Things to Consider when Choosing Fluids for Calibration Baths

Validation Solutions

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Choosing Fluids for Calibration Baths

To perform a high quality, safe and trouble-free calibration by using liquid baths, the appropriate fluid must be selected as part of the configuration. As many factors have to be taken into account, Ellab has performed several tests in order to make selecting the ideal liquid for the required application easier.

The relevant specifications and important facts regarding each fluid, have been set up in the table below:

Ellab Standard Oil

Fluid	Lower Temperature Limit*	Upper Temperature Limit*	Flash Point	Viscosity (centistokes)	Specific Gravity	Specific Heat (col/g/°C)	Thermal Conductivity (col/cm/°C)	Thermal Expansion (cm/cm/°C)	Resistivity (10^{12}Ω-cm)
Ethanol	-97°C (fr)	16°C (fl,cc)	16°C	1@20°C	0.809@20°C	0.61	0.00047	-	-
Ellab Low Temp Liquid	-89°C (fr)	10°C (fl,cc)	12°C	20@20°C	0.79@20°C/4°C				
Water	0°C (fr)	95°C (b)	none	1@25°C 0.4@75°C	1.00	1.00	0.0014	0.0002@25°C	
Ethylene Glycol - 50%	-30°C (fr)	90°C (b)	none	7@0°C 2@50°C 0.7@100°C	1.05	0.8@0°C	0.001		
Ellab Standard Oil 200.10	-30°C (v)**	209°C (fl,cc)	211°C	10@25°C 3@135°C	0.934@25°C	0.43@40°C 0.45@100°C 0.482@200°C	0.00032@25°C	0.00108	1000@25°C 50@150°C
Ellab High Temp Oil 710	80°C (v)	300°C (fl,oc)	302°C	50@80°C 7@204°C	1.11@25°C	0.363@40°C 0.454@100°C 0.505@200°C	0.00035@25°C	0.00077	100@25°C 1@150°C

*Limiting Factors - B-boiling point, e-high evaporation, fl-flash point, fr-freeze point, v-viscosity / Flash point test - oc-open cup, cc-closed cup
**Very low water solubility, ice will form as a slush from condensation below freezing

Usable Range – Lower/Upper Temperature Limits

The usable range is the temperature range in which a fluid can safely provide a good environment for the sensors and probes being compared. The range and specifications may differ depending on the manufacturer and could be limited by factors such as viscosity, flash points, freeze and boiling points, evaporation rates, etc.

While a single fluid may not cover the full range of the instrument calibrations, a combination of 2 or 3 may be sufficient. Ellab recommends dedicating one fluid to one liquid-bath in order to shorten calibration procedures by eliminating the need to change out fluids, which can be cumbersome and inefficient.

Flash Point

The flash point is the temperature at which a mixture of fluid vapor and air would ignite if exposed to a spark or flame.

There are two ways to measure the flash point, either by using the "open cup" or "closed cup" method. With the "open cup" method, neither fluid or the surrounding air is closed off, resulting in there being a higher ratio of air to fluid vapor. With the "closed cup" method, the fluid, fluid vapor and air are sealed away within the bath.

"Closed cup" flash points are typically lower than "open cup" flash points. In the material safety data sheets (MSDS), the flash point is often presented in a general and purposely lowered version in order to fit into a classification scheme used for hazard control, e.g. ">101.1°C".

Product specification sheets usually give more specific information, such as "211°C cc". Ellab fluids with flash points are listed using the "closed cup" method and the upper range limit is set slightly below the flash point.

Viscosity

Viscosity is a measure of a fluid's resistance to flow - often referred to as "thickness". Kinematic viscosity is the ratio of absolute viscosity to density and is measured in "centistokes". Higher centistoke readings mean higher viscosity, which in turn means thicker fluids. Viscosity is always stated at a specific temperature (often 25°C), but increases as the fluid's temperature decreases, and vice versa. Bath fluids that are too viscous create a strain on the stirring and pumping mechanisms and do not adequately transfer heat uniformly from the temperature sources to the thermometers.

Using fluids with less than 25 centistokes are recommended, which is reflected in the usable ranges stated for each fluid. Less than 10 centistokes viscosity, however, is deemed optimal, as low-uncertainty calibrations require a homogeneous temperature in the "calibration zone", whereas high-viscosity fluids often cause gradients in temperature.

Specific Gravity

The specific gravity is the ratio of a fluid's density to that of water. The higher the specific gravity, the denser and heavier a fluid is. If the fluid is too heavy, it may not work well in a bath equipped with a pump mechanism or circulator.

Heat Capacity

Specific heat is the amount of heat required to raise the temperature of an object (mass 1 kg) by 1°K. The higher the heat capacity is, the more energy is required to change the temperature, which results in a slower and more stable process.

For example, water has a high heat capacity, which means that it absorbs a lot of heat before it starts warming up. Due to its high heat capacity and viscosity, water would be one of the best medias for calibration if not for its highly limited liquid form temperature range.

Thermal Expansion

All fluids have a coefficient of thermal expansion. The coefficient indicates how much a fluid's volume will change (expand or contract) with changes in temperature. Fluid expansion has important ramifications for safety, cleanliness and care of equipment. For example, if a bath is filled too much at a low temperature and then heated with no regard to the volume increase, it will most likely begin to spill. Also, if the fluid in a bath is allowed to run too low, it can leave bath heaters exposed, which in turn can damage them. It is not unusual that silicone oils expand by 10-15% when heated over a 100°C interval.

Thermal Conductivity

Thermal conductivity is a fluid's ability to transfer heat from one molecule to another. The better the heat transfer, the quicker the fluid will heat or cool. Better thermal conduction improves a bath's uniformity.

LiquiCal HM Calibration Bath

LiquiCal LL Calibration Bath

Polymerization

Given enough time, temperature and catalysts, silicone oils will eventually polymerize. This means that they suddenly turn into molasses-like "syrup", doubling in volume and creating a mess. This phenomenon is caused by oxidation.

While silicone oils can safely be used near their flash points, the risk of polymerization increases when above their oxidation points.

Avoid polymerization by:

1. Limiting the bath's time above this point by keeping it below its vapor point when not being used.
2. Keep contaminants out of the oil, e.g. salts, other oils and oxidizers.
3. Change the oil if it becomes dark, viscous or unstable in temperature.

Water

There are a few things to know about water in non-water baths. First, **never** introduce water into a salt or hot oil bath, as this can be extremely dangerous. Second, water may condense in an oil bath being used at low temperatures, particularly where there is high ambient humidity. Water can freeze to cooling surfaces and cause poor stirring conditions. Occasionally, water must be boiled off.

Finally, alcohols absorb water, but this is not always bad - in fact, 5% water in methanol allows methanol to be used at -100°C. On the other hand, when too much water is absorbed, the alcohol becomes saturated and an ice slurry can form. This has a negative impact on the overall stability and uniformity during calibrations.

Ventilation

Fluids with high vapor pressure (like alcohols and water) evaporate quickly and require frequent refills. Furthermore, rapid evaporation at the fluid surface has a cooling effect on the fluid, making temperature control more difficult, especially with an uncovered bath. These fluids are generally only suitable for low temperature use.

Baths with good ventilation will prevent users from breathing in fumes from the bath fluids. Suction devices connected to the central exhaust system near the bath's opening are considered the best. Oil vapor can settle on the surface of eyes, causing some discomfort. Silicone oils can create benzene and formaldehyde as they break down at high temperatures, i.e. around or above the flash point. Keep baths sealed as much as possible to prevent fumes from entering the work space. This will help with operator safety, increase the oils lifetime and improve the bath's performance.

Using Multiple Fluids

Although using a single fluid would be optimal, this is rarely possible for a metrology departments due to the wide range of equipment that they are responsible for maintaining and calibrating. All fluids have temperature range limits for a variety of reasons. Not only will there occur issues with freezing and boiling, but viscosity changes, evaporation and flash points create limits for a fluid's useful temperature range.

This means that a single fluid may not cover the required range needed within a single bath, leaving users with a choice between inconvenient fluid changes or multiple temperature-dedicated baths. Ellab recommends a bath for each required fluid in order to cover the determined temperature range.

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Safety Tips

When using different kinds of oil and alcohol at high temperatures, it is extremely important to follow safety regulations and good practices.

Here are some recommendations:

- Always wear appropriate protective equipment. This includes gloves, aprons and face shields consisting of adequate material for the temperatures and liquids being worked with.
- Understand the fluids being used. MSDS sheets from manufacturers can be helpful and product specification sheets often include helpful information that may not be mentioned in the MSDS.
- Ventilate appropriately.
- Never mix fluids or add any chemicals to the fluid.
- Never add anything to bath fluids that potentially could cause a physical or chemical reaction.
- Never allow water to come into contact with hot salts or oils.
- Only place clean sensors and probes into bath fluids.
- Never operate a bath on or around flammable materials. Keep the area around the bath clean.
- Keep appropriate fire extinguishing equipment nearby.
- Ensure that all personnel/operators of liquid baths understand the precautions that should be taken and are trained in dealing with related emergencies.
- Abide by laws and/or regulations regarding the storage and disposal of hazardous or flammable bath fluids.
- Avoid using fluids at temperatures above their flash points. Special safety considerations should be taken for alcohols since their flash points are typically below room temperatures.