EXECUTIVE Report

New Designs of Charge Air Coolers Increase Performance and Durability

Part I: Laboratory Testing Verifies Claims of Durability and Efficiency

Editor's Note: Part II will show how testing is used to optimize CAC designs and manufacturing processes.

Bengt Gustafsson, Technical Manager for the Brazing Team at the Brazing Center, is an expert on CAC design.

The Brazing Center in Västerås, Sweden was established in 1999 for the purpose of fabricating and testing prototypical designs on behalf of prospective manufacturers of *Cu*proBraze products.

This tactic has worked well and as a result it has not taken very long for a number of manufacturers to move from prototype to production. Among the first to avail itself of the Brazing Center was SHAAZ, who subsequently began high-volume production on its dedicated *Cu*proBraze production line in Shadrinsk in 2003. Today, SHAAZ has captured nearly all of the Russian market for radiators and charge air coolers for heavy-duty trucks in Russia. Its heat exchangers are used in vehicles made by URAL, KAMAZ and other Russian truck and bus manufacturers. In addition, it has begun selling radiators to OEMs for use in passenger vehicles.

Typically, manufacturers are interested in producing better heat exchangers and keeping up with the latest technology. Most are initially interested in radiators but interest in charge air coolers is growing.

"It doesn't take long for our customers to see the advantages of making CACs and radiators on the same production lines," says Bengt Gustafsson, who is Technical Manager for the Brazing Team at the Brazing Center and resident CAC expert.

New CAC Materials

According to Bengt, much of the technology for making *Cu*proBraze radiators is readily transferable to CAC production but there are significant differences. "Many manufacturers have experience with copper-brass radiators but most have no experience whatsoever with copper-brass CAC designs," says Bengt. "Up until recently, many internationally renowned experts in charge air cooling have never even seen a copper-brass CAC."

Bengt explained that CACs were originally made of aluminum because soldered copper-brass could not withstand the high temperatures of the charge air. "When CACs were introduced 25 to 30 years ago, there was no brazing process for copper and brass," he says. "So, of course, the industry chose aluminum for CACs."

He should know. Bengt has been involved with CACs for his entire career, which spans four decades, from the 1970s to present, including stints with Valeo and other major heat-exchanger manufacturers.

Prototype Evaluation

Emission regulations worldwide are driving the development of diesel engines with a higher percentage of exhaust gas recirculation (EGR), which in turn requires turbo-charging to higher boost pressures, so the pressure resistance of CACs will be critical to the development of new clean diesel engines.

The failure mechanism for the aluminum CACs is fatigue cracking, which results from vibrations and other cyclic stresses. Cyclic stress tests are therefore important to run on the brazed copper-brass CACs, to evaluate their performance under similar conditions. "The fatigue properties for brazed copper-brass appear to be very good," said Bengt. "We have undertaken cyclic stress testing on tubes and tube-to-header joints with very encouraging results. The test results are valid for ambient temperatures as well as temperatures over 250 °C."

Typical test pressures are 50 percent above the maximum working pressure. A variety of CAC designs are subject to these tests, to determine which design features improve the durability and performance. According to Bengt, burst pressures and the pressure cycling lifetimes are influenced by a variety of factors, including the gauge and design of the inner fins, the gauge and design of the headers, the tank design and the quality of the brazed joints between the inner fin and tube walls.

The test procedure for design optimization involves cycling the prototype CACs at ambient temperatures through the following standard test sequence: 10,000 cycles between 0 and 0.2 MPa; then

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is the leading organization for the promotion of the use of copper worldwide. The Association's twenty-nine members represent about 80 percent of the world's refined copper output, and its six associate members are among the world's largest copper and copper alloy fabricators. ICA is responsible for guiding policy, strategy and funding of international initiatives and promotional activities. With headquarters in New York City, ICA operates in 28 worldwide locations through a network of regional offices and copper development associations.

For general mailing information about the *Cu*proBraze process or ICA's *Cu*proBraze consulting services, please contact International Copper Association at mrosario@copper.org. For technical information contact cuprobraze@copper.org. For European inquiries contact ndc@eurocopper.org.

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New *Cu*proBraze designs include CACs, from left to right, made by SHAAZ for KAMAZ trucks; made by SHAAZ for URAL trucks; and made by the Finnish Radiator Company (SJT) for the aftermarket.

10,000 cycles between 0 and 0.3 MPa; then 10,000 cycles between 0 and 0.4 MPa; and, finally, cycling to failure at 0.5 MPa.

Using various designs of CACs with standard material gauges, e.g., 0.05 mm thick fins and 1.2 mm thick headers, Bengt and his group achieved the following performance benchmarks:

- Burst pressures up to 1.6 MPa with good quality brazing of the core.
- Pressure cycling lifetimes between 10,000 to 30,000 cycles at 0.5 MPa, according to the test sequence.

Tests have been performed on well-brazed CACs made with "standard" material gauges, leaving plenty of latitude for general design improvements to meet more demanding specifications. If necessary the gauge could be increased for critical components, such as the inner fin, for example.

"In general, the durability of the copper-brass CACs is excellent, especially compared to the results for typical aluminum CAC designs," says Bengt. "More importantly, these tests allow us to optimize CAC designs."

Massey Ferguson Sees Advantages of *Cu*proBraze Technology*

Since early 2003, Massey Ferguson has been involved in evaluating *Cu*proBraze Technology for its tractors in Beauvais, northern France.

After first contact was established between Gabriel Menier, Technical Manager for engine installations at Massey Ferguson, and Andrew Burns, Technical Marketing Manager of Outokumpu Copper Strip, prototypes have been built and sent to Massey Ferguson. Gabriel Menier has also visited the Brazing Center in Västerås, Sweden.

Testing of prototype radiators and charge air coolers has taken place in the testing house in Beauvais and also in vehicles in the field. Currently a charge air cooler has been running for one year in a vehicle.

"Tests have shown satisfactory results," says Menier. "However, we see foremost an advantage with the charge air cooler design in *Cu*proBraze due to the high specific cooling capacity and the lower air side pressure drop which can be achieved with the technology and also the favorable strength properties the materials show at elevated temperatures. Temperatures are rising constantly and there should be an advantage with the *Cu*proBraze design due to the strength. Even though we are currently not using *Cu*proBraze in our vehicles we are open to the possibility for this in the future due to the technical advantages mentioned."

Furthermore, Gabriel Menier has been very impressed with the *Cu*proBraze Team in Västerås, Sweden, and the excellent handling of the evaluation work carried out.

High Temperatures

Bengt points out that it is especially important to identify the maximum material temperatures, and the materials properties at these temperatures. "Ironically, manufacturers are now interested in brazed copper-brass charge air coolers because the performance of aluminum CACs deteriorates when inlet air temperature exceeds approximately 180 °C," says Bengt. "Brazed copper-brass retains its strength at much higher temperatures." ■

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