Bombardier Achieves Superior Performance at a Lower Initial Cost

Brazed Copper-Brass Cools Locomotive Electrical Equipment

OEMs around the world are adopting brazed copper-and-brass at a rapid pace for a variety of heat-exchanger applications. Most commonly, *Cu*proBraze technology is used to make heat exchangers for diesel engines, yet many other cooling applications can benefit from its durability and cooling efficiency. Transportation giant Bombardier, for example, recently installed brazed copper-and-brass oil coolers on refurbished electric locomotives that transport coal in South Africa.

From Snowmobiles to Locomotives

Bombardier traces its origins to all-terrain vehicles and snowmobiles. Its founder Joseph-Armand Bombardier invented the first snowmobile in 1937 for use in rural Quebec and thereafter founded L'Auto Niege Bombardier Limiteé in 1942. In the 1970s and 1980s, the company diversified into railway and aeronautical products and evolved into the multinational corporation known as Bombardier Inc.

Today, with more than 55,000 employees, it is one of the world's largest manufacturers of innovative transportation products, from regional aircraft and business jets to rail transportation equipment. In the USA, along with Alstom, it is renowned for the development of the Acela Express train, the first high-speed rail-line in North America; and it is also known for the restoration of New York City subway cars.

Why *Cu*proBraze?

The project leader Jan Andersson who earlier was directly employed by Bombardier nowadays is employed by Råbe Consulting but still has an office at Bombardier Transportation in Västerås, Sweden. Andersson first learned about *Cu*proBraze technology in the year 2003. He says that interest in *Cu*proBraze at Bombardier has been high from the beginning and discussions have been moving forward ever since.

Laboratory testing and study of *Cu*proBraze was ongoing among the cooling experts in the Propulsion & Controls section of Bombardier Transportation for some time. Finally, an opportunity to test the technology in real-world applications materialized when Bombardier began overhauling of 45 Class 11E electric locomotives for South African Railways (SAR). The original design of the heat exchangers was inefficient and SAR had many problems with overheated locomotives. SAR asked during the refurbishment if the heat exchangers could be overhauled or replaced with a more efficient cooler.

"The oil cooler design was one of the weakest components in the locomotives," said Andersson. "These heat exchangers were being made by a number of small private companies at great expense, yet they were not measuring up in terms of durability. The oil coolers frequently had to be overhauled, taking the locomotives out of service due to overheating."

According to Andersson, the old design was based on round copper-alloy tubes with aluminum fins. The latter were not rugged enough for the operating environment. "It become a matter of pride with us," says Andersson. "We did not want our refurbished system to be a problem for SAR.

Ermelo is located in Mpumalanga province in the northeast of South Africa. Every day, about eight trains leave Ermelo for the port city of Richards Bay, which is about 170 kilometers north of Durban, traveling a distance of 400 kilometers. Typically one train is 3.5 kilometers long and carries close to 22,000 tons of coal in 200 wagons pulled by four electric locomotives. Currently SAR transports 78 million tons per year however there are plans to transport 100 million tons a year (or about 250,000 tons per day) of coal from Ermelo to Richards Bay for export to Far East as the demand for coal increases. Improving the operating-efficiency of the locomotives and reducing their downtime is necessary to reach this milestone.

When it came time to refurbish the locomotives a few years ago, one of the priorities was to upgrade the oil coolers used to cool the electric converter and transformers used to power the engine. The original coolers relied on welded copper pipes to transfer the heat away from the transformers. Unfortunately, high levels of dust led to increased temperatures in the transformer and ultimately the premature failure of the transformer and the oil cooler leading to excessive downtime for the locomotives due to overheating.

To reduce maintenance cost/time and reduce the failure rate of the old system a new computerized MITRAC® control system was installed and other worn-out parts were changed. A rugged oil-cooler was required to reduce the temperatures of the transformer and rectifier and minimize downtimes and lost revenue. The goal of the refurbishment was to deliver a locomotive that could operate successfully in this harsh environment for 30 years. Also, when a problem occurs, it would be essential to make repairs quickly in the field. *Cu*proBraze products are easy-to-clean and repair, allowing the locomotives to be returned to service faster.

The Acela Express is a high-speed train designed in part by Bombardier.

So we studied the problem closely and looked for alternative cooling systems."

These particular locomotives must haul coal through harsh terrain. A single train may be three and one-half kilometers in length and contain as many as 200 wagons plus four locomotives. The wagons exit the mines loaded with coal and are linked together prior to the 400-kilometer trip to Richards Bay Coal Terminal. This journey requires passing through some very steep inclines; electric braking is necessary as the altitude drops from 1700 meters to sea level in a short distance.

Andersson explained that the heat exchangers are subject to three extreme conditions of service: 1) clogging, shock and vibration; 2) high air humidity and salt water; and 3) dirt from the many sugar fields that the train passes in its journey.

Pure Locomotive Power

Electric locomotives require large heat exchangers for cooling the electrical transformers and inverters that convert the high voltage electricity from the transmission lines into the lower voltage, higher amperage electricity necessary to drive the trains.

Although the electrical equipment is extremely efficient, nonetheless a certain percentage of waste heat continuously must be removed. The *Cu*proBraze heat exchanger in this application is rated for a cooling capacity of 38 kW for the converter plus 220 kW for the transformer. By comparison, the locomotive is rated at is 3780 kW at the wheel rims (i.e., 3.78 MW, or about 5000 horsepower).

The cooling system circulates a special type of oil that is used as a coolant. Transformer oil is usually a highly refined mineral oil that is stable at high temperatures and has excellent electrical insulating properties. The coolant passes through the electrical equipment and then through the huge oil cooler.

The two *Cu*proBraze heat exchangers are 64.75 inches in length, 13.77 inches high and 30.00 inches wide mounted on same frame. The oil coolers have seven rows of tubes for converter cooling and fifteen rows of tubes for the transformer cooling mounted in one assembly. They are in close proximity to the transformer and converter, with the main transformer requiring the most cooling.

The final coal wagon leaves a tunnel (circled) on its way to Richards Bay. The photograph was taken from the driver's cab, three kilometers in front of the last wagon.

Oil temperature reaches 60 °C to 90 °C as it passes through the transformer. Two large fans drive air through the oil cooler and out through the bottom of the locomotive.

Tubes and Turbulators

The new design of oil cooler has corrugated fins with spacing of eight fins per inch for easy cleaning. Heat exchangers can be designed with a depth of many rows. Standard ¾ inch tubes with a wall thickness of 0.016 inches are used. Internal fins, or "turbulators," are inserted inside the tubes to enhance the exchange of heat between the transformer oil and the tube walls.

Superior Performance at a Lower Cost

A prototype was completed and placed in a locomotive in service for comparison with the old-style oil coolers remaining in the rest of the fleet. The cooling system experts at Bombardier carefully studied the *Cu*proBraze cores in this application for more than one year. They concluded that the durability was clearly superior for the *Cu*proBraze cores compared to the old-style cores.

Meanwhile, Andersson identified companies who could deliver the huge *Cu*proBraze cores; a furnace with large dimensions was necessary for their manufacture. For comparison, up-to-date quotes were also obtained from existing suppliers for the initial costs of heat exchangers cores built using the old technology.

One of 45 Class E Locomotives being overhauled by Bombardier for South African Railways.

The International Copper Association, Ltd. (ICA)

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.

References

1. Cooling Capacity for the converter
2. Cooling Capacity for the transformer using a *Cu*proBraze Heat Exchanger is 222 kW

Contact Information

Jan Andersson, Consultant
Bombardier Transportation Västerås
Östra Ringvägen 2
SE-721 73 Västerås
Telephone: +46 21 317 000
jan.andersson@se.transport.bombardier.com

Astonishingly, the price quotes obtained for the initial cost of *Cu*proBraze heat exchangers were lower than the initial cost of old-style cores. "At that point, the decision to use *Cu*proBraze was easy. The cost savings was direct."

Considering the superior performance at a lower price point for the *Cu*proBraze oil coolers, it wasn't long before oil coolers plus spares were ordered for 45 locomotives and three spare units. Bombardier expects to place orders for 400 to 500 locomotives in the next five years. "We are looking to replace the oil coolers not only in South Africa but also in Sweden, Australia and the United States. Many locomotives are reaching 20-30 years of service, which is about the middle of their life cycle. They are ready for refurbishing."

New Applications, New Designs

The cooling experts at Bombardier are looking forward to using *Cu*proBraze technology in new designs of original equipment. "We have many new designs on the drawing boards. *Cu*proBraze is the technology of choice for future generations of heat exchangers. The experience gained from installations of *Cu*proBraze in the harsh environments of South Africa is good assurance that *Cu*proBraze is durable enough for practically any application," concludes Andersson. ■

Class 11E Locomotive Specifications

First Delivery	1985
Line Frequency	50 Hz
Line Voltage	25 kV
Gauge	1,067 mm
Driving wheel diameter (new)	1,220 mm
Bogie Wheelbase	4,400 mm
Total Wheelbase	15,960 mm
Height With Pantograph Down	4,200 mm
Maximum Width	3,050 mm
Length Over Couplers	20,470 mm
Maximum Speed	90 km/h
Continuous Transformer Rating Excluding Auxiliaries	5,740 kVA
Continuous Rating (main transformer)*	3,780 kW
Maximum Starting Tractive Effort*	580 kN
Axle Load Max	28,000 kg
Weight, Total	168,000 kg
Number of Traction Motors	6
Traction Motor Control	Thyristors
Transmission	Axle-hung nose-suspended motors and flexible gear-wheeled drive
Auxiliary Machines	50 Hz 3-phase
Brake Systems	Extended range dynamic brake and tread brake

* At wheel rims

Coal is mined near Ermolo and transported 400 km by train to Richards Bay. Locomotives are upgraded in Durban.

COPPER
International Copper Association, Ltd.

International Copper Association, Ltd.
260 Madison Avenue, 16th Floor, New York, NY 10016-2401
Tel: 212.251.7240, Fax: 212.251.7245