERMOSTATIC CONTROL IN AVIONICS COOLING

MANAGING MODERN ELECTRICAL THERMAL OUTFIT WITH THERMOSTATIC COOLANT CONTROL

Modern aerial vehicles and military aircraft carry advanced electronics and equipment critical to their effective operation and overall application success.

While innovation is carrying airborne technologies farther and higher than ever before, avionic cooling practices are evolving to keep up. To efficiently remove excess thermal heat generated by complex circuitry, many design engineers have turned to liquid cooling systems.

Liquid Cooling In Modern Avionics

To accommodate the increasing thermal relief demands of modern electronics, many aircraft system designs now feature liquid-cooled cold plates. In these designs, coolant runs through the cold plate, removing heat and releasing it through a heat exchanger.

Using this method, the cold plates are kept at a fairly even temperature, avoiding temperature spikes and allowing for effective thermal transfer.

This technology also applies to systems exposed to temperatures approaching cryogenic in which a heating fluid rather than a cooling fluid passes through the plates to keep the electronic system within an optimal operating temperature range.

Compact and efficient, liquid cooling is ideal for designs with space constraints and high thermal output, making them a good fit for many aircraft applications. The downfall of this perfect match, however, comes in the form of increased cost, design complexity and the demand for more engineering hours.

For many high-pressure Aerospace & Defense applications, this trade-off is well worth it.

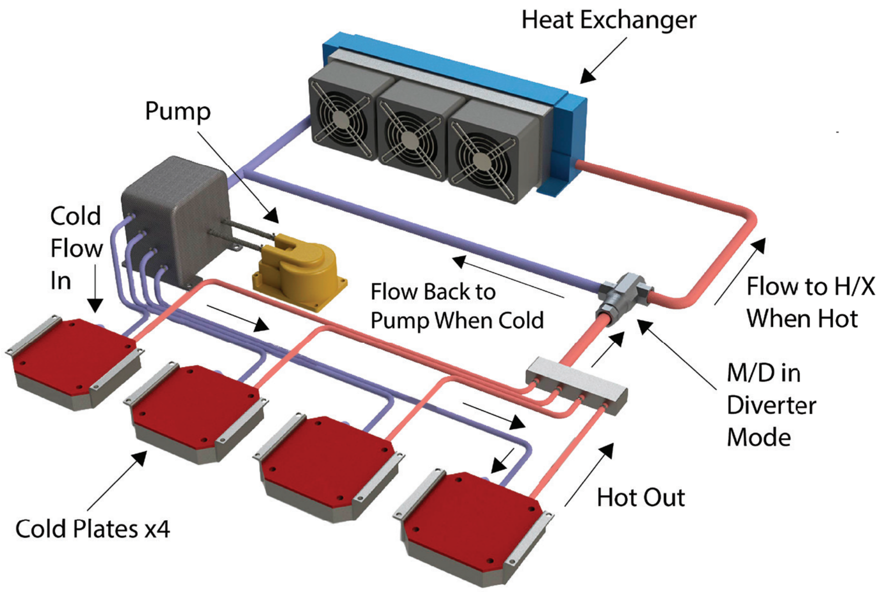


Figure 1. Typical fluid cooled system design.

Fixed vs. Thermostatic Liquid Control

In liquid-cooled cold plate designs, coolant is circulated in one of two ways – fixed flow or thermostatic flow. With traditional fixed flow through a liquid cooling design, coolant continuously moves between the cold plate and the heat exchanger, regardless of the coolant's actual temperature. This decreases cooling efficiency and increases coolant usage.

To remedy this design limitation, thermostatic valves are used to direct coolant flow either to the heat exchanger or back through the system, solely based on coolant temperature.

This ensures efficient usage of coolant, facilitates stable and uniform electronic device temperatures, and reduces overall system wear, extending the life of system components.

Thermostatic Technology: From Automotive To Aerospace

The wax-filled thermostatic element was invented in 1936 by Sergius Vernet (1899-1968), with its initial primary application being in automotive thermostats used in the engine cooling systems.

Wax thermostatic elements transform heat energy into mechanical energy using the thermal expansion of waxes when they melt. In addition to engine cooling systems, this wax motor principle also finds applications in heating system thermostatic radiator valves, plumbing, industrial, and agriculture.

Today this technology is widely used across a broad spectrum of industries including Aerospace & Defense, most often for temperature control of various fluid systems.

Actuator Components

The operation of a wax-filled thermostatic actuator is based on the principal that there is a significant change in volume of a paraffin wax as it goes through a phase change from liquid-to-solid; solid-to-liquid as the wax temperature increases and decreases.

The volume change is transduced into a linear, repeatable mechanical motion which can produce a significant amount of force due to the non-compressible nature of the wax.

The basic elements of a thermostatic actuator include:

- Wax – motion producing element
- Cup – contains the wax and other key compounds
- Diaphragm – seals in the wax and creates motion during expansion
- Guide – retains the Diaphragm creating a seal while guiding the Plug and Piston
- Plug - transmits and amplifies the wax expansion via the Diaphragm increasing stroke
- Anti-Chafing Disc – prevents the Plug from extruding around Piston when force is applied
- Piston – transmits the Plug's movement into usable stroke

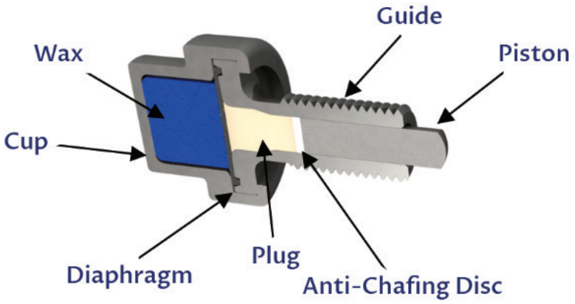


Figure 2. Actuator components

Actuator Operation

The thermostatic wax-blend material that drives the operation of all thermostatic valves is sealed inside the actuator, and as temperature increases above the melting point of the material, it expands in volume and pushes against a diaphragm, which in turn pushes on a piston.

The piston acts as a valve stem, opening or closing a valve or other mechanical device.

As the material cools below its melting point, its volume decreases and a spring or some other external applied force returns the piston and diaphragm to the “cold position”.

The phase change, and resulting large volume change, produce motion over a narrow and highly predictable temperature range, and the temperature range at which the phase change occurs can be varied depending on the chemical composition of the wax material that is used.

The material commonly operates at temperatures ranging from 35°F to 210°F (1.7°C to 98.9°C), making it versatile enough to use in hundreds of A&D applications.

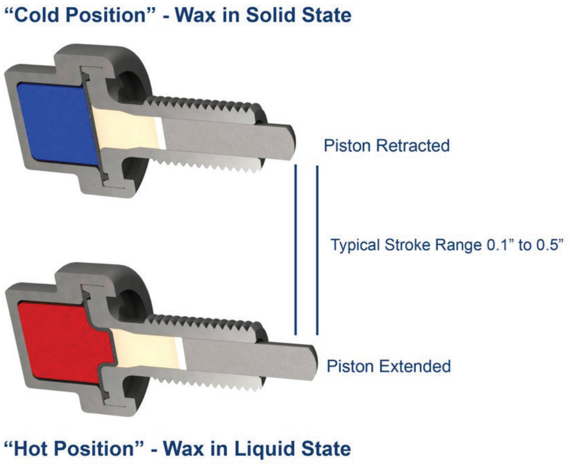
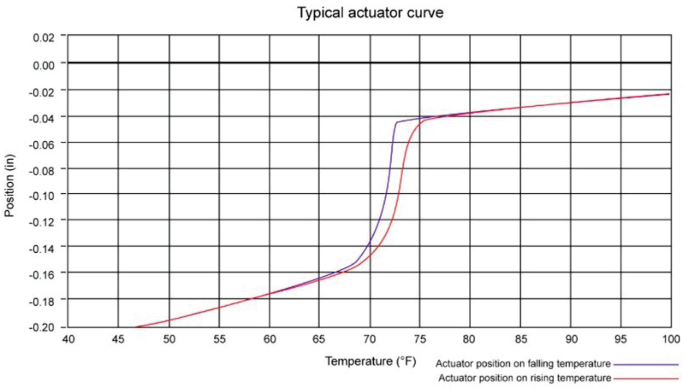


Figure 3. Piston position in hot vs. cold states



The table above shows the typical stroke of a small actuator. This particular curve shows an actuator piston’s effective movement of approximately 0.12 in over the course of a 10°F temperature change. An actuator of this size can easily exert 35lb. of force.

Figure 4. Typical actuator curve

Because of the gradual transition of the phase change of the wax material, these valves act more like modulating valves, as opposed to on/off valves, and the precise motion of these thermal actuators can be used to operate a wide variety of devices.

Due to their inherent flexibility and capacity to be implemented into just about any thermally controlled application, their use is limited only by the imagination of the designer.

No external power or signal is required, making these valves ideal for many hazardous and extreme environments.

Thermostatic Valves

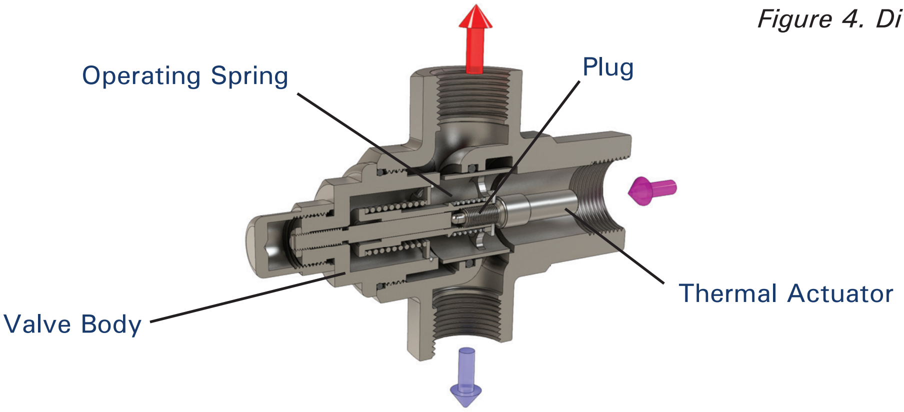
Thermostatic and self-actuating, these valves have the previously discussed thermostatic actuators as their primary element.

These valves come in many shapes, sizes and temperature ranges based on the particular application, all designed to modulate the flow of a fluid through the valve based either on the fluid's temperature or ambient temperature.

The basic elements of a thermostatic valve include:

- Thermal Actuator – produces linear motion, causing the valve to open/close based on increasing/decreasing fluid or ambient temperature
- Plug – interface between actuator and output port of valve
- Operating Spring – produces an opposing force on the actuator piston to ensure that piston fully retracts back into the actuator as the wax temperature (volume) decreases
- Valve body – housing of the valve that contains the thermal actuator, plug and spring. Provides the external connections for the fluid to flow into and out of the valve

Figure 4. Diverting valve



Benefits of Thermostatic Control in Liquid Cooling

The main benefits of thermostatic control are in its simplicity and repeatability.

Self-actuating and maintenance-free, they are the true "set and forget" solution to cooling control. Their minimal design avoids continuous part failures to be replaced, and the highly-repeatable and predictable nature of thermostatic wax ensures that the system will continue to design as operated, with no interruptions due to power outages or malfunctions of extra accessories.

As previously stated, thermostatic valves can be used to monitor fluid temperature and direct coolant through a liquid-cooling system to guarantee it utilizes the maximum amount of thermal output before sending the fluid through the heat exchanger.

This ensures efficient usage of coolant, facilitates stable and uniform electronic device temperatures, and reduces overall system wear, extending the life of system components.