Technical Data sheet (Alumina nano-coolants)

Version-1

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Who are we and what do we do?

Synano is a SME located in The Netherlands with an aim to develop purposely engineered nano-fluids with superior heat transfer capabilities.

Synano's Alumina nano-coolants are manufactured following a proprietary chemical formulation method developed and refined after continuous research at Synano labs working closely with experts from Delft Technical University (TU Delft).

Synano's Alumina nano-coolants are:

- **Highly stable and homogeneous**
- **Safe and non-toxic**
- **Non-flammable and non-corrosive**

These coolants possess higher thermal conductivity than conventional antifreeze and can be optimized by tuning the size and concentration of nano-particles to achieve an overall reduction in thermal resistance across the heat exchanger.

Synano can develop tailor-made nano-coolants with different glycol ratios and nanoparticle concentrations to suit the customer requirement.

What are nano-coolants and how do they work?

Nano-fluids are suspensions of nanometer sized particles in base fluids like water, glycol, their mixtures and other organic/inorganic liquids. These nano-particles can be made of metal (Al, Cu, Ti), metal oxides (Al_2O_3, CuO, TiO_2), graphene or carbon nanotubes.

By dispersing nanoparticles with higher thermal conductivity in the base fluid, overall thermal conductivity of the resultant nanofluid will be higher. Increasing the thermal conductivity of the working fluid, the heat transfer coefficient also increases. For nanoparticles, the conductivity is much higher than for liquids due to their lattice structures. Dispersing nanoparticles in liquid makes phonons in such media propagate faster because they have to travel partially via nanoparticles where their velocity is higher. Therefore, nanofluids enhance the thermal conductivity.

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In liquid state, the Brownian motion of particles spread them in the flow. In the boundary layer, where strong temperature gradients occur, the thermo-diffusivity shifts the nano-particles from the boundary towards the bulk of the liquid flow. These particles carry energy/heat with them (removing it from the boundary), thus resulting in mass and energy transport in a quicker manner than water. This process reduces the thermal resistance across the heat exchanger.

Why are nano-coolants useful?

Efficient thermal management in constricted spaces encompassing power electronics or heat exchanger equipment with high heat load is a difficult battle. Cooling plays an important role in improving the energy efficiency and lifetime of the electronics and heat exchanger equipment. Typically, the higher the performance, the more heat is generated. High-performance cooling of the electronics and efficient heat transfer can go a long way in extending the life of equipment and power modules.

The convective heat transfer coefficient of nanofluids will depend on the thermal conductivity, viscosity, density, specific heat and velocity of nanofluid. It will also depend on the heat exchanger dimensions such as diameter and length of the tube or cold-plate. Higher thermal conductivity increases the heat transfer coefficient. With higher heat transfer coefficient and increased surface areas, thermal resistance can be reduced. Customers can achieve better cooling, faster machines, smaller systems or save on energy costs, translating it into direct economic benefits.

Measured thermal and physical properties

Synano has developed alumina nano-coolants with de-mineralised water and mixtures of water with Ethylene and Propylene glycol in different volume ratios. The thermal and physical properties of these liquids, both base fluids and nanofluids, are measured. All the nanofluids are prepared with the same base fluid as they are compared with.

The properties shown in the technical sheet are with the highest loading of alumina nanoparticles (100 nm) in base fluids. Based on specific applications and requirement, **nanofluids with different glycol ratios and alumina nanoparticle concentrations can be formulated.** The thermal and physical properties will change accordingly. **Please contact our technical team for your requirements and formulation needs.**

Case-1: Pure demineralized water as base fluid

Thermal conductivity measurements:

Temperature (^{0}C)	Thermal conductivity of base fluid (mW/mK)	Thermal conductivity of nano-fluid (mW/mK)	% increase
25 ^{0}C	600	658	10%
35 ^{0}C	615	667	8.5%
45 ^{0}C	624	675	8.2%
55 ^{0}C	637	685	7.5%

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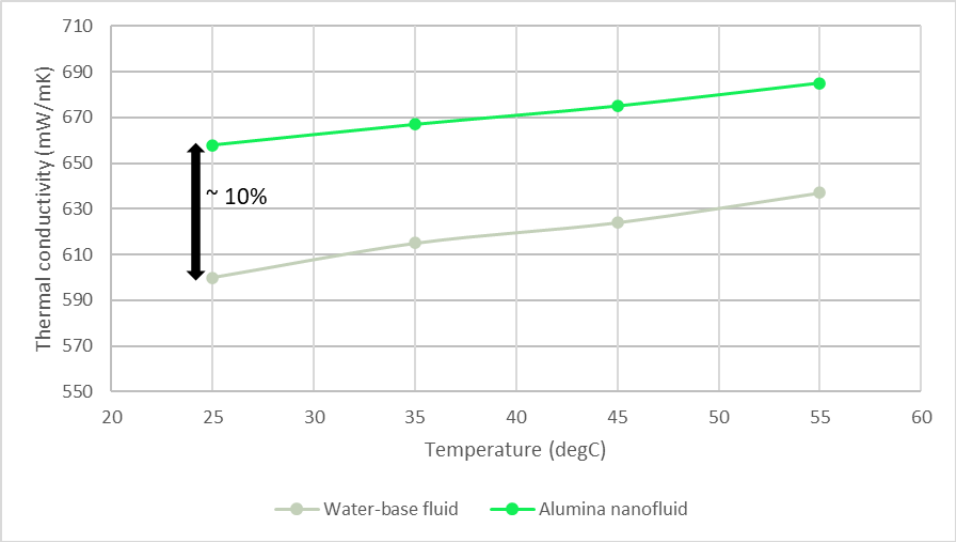
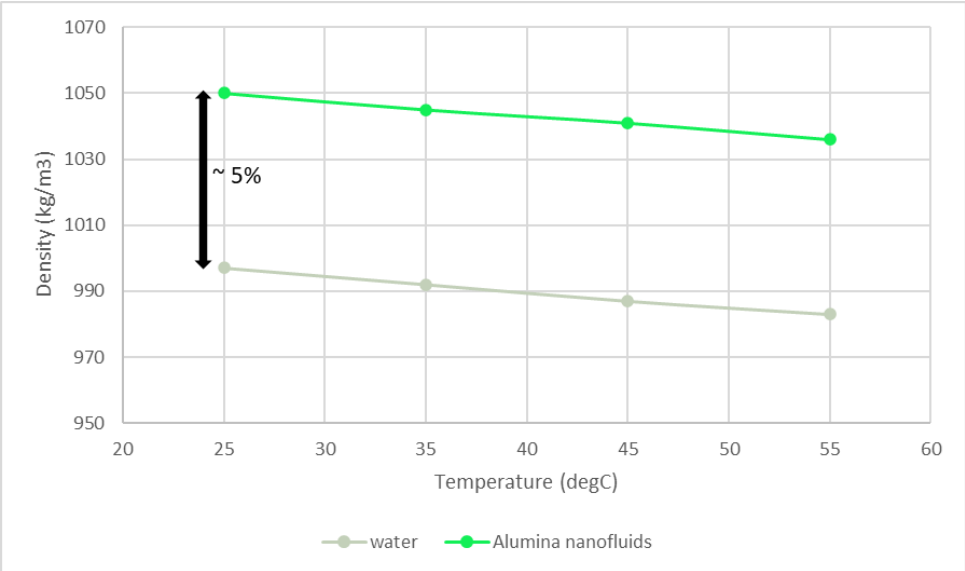


Thermal conductivity of pure demi water compared with nanofluids with same base fluid and alumina nanoparticles

Density measurements

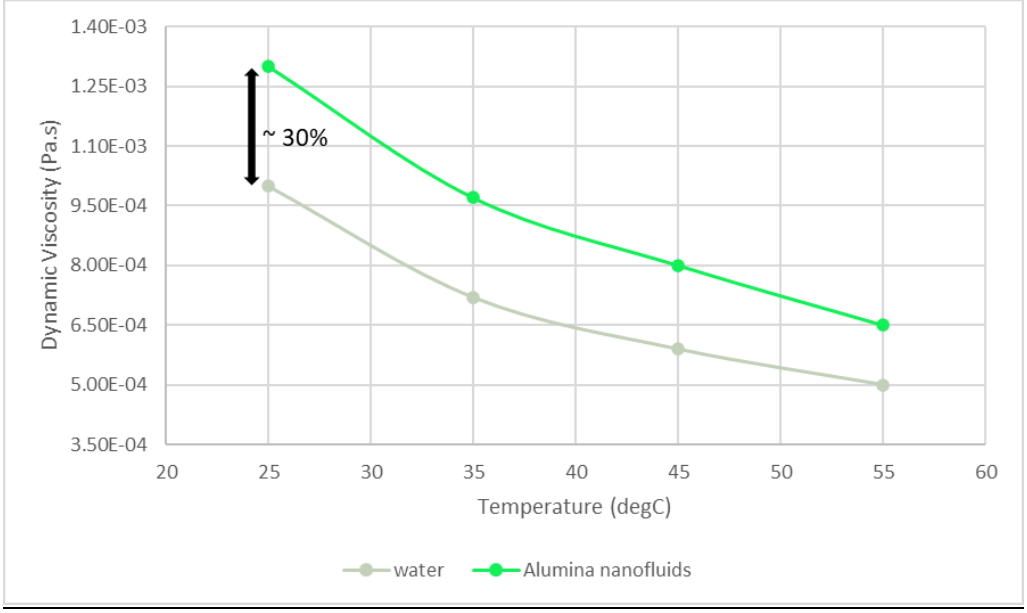
Temperature (^{0}C)	Density of base fluid (kg/m3)	Density of nano-fluid (kg/m3)	% increase
25 ^{0}C	997	1050	5.3%
35 ^{0}C	992	1045	5.3%
45 ^{0}C	987	1041	5.4%
55 ^{0}C	983	1036	5.3%



Density of pure demi water compared with nanofluids with same base fluid and alumina nanoparticles

Dynamic viscosity

Temperature (^{0}C)	Viscosity of base fluid (Pa.s)	Viscosity of nano-fluid (Pa.s)	% increase
25	1E-03	1.3E-03	30%
35	0.72E-03	0.97E-03	35%
45	0.59E-03	0.8E-03	35%
55	0.5E-03	0.65E-03	31%



Dynamic viscosity of pure demi water compared with nanofluids with same base fluid and alumina nanoparticles

Specific heat capacity

Specific heat of nanofluid will reduce compared to base fluid since water has the highest specific heat of all known materials. At room temperature the Specific heat capacity of water is 4180 J/kgK and 4050 J/kgK for Alumina nanofluids respectively.

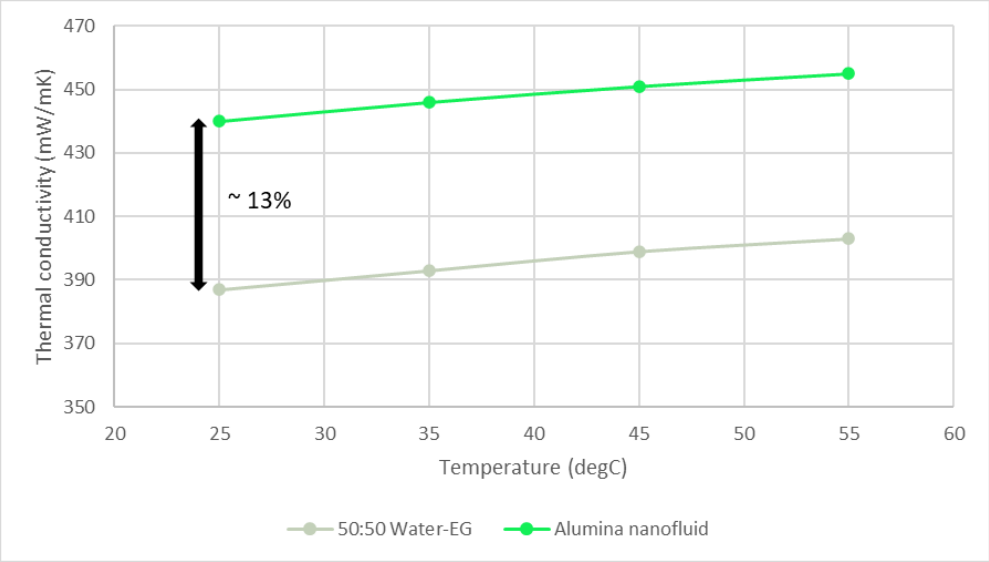
Other values

Nano-coolant boiling point	100^{0}C
Nano-coolant freezing point	-0.5^{0}C

Case-2: 50:50 ratio of demi water and Ethylene glycol as base fluid

Thermal conductivity measurements:

Temperature (^{0}C)	Thermal conductivity of base fluid (mW/mK)	Thermal conductivity of nano-fluid (mW/mK)	% increase
25 ^{0}C	387	440	13.6%
35 ^{0}C	393	446	13.3%
45 ^{0}C	399	451	13%
55 ^{0}C	403	455	13%



Thermal conductivity of 50:50 demi water and ethylene glycol mixture compared with nanofluids with same base fluid and alumina nanoparticles

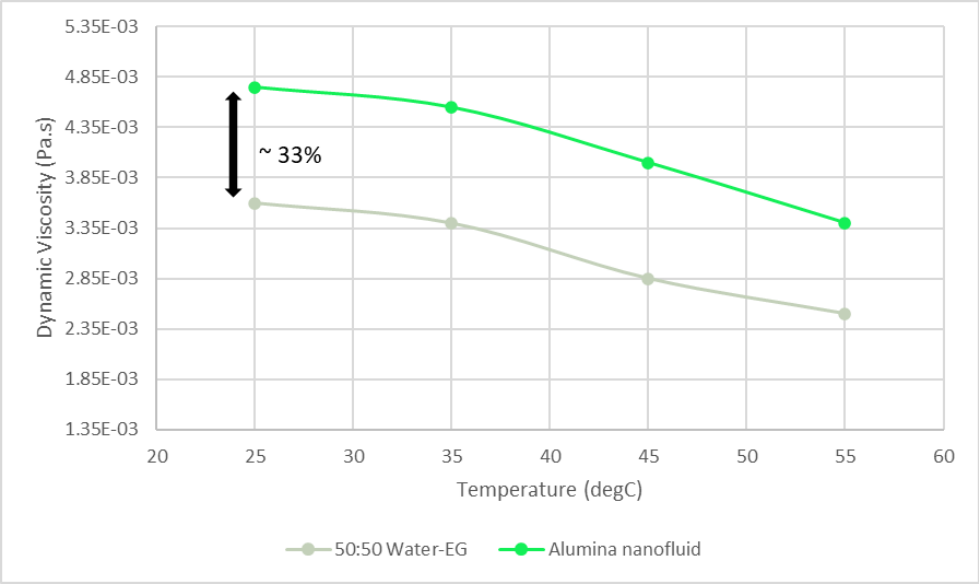
Density at 25^{0}C

Density of base fluid (kg/m^3)	Density of nano-fluid (kg/m^3)
1067	1120
% increase	5%

The density decreases linearly with temperature as seen with the density trend of water.

Dynamic Viscosity

Temperature (^{0}C)	Viscosity of base fluid (Pa.s)	Viscosity of nano-fluid (Pa.s)	% increase
25	3.6E-03	4.75E-03	32%
35	3.4E-03	4.55E-03	33.5%
45	2.85E-03	4E-03	40%
55	2.5E-03	3.4E-03	36%



Dynamic viscosity of 50:50 demi water and ethylene glycol mixture compared with nanofluids with same base fluid and alumina nanoparticles

Specific heat capacity

Specific heat of nanofluid will reduce compared to base fluid since metals and metal oxides have lower specific heat capacity compared to liquids like water and glycol. At room temperature the Specific heat capacity of 50:50 ratio of demi water and Ethylene glycol (base fluid) is 3473 J/kgK and 3310 J/kgK for Alumina nanofluids respectively.

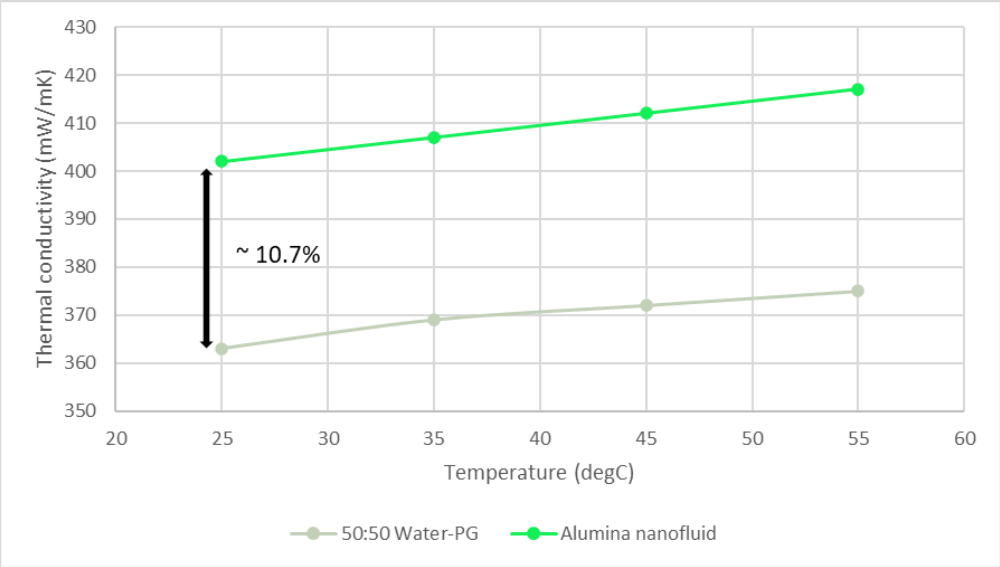
Other values

Nano-coolant boiling point	107^{0}C
Nano-coolant freezing point	-38^{0}C

Case-3: 50:50 ratio of demi water and propylene glycol as base fluid

Thermal conductivity measurements

Temperature (^{0}C)	Thermal conductivity of base fluid (mW/mK)	Thermal conductivity of nano-fluid (mW/mK)	% increase
25 ^{0}C	363	402	10.7%
35 ^{0}C	369	407	10.3%
45 ^{0}C	372	412	10.7%
55 ^{0}C	375	417	11.2%



Thermal conductivity of 50:50 demi water and propylene glycol mixture compared with nanofluids with same base fluid and alumina nanoparticles

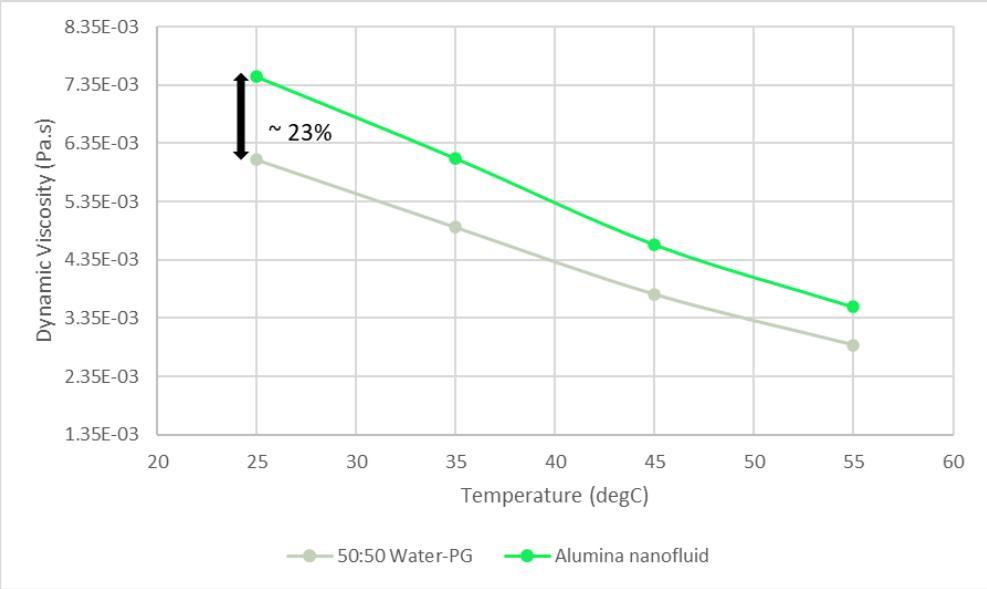
Density measurements

Density of base fluid (kg/m^3)	Density of nano-fluid (kg/m^3)
1038	1090
% increase	5%

The density decreases linearly with temperature as seen with the density trend of water.

Dynamic viscosity

Temperature (^{0}C)	Viscosity of base fluid (Pa.s)	Viscosity of nano-fluid (Pa.s)	% increase
25	6.07E-03	7.49E-03	23.5%
35	4.91E-03	6.09E-03	24.08%
45	3.76E-03	4.61E-03	22.63%
55	2.89E-03	3.54E-03	22.26%



Dynamic viscosity of 50:50 demi water and propylene glycol mixture compared with nanofluids with same base fluid and alumina nanoparticles

Specific heat capacity

Specific heat of nanofluid will reduce compared to base fluid since metals and metal oxides have lower specific heat capacity compared to liquids like water and glycol. At room temperature the Specific heat capacity of 50:50 ratio of demi water and Propylene glycol (base fluid) is 3559 J/kgK and 3410 J/kgK for Alumina nanofluids respectively.

Other values

Nano-coolant boiling point	106^{0}C
Nano-coolant freezing point	-35^{0}C

What are other properties of nano-coolants?

Following nanofluid properties are same for all irrespective of the base fluid or the concentration of alumina nanoparticles.

Nanoparticle material	Aluminum oxide
Nanoparticle size (avg)	100 nm
pH range	3.5 – 4.5
Compatible materials	Aluminum, Copper, brass, Stainless steel Plastic, silicone and rubber tubing & seals

Corrosion protection

We add inhibitors in the nano-coolants to prevent corrosion against common heat exchanger materials. Our nano-coolants are also non-toxic, non-flammable, non-carcinogenic or bio-accumulative. They are safe, stable and corrosion-free.

Viscosity rise

In addition to thermal conductivity, it is also evident that viscosity has a significant impact on the overall performance of a heat transfer fluid. Adding nanoparticles to the base fluid results in a higher viscosity of the resultant nanofluid. Criteria for the overall effectiveness of nanofluids as heat transfer fluids have been proposed[1], which suggest that the increase in the viscosity has to be more than four times larger than the comparable increase in thermal conductivity for a nanofluid to be not beneficial at all. Our nano-coolants can ensure that viscosity rise relative to thermal conductivity rise is managed such that maximum heat transfer effectiveness is achieved.

Stability at different temperatures

The suspension does not become unstable when the temperatures go up until boiling point or down till freezing point. It is interesting to note that even after freezing, when the nanofluids melt to room temperature, the nanoparticles remain dispersed in the suspension and do not fall out of the fluid.

[1] D.C. Venerus, J. Buongiorno, R. Christianson, et al., "Viscosity Measurements on Colloidal Dispersions (Nanofluids) for Heat Transfer Applications", Applied Rheology 20 (2010) 44582-7.

It was also observed that after fluid has completely boiled over or evaporated, the nanoparticles form larger agglomerates and appear like crystals. Also, these larger agglomerates (mm to µm size), visible to the naked eye are not air borne and will disperse again if added to water and ultrasonicated.

Alumina agglomerates left behind after evaporation of fluid

Are nano-coolants safe?

Our Alumina nanofluids are safe, non-toxic, non-flammable and do not have harmful reactions, however, precautions shall be taken while using these fluids. Always wear gloves while using nanofluids. If the fluid comes in contact with skin or eyes, wash immediately with soap and water. It can cause mild irritation on the area where it comes in contact with the skin, but if washed immediately, can be prevented.
In case of disposal, regulation in Europe regarding nanoparticles is based on existing laws and regulations for chemicals. Due to these, all nanomaterial wastes are characterized as potentially hazardous wastes and use related regulations to manage waste disposal.
However, we believe in recycling and reusing. Therefore, we plan to collect the spent nanofluids from customers to recover the nanoparticles from discharged nanofluids and recycle them. Once the tests are done, nanofluids can be collected and sent back to our lab facility for recycling.

Clogging and agglomeration of nanoparticles

When dealing with nanoparticles, it's crucial to be aware of their potential to agglomerate upon contact with unfamiliar chemicals. In particular, substances like salt solutions,

inhibited glycol, and surface treatment chemicals can initiate reactions with nanofluids, leading to blockages and clogging. The outcome is a rapid surge in viscosity and the development of a nanofluid slurry, severely compromising heat exchange efficiency within your system. To counteract this issue, the implementation of a pre-treatment agent becomes essential.

Ensure thorough cleansing of your system with **Synano's pre-treatment agent** prior to introducing nanofluids into the loop. This pre-treatment agent effectively eliminates residual chemicals, metallic debris, ions, and other impurities from the loop, creating an environment conducive to the optimal performance of nanofluids.

Cleaning the loop with demineralised water after pre-treatment process, followed by the addition of nanofluids, guarantees prime nanofluid performance, eliminating the need for ongoing maintenance and enabling worry-free operation of the loop.

Lifetime of Synano’s nano-coolants

Based on internal validation tests, Synano’s water-based alumina nano-fluids appear to be stable for several years. No clear phase separation between solid and liquid was observed after a monitoring period of two years with nano-fluids in static condition: sedimentation of about <10% of total particle weight added was observed. In operating conditions, when the fluid supposedly is in constant flow and the particles are constantly being mixed, the nano-fluids sedimentation is expected to be even less. The thermal properties of nano-fluids checked after a two years shelf period were found to be almost identical to freshly prepared fluid with maximum 1.5% reduction in thermo-physical properties. The results show that the Synano’s alumina nano-fluid feature reasonably good stability and, therefore, can be a promising candidate for practical applications requiring long-term lifetime.