BOURNS®

Optimization for Immersion Cooling in High-Performance Computing Applications

BOURNS® SRP SERIES INDUCTORS WHITE PAPER

Introduction

The relentless demand for High Performance Computing (HPC), driven by maturing AI and machine learning technologies, is causing an unprecedented surge in data center power and capacity requirements. Traditional air-cooling methods are increasingly struggling to efficiently handle greater power densities and the resulting heat. Next-generation processing units are expected to maintain Thermal Design Powers (TDP) of 400 watts, making them virtually impossible to cool with just air cooling, and highlighting the need for superior cooling technology to prevent downtime.

Immersion cooling is a revolutionary heat transfer method that directly addresses these challenges by submerging electronic components—like servers or processors—into a thermally conductive, dielectric (non-conductive) liquid. This technique takes cooling a step further by placing the heat source directly in contact with the coolant. The liquid absorbs the heat generated by the components and carries it away, making this method highly efficient. This process is significantly more effective than air cooling, vastly conducting more heat. Immersion cooling can extend the lifespan of hardware by maintaining consistent and optimal temperatures.

The Advantages of Immersion Cooling

Immersion cooling is a highly efficient and sustainable approach as it eliminates the need for energy-intensive air conditioning or complex cooling systems, significantly reducing power consumption and operational costs. Immersion cooling is gaining traction in industries like blockchain, AI, and cloud computing, where high-performance systems generate significant heat. Here are the key benefits:

1. **Greater Efficiency:** Immersion cooling is far more effective at transferring and dissipating heat, as liquids have higher thermal conductivity compared to air.
2. **Energy Savings:** Air cooling requires energy-intensive systems like fans and air conditioners. Immersion cooling eliminates the need for these, significantly reducing power consumption and operational costs.
3. **Reduced Hardware Wear and Tear:** Consistent and uniform cooling prevents hotspots and thermal cycling, which can degrade hardware over time.
4. **Noise Reduction:** Unlike air cooling, which relies on fans, immersion cooling systems are quiet, creating a better working environment in data centers.
5. **Space Optimization:** Immersion-cooled setups can be more compact, as they do away with bulky air ducts, fans, and large spaces for airflow.
6. **Eco-Friendliness:** By cutting down on energy use and cooling infrastructure, immersion cooling contributes to lower carbon emissions, aligning with sustainable practices.
7. **Scalability:** Immersion cooling is well-suited for handling high-density and high-performance workloads, making it ideal for AI, blockchain, and data-intensive tasks.

Selection Guide for Electronic Components in Immersion Cooling

Bourns® molded inductors, particularly the SRP series, are exceptionally well-suited for these demanding environments. Their robust molded construction provides excellent mechanical protection against dielectric fluids and environmental conditions. This encapsulation effectively shields the inductor's internal windings and core from direct fluid exposure, preventing potential corrosion or fluid ingress, and helps maintain stable performance across varying temperatures.

When selecting products for inductive components in immersion cooling systems, it's essential to focus on materials and designs compatible with dielectric fluids.

While specific product recommendations depend on the application, here are some general guidelines:

1. **Dielectric Fluids:** Dielectric fluids are commonly used for immersion cooling due to their high thermal stability and electrical insulation properties.
2. **Encapsulated Inductors:** Inductors with encapsulated designs are ideal for immersion cooling as they protect the windings and core from direct exposure to the fluid.
3. **Ferrite Core Materials:** Ferrite cores with low losses are recommended for high-frequency applications to minimize heat generation.
4. **Insulated Wires:** Use wires with insulation that can withstand prolonged exposure to dielectric fluids without degradation.

Optimization for Immersion Cooling in High-Performance Computing Applications

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Bourns® SRP Series Inductors: Rigorous Testing for Immersion Cooling Validation

In the context of immersion cooling, where components are submerged in cooling liquids, it's crucial to verify that these liquids don't degrade or compromise the materials of the components over time.

Test Setup and Methodology

The validation process for Bourns® SRP series inductors in immersion cooling environments begins with a precisely controlled test setup, typically conducted at room temperature. For sample integrity, a preferred sample size of 30 pieces per part number (PN) is utilized, though flexibility allows for case-by-case discussions for larger components or mixed PNs to expedite testing, provided all components remain identifiable. Testing samples with different date codes is also preferred to ensure broader product representation. The core of our test methodology centers around Soxhlet Extraction, a robust method for analyzing and removing potential contaminants and, in this context, for assessing material compatibility with dielectric fluids. The equipment used for component parameter measurements (such as Inductance (L) and DC Resistance (RDC)) is carefully selected based on the component type, and crucially, the same equipment is used for both pre- and post-test measurements to ensure consistency and accuracy.

The multi-step pre-conditioning and extraction process is as follows:

Step 1: Appearance Recording: The visual appearance of all test samples is meticulously recorded before the test commences to establish a baseline.

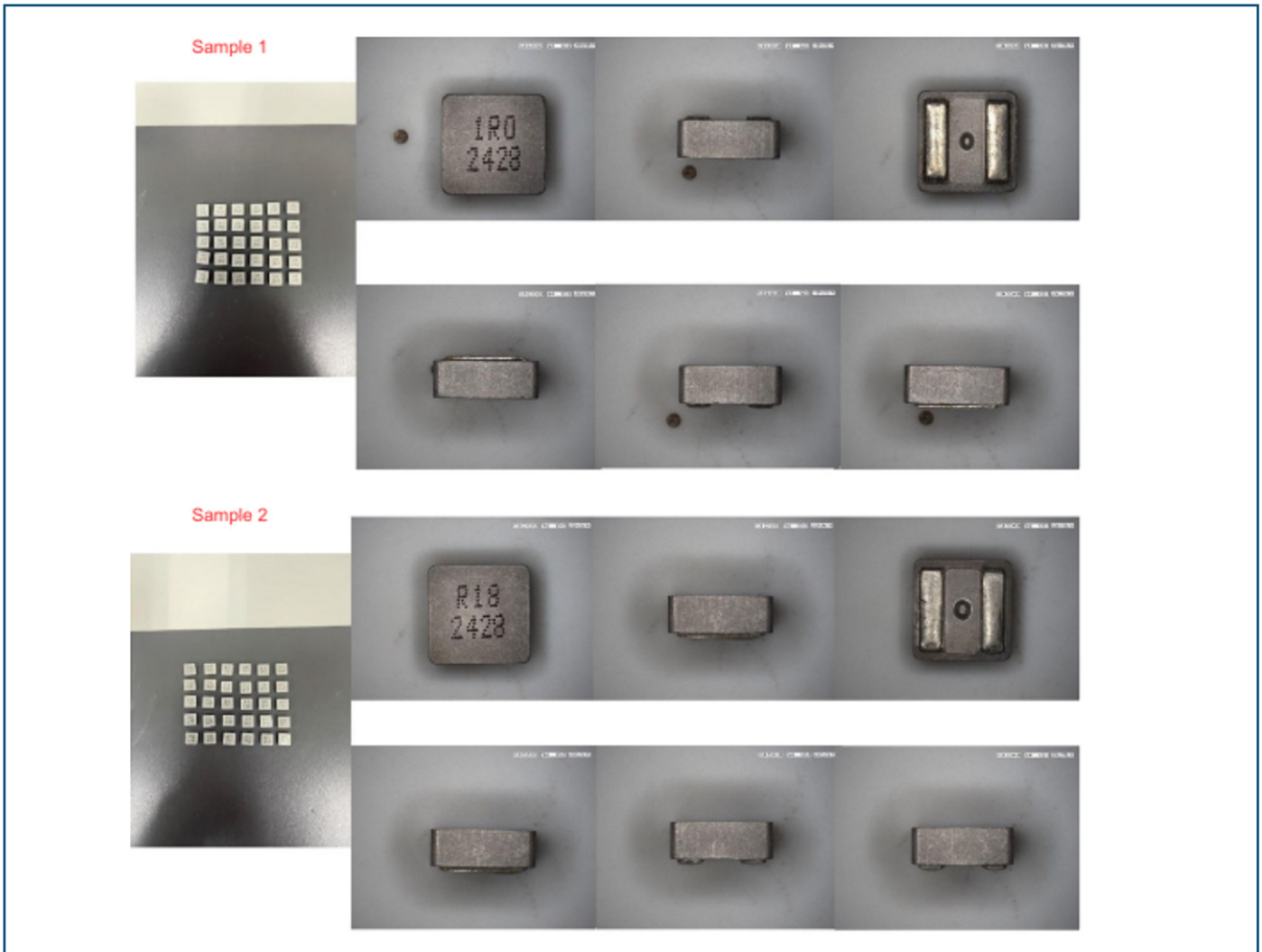

Figure 1 - Test samples (before test)

Bourns® SRP Series Inductors: Rigorous Testing for Immersion Cooling Validation (Continued)

Step 2: Component Pre-Conditioning: Reflow Profile (Samples undergo a pre-conditioning reflow process, involving two cycles at a peak temperature of 265 °C.)

This is performed without solder paste and not mounted on a PCB, simulating thermal stress without electrical connection.

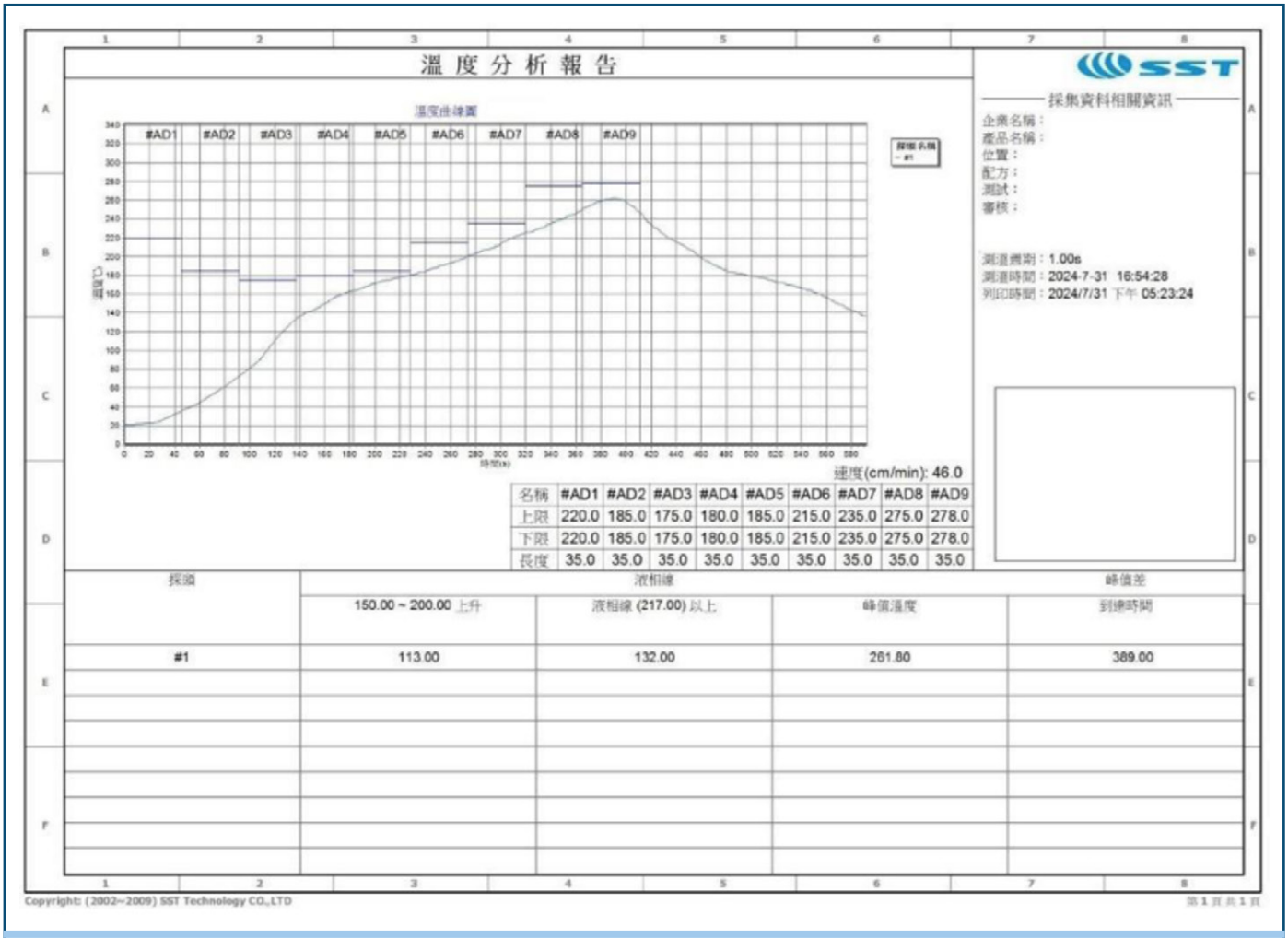

Figure 2 - Pre-Conditioning – Reflow Profiles

Bourns® SRP Series Inductors: Rigorous Testing for Immersion Cooling Validation (Continued)

Step 3: Component Pre-Conditioning: Cleaning Solution : Components are then subjected to a rigorous cleaning process. This involves stirring for 8 minutes in a 15 % concentration (by weight) cleaning solution in DI water at 65 °C on a magnetic stirrer. Following this, the components are stirred for 1 minute in fresh DI water (at least 10 times the volume) at 65 °C. This entire cleaning sequence is repeated twice more for a total of three cycles, each with fresh DI water.

Figure 3 - Pre-Conditioning – Water Wash

Bourns® SRP Series Inductors: Rigorous Testing for Immersion Cooling Validation (Continued)

Step 4: Component Pre-Conditioning: Baking & Weighting Measurement After washing, samples are baked for 30 minutes at 125 °C in an oven to ensure they are 100 % dry without any damage. Following drying, precise weighting measurements are taken for each sample (e.g., Bourns® Model SRP6030CA-1R0M and SRP6030CA-R18M samples), establishing their initial dry weight.

Figure 4 - Pre-Conditioning – Baking & Weight

Bourns® SRP Series Inductors: Rigorous Testing for Immersion Cooling Validation (Continued)

Step 5: Soxhlet Extraction: Thirty pre-conditioned samples are placed into the Soxhlet Extraction apparatus. The solvent used for the extraction is a commonly used dielectric fluid in immersion cooling applications.

The process maintains a typical siphon cycle time of approximately 30 minutes, with strict adherence to this timing (no siphon cycle or cycles longer than 40 minutes are deemed unacceptable). Samples undergo a prolonged dwell time of four days (96 hours) within the solvent. Throughout this phase, sample appearance is regularly checked. This entire extraction process is completed through three total test cycles..

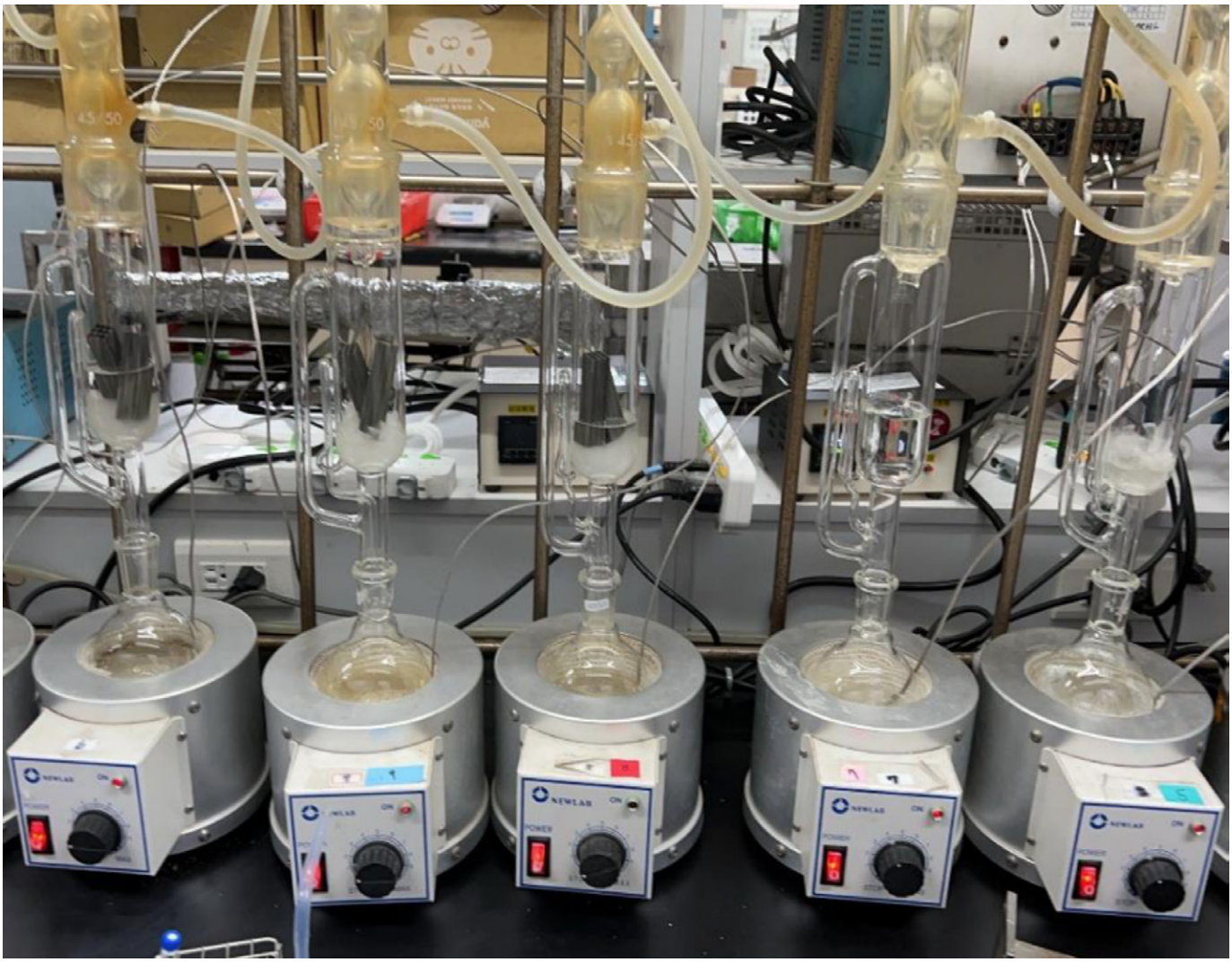

Figure 5 - Soxhlet Extraction

Pass/Fail Criteria

The rigorous testing concludes with stringent pass/fail criteria to validate component integrity and performance:

- **Electrical Performance:** All pre- and post-test measurements for all Samples Under Testing (SUT) must remain within their specified tolerances. This includes critical parameters like Inductance (L) and DC Resistance (RDC).
- **Physical Integrity:** Upon de-cap or Destructive Physical Analysis (DPA), no cracks, corrosion, liquid invasion, or other abnormalities should be observed, confirming the physical integrity of the components after exposure to the immersion cooling environment.

Results and Validation

Following the comprehensive testing process, Bourns® Model SRP6030CA-1R0M and SRP6030CA-R18M molded inductors demonstrated exceptional performance and resilience.

A thorough post-test appearance check confirmed that **no cracks, corrosion, liquid intrusion, or other abnormalities were observed** in the test samples.

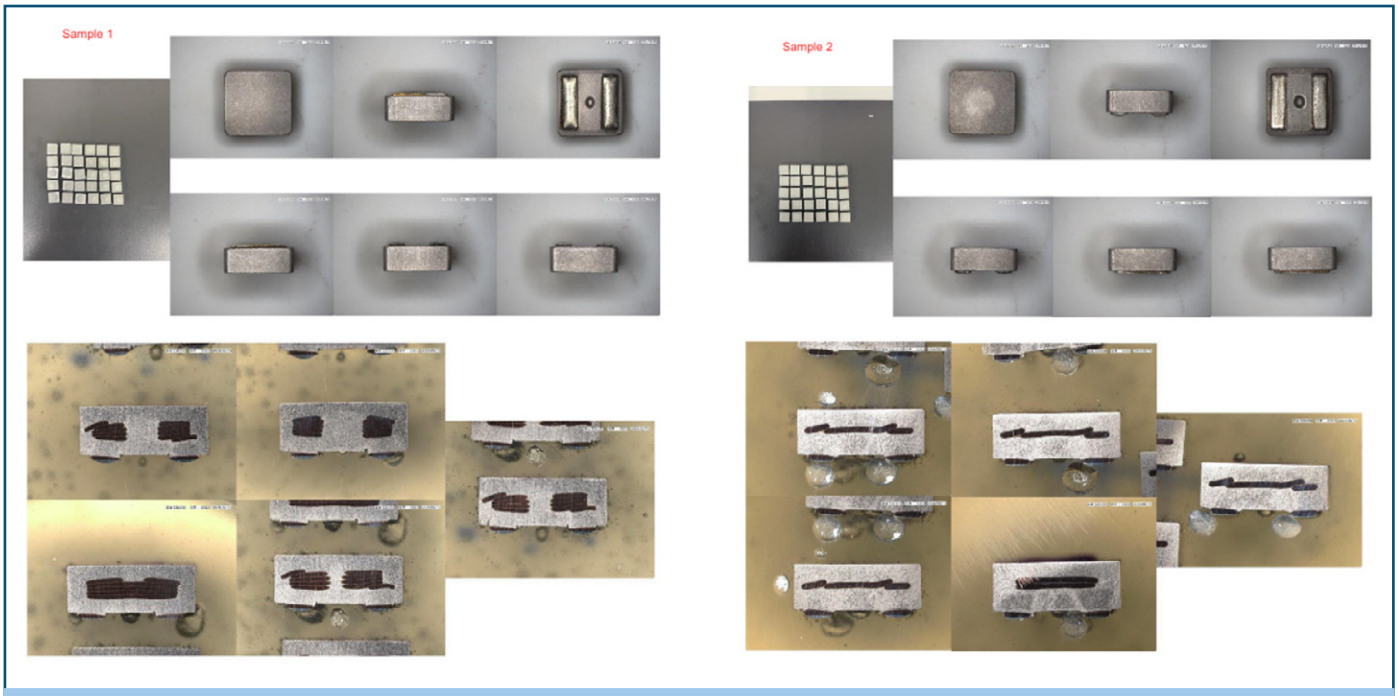

Figure 6 - Samples – After Test

Results and Validation (Continued)

Weight confirmation after the test showed that the change before and after the test for both Model SRP6030CA-1R0M (ranging from -1.62 % to 0.50 %) and SRP6030CA-R18M (ranging from -1.72 % to 0.25 %) met the specifications, confirming the material stability of the inductors in the dielectric fluid.

SRP6030CA-1R0M

NO.	Before	After	Change Rate, %	Appearance
	Weight(g)	Weight(g)	Weight(g)	
1	0.6795	0.6802	0.10%	PASS
2	0.6847	0.6831	-0.23%	PASS
3	0.6748	0.6723	-0.37%	PASS
4	0.6938	0.6859	-1.13%	PASS
5	0.6713	0.6701	-0.18%	PASS
6	0.6832	0.6822	-0.16%	PASS
7	0.6812	0.6760	-0.77%	PASS
8	0.6858	0.6822	-0.53%	PASS
9	0.6970	0.6954	-0.23%	PASS
10	0.6696	0.6673	-0.34%	PASS
11	0.6650	0.6613	-0.56%	PASS
12	0.6798	0.6722	-1.12%	PASS
13	0.6816	0.6716	-1.47%	PASS
14	0.6793	0.6792	-0.02%	PASS
15	0.6820	0.6806	-0.21%	PASS
16	0.6773	0.6735	-0.57%	PASS
17	0.6932	0.6907	-0.36%	PASS
18	0.6804	0.6768	-0.52%	PASS
19	0.6759	0.6684	-1.11%	PASS
20	0.6882	0.6811	-1.04%	PASS
21	0.6940	0.6846	-1.36%	PASS
22	0.6868	0.6834	-0.50%	PASS
23	0.6992	0.6878	-1.62%	PASS
24	0.6917	0.6844	-1.05%	PASS
25	0.6877	0.6804	-1.06%	PASS
26	0.6870	0.6795	-1.09%	PASS
27	0.6811	0.6792	-0.29%	PASS
28	0.6740	0.6773	0.50%	PASS
29	0.6841	0.6770	-1.03%	PASS
30	0.6887	0.6910	0.34%	PASS

SRP6030CA-R18M

NO.	Before	After	Change Rate, %	Appearance
	Weight(g)	Weight(g)	Weight(g)	
1	0.6209	0.6183	-0.42%	PASS
2	0.6130	0.6131	0.02%	PASS
3	0.6191	0.6126	-1.05%	PASS
4	0.6321	0.6212	-1.72%	PASS
5	0.6019	0.5971	-0.79%	PASS
6	0.6211	0.6187	-0.38%	PASS
7	0.6119	0.6064	-0.91%	PASS
8	0.6294	0.6247	-0.75%	PASS
9	0.6168	0.6091	-1.24%	PASS
10	0.6207	0.6194	-0.20%	PASS
11	0.6192	0.6105	-1.40%	PASS
12	0.6122	0.6131	0.15%	PASS
13	0.5988	0.5973	-0.25%	PASS
14	0.6261	0.6246	-0.23%	PASS
15	0.6145	0.6077	-1.11%	PASS
16	0.6006	0.5969	-0.62%	PASS
17	0.6154	0.6119	-0.56%	PASS
18	0.6305	0.6302	-0.04%	PASS
19	0.6220	0.6115	-1.70%	PASS
20	0.6320	0.6289	-0.49%	PASS
21	0.6220	0.6110	-1.78%	PASS
22	0.6127	0.6099	-0.46%	PASS
23	0.6121	0.6054	-1.09%	PASS
24	0.6201	0.6126	-1.21%	PASS
25	0.5934	0.5945	0.18%	PASS
26	0.6164	0.6135	-0.48%	PASS
27	0.6165	0.6148	-0.28%	PASS
28	0.6255	0.6170	-1.36%	PASS
29	0.6178	0.6097	-1.31%	PASS
30	0.6009	0.5947	-1.03%	PASS

Figure 7 - Weight Confirmation After the Test

Results and Validation (Continued)

Similarly, characteristic confirmation after the test for both Inductance (L) and DC Resistance (RDC) revealed that the changes remained within specifications. For Model SRP6030CA-1R0M, L changed from -2.99 % to 0.72 %, and RDC from -0.80 % to 5.98 %. For Model SRP6030CA-R18M, L changed from -4.60 % to 3.92 %, and RDC from -2.92 % to 2.48 %. These results collectively affirm the stable electrical performance and robust physical integrity of the inductors.

Key Outcome: We are proud to announce that our SRP series of molded inductors have been rigorously tested for NVIDIA and have successfully passed the immersion cooling compatibility requirements. This validation confirms their robust performance and reliability in the demanding conditions of high-performance server applications utilizing immersion cooling.

SRP6030CA-1R0M

NO.	Before		After		Change Rate, %		Appearance
	L(uH)	RDC	L(uH)	RDC	L(uH)	RDC	
1	1.059	5.04	1.090	5.03	2.95%	-0.28%	PASS
2	1.059	4.96	1.040	4.94	-1.77%	-0.37%	PASS
3	1.074	4.98	1.010	5.02	-5.98%	0.71%	PASS
4	1.031	5.01	1.090	5.03	5.76%	0.38%	PASS
5	1.071	4.98	1.050	4.98	-1.96%	0.08%	PASS
6	0.994	4.98	1.030	4.99	3.63%	0.13%	PASS
7	1.056	5.02	1.060	4.96	0.38%	-1.25%	PASS
8	1.070	4.99	1.040	5.03	-2.79%	0.74%	PASS
9	1.050	5.01	1.040	5.02	-0.98%	0.23%	PASS
10	1.074	5.02	1.060	5.00	-1.32%	-0.42%	PASS
11	1.083	5.03	1.020	5.03	-5.80%	-0.04%	PASS
12	1.107	4.99	1.010	4.96	-8.75%	-0.64%	PASS
13	1.100	4.93	1.070	5.02	-2.74%	1.77%	PASS
14	1.025	4.96	1.090	4.98	6.29%	0.40%	PASS
15	1.044	5.00	1.060	4.98	1.51%	-0.41%	PASS
16	1.048	4.99	1.050	5.06	0.24%	1.38%	PASS
17	1.101	5.01	1.040	5.02	-5.54%	0.29%	PASS
18	1.067	5.01	1.070	4.99	0.31%	-0.38%	PASS
19	1.055	5.00	1.080	5.04	2.34%	0.85%	PASS
20	1.058	5.02	1.070	4.98	1.10%	-0.79%	PASS
21	1.070	4.99	1.039	5.06	-2.85%	1.41%	PASS
22	1.063	5.07	1.095	5.01	2.97%	-1.25%	PASS
23	1.093	4.99	1.077	4.94	-1.44%	-1.07%	PASS
24	1.055	5.02	1.049	4.98	-0.55%	-0.70%	PASS
25	1.055	4.97	1.068	4.98	1.17%	0.09%	PASS
26	1.089	5.00	1.049	4.97	-3.67%	-0.70%	PASS
27	1.062	5.00	1.031	4.96	-2.93%	-0.85%	PASS
28	1.062	5.00	1.069	5.02	0.72%	0.39%	PASS
29	1.062	5.02	1.057	5.00	-0.48%	-0.40%	PASS
30	1.028	5.03	1.047	5.02	1.84%	-0.16%	PASS

SRP6030CA-R18M

NO.	Before		After		Change Rate, %		Appearance
	L(uH)	RDC	L(uH)	RDC	L(uH)	RDC	
1	0.180	1.67	0.177	1.69	-1.46%	0.97%	PASS
2	0.178	1.73	0.182	1.71	2.48%	-1.11%	PASS
3	0.180	1.78	0.174	1.78	-3.34%	0.10%	PASS
4	0.186	1.73	0.184	1.71	-0.95%	-0.95%	PASS
5	0.181	1.68	0.180	1.62	-0.77%	-3.50%	PASS
6	0.183	1.76	0.175	1.69	-4.60%	-3.92%	PASS
7	0.178	1.67	0.182	1.71	2.46%	2.24%	PASS
8	0.178	1.76	0.182	1.80	1.97%	2.01%	PASS
9	0.180	1.80	0.179	1.80	-0.83%	-0.02%	PASS
10	0.178	1.77	0.185	1.68	3.95%	-4.96%	PASS
11	0.182	1.70	0.184	1.77	0.89%	3.86%	PASS
12	0.185	1.67	0.177	1.70	-4.42%	1.54%	PASS
13	0.178	1.64	0.178	1.68	0.02%	2.61%	PASS
14	0.182	1.70	0.180	1.74	-1.24%	2.36%	PASS
15	0.183	1.63	0.182	1.63	-0.48%	0.05%	PASS
16	0.183	1.71	0.186	1.66	1.60%	-2.92%	PASS
17	0.178	1.73	0.182	1.72	2.02%	-0.34%	PASS
18	0.180	1.81	0.179	1.76	-0.80%	-2.86%	PASS
19	0.182	1.71	0.178	1.70	-2.01%	-0.71%	PASS
20	0.176	1.63	0.183	1.66	4.25%	1.62%	PASS
21	0.182	1.71	0.178	1.70	-1.81%	-0.49%	PASS
22	0.179	1.73	0.179	1.63	0.25%	-5.90%	PASS
23	0.179	1.67	0.178	1.70	-0.78%	2.07%	PASS
24	0.183	1.71	0.183	1.66	-0.50%	-3.03%	PASS
25	0.191	1.74	0.180	1.69	-5.34%	-2.39%	PASS
26	0.181	1.72	0.187	1.72	3.09%	-0.53%	PASS
27	0.187	1.76	0.182	1.68	-2.53%	-4.06%	PASS
28	0.179	1.76	0.181	1.68	1.03%	-4.62%	PASS
29	0.182	1.76	0.180	1.69	-1.09%	-3.88%	PASS
30	0.183	1.68	0.185	1.75	1.15%	4.40%	PASS

Figure 8 - Characteristic Confirmation After the Test

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Conclusion

Immersion cooling is rapidly becoming the essential thermal management solution for high-performance computing, offering superior efficiency, energy savings, and environmental benefits. Successful implementation, however, relies on selecting electronic components engineered for direct dielectric fluid exposure. Bourns® SRP series molded inductors are precisely designed and rigorously tested to excel in these challenging environments. Their robust construction, proven material compatibility, high efficiency, and compact footprint make them an ideal and reliable choice for demanding applications like AI servers and other high-density computing systems. Bourns is committed to providing dependable inductive solutions for advanced cooling technologies, supporting the evolving needs of the HPC industry.

Learn more about Bourns® SRP Series Inductors:
Surface Mount Power Inductors & Common Mode Chokes & Chip Inductors Brochure