



ALUMINUM VS. COPPER BRASS

SELECTING THE BEST FIT FOR YOUR COOLING NEEDS

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INTRODUCTION

When it comes to industrial applications and machinery operation, having a reliable cooling system is absolutely essential. Understanding the importance of cooling systems in maintaining optimal operational temperatures is crucial for maximizing performance, longevity, and efficiency. Choosing the right material is a vital decision when it comes to these systems. The choice of material has a significant impact on both the cooling efficiency and the economic feasibility of the solution.

As industries evolve and demand more sophisticated and cost-effective cooling solutions, understanding the nuances of selecting the right material for the final application becomes paramount. The final application of a cooler, whether it be in off-highway vehicles, railway, or stationary powergen applications, dictates its requirements in terms of heat dissipation, weight, cost, and environmental resilience; here are the technical and economical sides of cooling system materials, guiding you through the labyrinth of choices to unveil how specific material properties, from heat conductivity to corrosion resistance, align with the diverse needs of various applications. By conducting a thorough analysis, we aim to illuminate the best approach for choosing and maximizing the performance and cost-effectiveness of a cooling system.



SELECTING THE RIGHT RAW MATERIAL: COPPER VS ALUMINUM ALLOYS

When it comes to finding the best cooling system, deciding between copper and aluminum is an important consideration. Both metals have unique properties that affect the efficiency, cost, and suitability for various applications. Having a good grasp of these intricacies allows you to choose a material that not only fulfills technical requirements but also fits within budget limitations.

COPPER: THE PREFERRED CONDUCTOR

Copper is well-known for its excellent thermal conductivity, surpassing that of aluminum by approximately 60-70%^{1,2}. The heat dissipation capability of copper makes it a perfect choice for applications that demand superior cooling efficiency. In addition to its excellent thermal properties, copper's resistance to corrosion enhances the longevity and durability of cooling systems, particularly in environments that are susceptible to corrosive elements.

Nevertheless, there are certain factors to consider when it comes to the cost and weight of copper. The cost of the cooling system can be significantly affected by the higher price of copper³. In addition, the higher density of the material leads to the inclusion of heavier components, which may not be ideal for situations where weight is a necessary consideration.

ALUMINUM: A PRACTICAL CHOICE FOR EFFICIENCY AND COST- EFFECTIVENESS

Aluminum proves to be a compelling alternative, striking a balance between efficient thermal conductivity and significant benefits in terms of weight and cost. Although it may not have the same thermal dissipation as copper⁴, aluminum's lightweight properties make it perfect for situations where weight reduction is a must. In addition, the affordability of aluminum-based cooling systems compared to copper makes them a more financially feasible option, particularly for projects with limited budgets.

Aluminum's versatility is clear in its manufacturing and formability⁵, enabling the creation of intricate shapes and structures that greatly improve cooling performance. However, it is important to keep in mind that aluminum has a lower corrosion resistance compared to copper⁷. This means that in certain environments, additional treatments or coatings may be required.

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2. Markham, D. (2024, March 26). Markham Metals - Steel & Aluminum. <https://markhammetals.com/copper-vs-aluminum-which-is-the-better-conductor-of-heat/>
3. Bastin, N. (2024, March 18). Copper MMI: Copper prices rise to highest level since April. MetalMiner. <https://agmetalmminer.com/2024/03/18/copper-mmi-copper-prices-rise/>
4. Sharma, M., Narayan Vishwakarma, P., Sharma, A., & Shubham, P. (2022). Performance investigation of copper and aluminium radiators for lower HP Tractor Engines. *Journal of Physics: Conference Series*, 2178(1), 012011. <https://doi.org/10.1088/1742-6596/2178/1/012011>
5. Hecker, S. S. (1975). Formability of aluminum alloy sheets. *Journal of Engineering Materials and Technology*, 97(1), 66-73. <https://doi.org/10.1115/1.3443263>
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7. Brusic, V., Frisch, M. A., Eldridge, B. N., Novak, F. P., Kaufman, F. B., Rush, B. M., & Frankel, G. S. (1991). Copper corrosion with and without inhibitors. *Journal of The Electrochemical Society*, 138(8), 2253-2259. <https://doi.org/10.1149/1.2085957>

CHOOSING THE BEST OPTION

Choosing between copper and aluminum depends on a thorough assessment of the specific needs of the application. Various factors, including the anticipated thermal load, environmental conditions, weight limitations, and budget constraints, are essential in making this decision.

When selecting materials for applications demanding superior cooling efficiency and extended durability, copper stands out as the premier choice. Its excellent thermal conductivity ensures efficient heat dissipation, crucial for maintaining optimal operating temperatures in various environments. Despite not being the most lightweight or cost-effective option upfront, copper’s unmatched performance and exceptional life cycle cost justify its consideration. Over the lifespan of cooling systems, copper’s durability reduces maintenance needs and replacement costs, making it a good investment for industries prioritizing long-term reliability and operational efficiency. On the other hand, when it comes to projects that prioritize weight reduction and cost savings, aluminum provides a compelling solution that doesn’t compromise performance too much.

Choosing the appropriate raw material for a cooling system involves a careful evaluation of technical specifications and economic factors. Through a comprehensive analysis of the specific requirements of each application, designers and engineers can effectively balance the advantages and disadvantages of copper and aluminum to create cooling solutions that are both high-performing and cost-effective.

FEATURE	COPPER	ALUMINIUM
Thermal Conductivity	▲ High (superior heat dissipation)	▼ Moderate (good but lower than copper)
Weight	▼ Heavy (greater density)	▲ Light (lower density, advantageous where weight is a concern)
Cost	▼ Expensive (higher raw material cost)	▲ Economical (lower raw material cost)
Corrosion Resistance	▲ Good (naturally resistant to corrosion, enhancing durability)	▼ Moderate (may require additional treatments or coatings in certain environments)
Manufacturability	▼ Good (flexible in manufacturing, though not as easy to shape as aluminium)	▲ Excellent (easily manufactured into complex shapes, offering design flexibility)
Application Suitability	▲ Ideal for high-efficiency cooling needs and for environments which are corrosive and harsh	▼ Suited for applications where weight and cost savings are priorities without significantly compromising on performance

Table 1 Comparative Overview: Copper vs. Aluminium in Cooling Systems

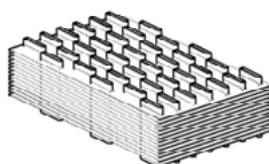
COPPER BRASS CORES

This configuration utilizes copper-brass fins and tubes, varying in its different configurations. Selecting the appropriate configurations for a cooling system is crucial for maximizing performance and efficiency. Each system type offers distinct advantages in efficiency, maintenance, and performance. Below are insights into various system types and their applications:

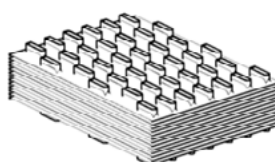
FLAT FIN

Flat fins are ideal for environments that require easy cleaning, such as agricultural or off-road applications. With a simpler design, dirt accumulation is minimized, ensuring consistent performance even in dusty conditions. Depending on the application, different tube configurations are needed. For instance, in an application where a lot of dirt, debris, or organic matter will be present, a flat fin configuration with a greater tube distance would be a good option. Alternatively, for environments where fewer obstructions are present but higher thermal performance is desired, a grid configuration with less tube distance would be beneficial.

Systems within this category, outlined below, are designed with varying tube diameters, row numbers, and configurations to support a range of vehicle types, from trucks to cars, offering flexibility in design. This flexibility, combined with the customization of the distance and position of the tubes, allows NRF to meet the required thermal performance while ensuring cleanliness to maintain optimal airflow. Below you can find some examples of different configurations and their best use.



Designed specifically for automotive applications



Engineered for the rigors of public works and heavy civil engineering machinery.



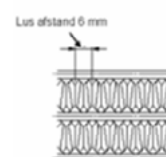
Designed for heavy-duty public works machinery under harsh conditions.



Scan or click here for more information about NRF's configurations

SERPENTINE FIN

Renowned for their unique snake-like design, serpentine fins provide superior heat dissipation capabilities, making them perfect for demanding applications. Nevertheless, the intricate designs of these objects tend to accumulate dirt, which can ultimately impact their performance over time. NRF offers different variants to cater to different cooling intensity requirements.



ALUMINIUM CORES

Bar and Plate (B&P): This configuration utilizes aluminium bars and plates, embodying a specialized manufacturing technique for aluminium cores. It offers a flexible and adaptable framework for radiator construction.

B&P APPLICATIONS

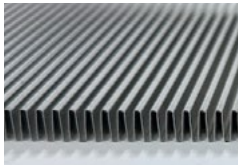
- **Robustness:** B&P cores are generally more robust than aluminium tube & fin cores, primarily due to the elimination of the header moment arm and is often used for high pressure requirements.
- **Thermal Performance Perception:** While some market sectors believe that B&P cores offer higher thermal performance, this perception is largely due to the greater number of fin/turb options available to B&P applications. There is little technical evidence to support this claim.
- **Weight and Cost:** B&P cores are heavier and more expensive than aluminium tube & fin cores. However, B&P cores usually provide more flexibility in terms of size, making them suitable for small production volumes.
- **Versatility:** B&P cores are versatile and can be used for all types of heat exchanger applications, including radiators, charge air coolers (CACs), and oil coolers.
- **Material Limitations:** The application of B&P cores is generally limited by material properties such as strength versus temperature and corrosion resistance rather than by design.
- **Corrosion Considerations:** Special attention should be given to potential corrosion issues in marine environments, including the risk of galvanic corrosion, exposure to oxygen, earthing, and the effects of cleaning fluids and water.



B&P SURFACE OPTIONS



Hemmed or unhemmed? Fins can be hemmed in order to make them more resistant to cleaning and damaging. Hemming is a process where the border of the fin that is exposed is folded before creating the fin shape. [Click here to see a demonstration video.](#)



Plain Fins designs feature a stamped rectangular pattern that creates large, continuous, straight channels for air passage. Each channel has square corners and straight sidewalls. Plain fins offer minimal pressure drop, enabling higher airflow, making them well-suited for environments with significant fouling. Additionally, the increased airflow velocity that plain fins allow can partially act as a self-cleaning mechanism. However, due to their simple design and lower turbulence, plain fins are the least effective option for applications requiring high thermal performance.



Wavy Fins serve as an intermediary between Plain and Offset fins, blending the straight design of plain fins with an undulation along the fins paths. This wavy configuration imposes less airflow resistance compared to offset fins while still enhancing surface area and generating beneficial turbulence beyond that of plain fins. Wavy fin designs are ideal for high-pressure, high heat transfer applications where there is a moderate risk of clogging.



Offset Fins design modifies the continuous line concept of Plain Fins by introducing rows of slightly misaligned (or offset) fins. This offset configuration disrupts airflow, generating turbulence and increasing surface area, which together enhance the radiator's heat transfer efficiency. Offset fin radiators are best suited for cleaner environments, as the small annular gaps between channel edges are more prone to clogging. Nonetheless, offset fins provide superior cooling capacity, making them an excellent choice for high-performance applications.⁸

ADVANTAGES AND DISADVANTAGES OF ALUMINIUM BAR AND PLATE (B&P) CORES RELATIVE TO ALUMINIUM TUBE & FIN CORES

ADVANTAGES	DISADVANTAGES
Robust - No header moment arm gives greater pressure retention capability.	Welding - Generally there is no option other than to weld tanks to cores, which is an expensive operation, precludes removable tanks and introduces an additional heat cycle into the manufacturing process (disturbs braze joints, residual stresses).
Internal surfaces - Easier to add internal surfaces with high surface area density and/or boundary layer disruption.	Weight - Use of bars dictates B&P cannot be as light as T&F, therefore more material cost and fuel cost in mobile applications.
Greater external surface - Core depth being the same as tank depth gives the potential to have more external surface area in the same space envelope.	Materials - limited to aluminium (implications for corrosion and temperature).
Design flexibility - Easier to make a wide range of sizes, mix 'n' match surface options etc.	Labour cost - Manually intensive assembly process that is very difficult to automate.

8. Comparing Fin Designs in Heavy-Duty Radiators. [online] Available at: <https://www.cincyradiator.com/blog/comparing-fin-designs-in-heavy-duty-radiators.html>

CORE/COOLER APPLICATIONS AND RECOMMENDATIONS

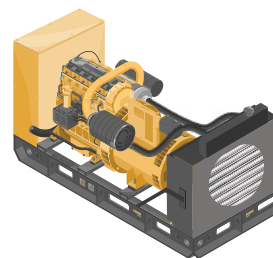
Maximize performance and durability in every environment with our specialized cooling solutions. Find the perfect fit for your needs:

STATIC APPLICATIONS: MINIMAL IMPACT & VERSATILE

For: Mining electricity generators, port cranes, construction auxiliary generators, chemical environment forklifts.

Exposed Conditions: Enhance material resistance for maritime, desert, rain, and wind exposure with thicker fins, tubes, and copper flat fin. Aluminium is an alternative for specific scenarios.

Sheltered Applications: Opt for Serpentine fin in copper brass cores for unmatched heat dissipation at a lower cost. For applications where radiator weight matters, aluminium B&P offers an efficient, lightweight solution.



AGRICULTURAL VEHICLES

For: Harvesters and tractors.

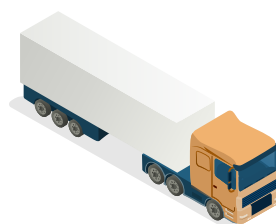
Best Option: Flat fin design for its simplicity and easier cleaning properties; making it preferable for environments with a lot of dirt. Tube distance and configurations may vary depending on environment and application.



TRUCKS AND CARS

Best Option: There are plenty of Aftermarket options depending on brand, model, and make; which are made of aluminium. But for specific models the suggestion is a copper brass core with a serpentine fin as the standard for superior thermal management and longer lifecycle.

Visit [NRF Aftermarket Webshop](#) to find a radiator for your make and model.



HEAVY-DUTY MACHINERY

For: Excavators, asphalt spreaders, crushers, compactors, backhoe loaders, bulldozers.

Best Option: Copper brass core, especially with a seam tube for enhanced resilience. Seamless tubes recommended for areas prone to leakage or difficult access.



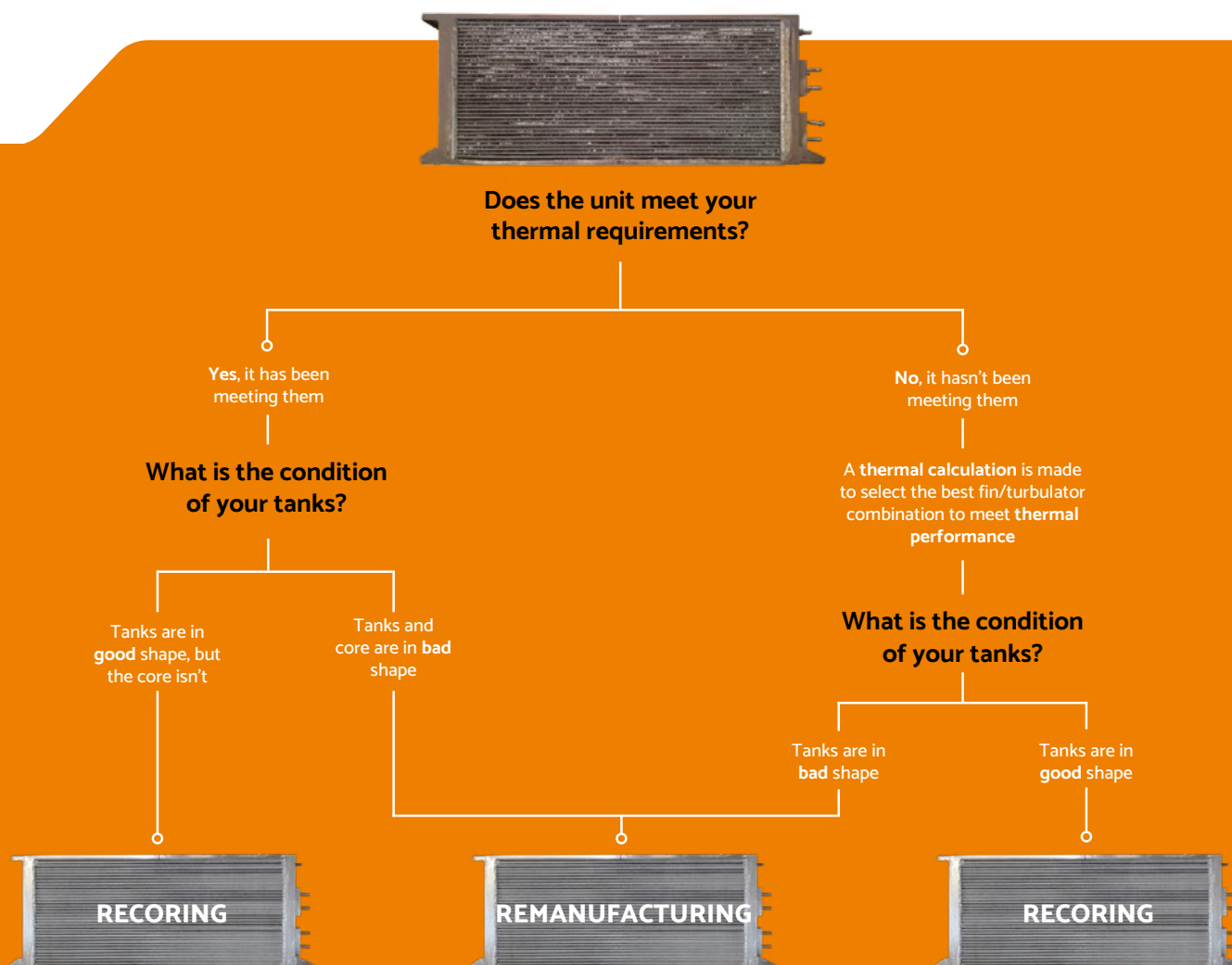
RECORING OR REMANUFACTURING?

A positive point for aluminium and copper cores is that they can both undergo comprehensive maintenance, extending their lifespan significantly. NRF offers complete maintenance and repair services for aluminium and copper brass radiators, allowing these cores to be rejuvenated and remain functional for longer periods. This includes fixing leaks, adjusting structures, and providing a one-year warranty that underscores the durability and ease of maintenance of aluminium radiator cores.

An additional benefit of our maintenance services is their contribution to environmental sustainability. Through the process of recoring, coolers receive a second life; the cooling section is replaced while other parts are reused. This practice not only extends the life of the equipment but also reduces waste and promotes the reuse of materials, aligning with our commitment to sustainable practices.

While the guidelines described in this White Paper offer a good starting point, we recommend contacting our knowledgeable technical assistance team to ensure the best cooling system is selected for your specific requirements.

RECORING OR REMANUFACTURING?





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