EXECUTIVE Report

Diesel Engine Makers Strive to Meet EPA, EU and Japanese Emissions Standards for Highway, Off-road and Locomotive Applications, Part II

New Low-Emission Engine Technologies Adopt CuproBraze Heat-Exchangers

Part II – Review of Diesel Emissions Standards for Off-Road Equipment, Locomotives and Stationary Power Generators

[Editor's Note: Part I provided an overview of legislation and reviewed heavy duty on-highway diesel emissions standards. See *CuproBraze Executive Report* Number 58.]

Diesel engine manufacturers and suppliers of ancillary parts and equipment around the world are facing unprecedented challenges to their industry due to stringent new emissions control requirements. These increasingly tough standards are the result of threats to human health. Manufacturers that fail to develop products that meet or exceed these standards will be effectively banned from the international markets in the near future.

The first half of this special two-part report (see *CuproBraze Executive Report*, Number 58) examined the history of diesel emissions standards globally and initial implementation for heavy duty (HD) on-highway trucks and buses. Here we look at diesel emissions standards for off-road equipment and locomotives as well as large stationary diesel engines such as those used for power generation.

Off-Road Emissions

The U.S. Environmental Protection Agency (EPA) refers to off-highway or off-road vehicles as "nonroad" equipment. Diesel engine emissions regulations governing such mobile equipment is structured according to a Tier system. Model years 1996 through 2000 are covered by Tier 1 emission standards, while Tier 2 applies to 2001-2006 vehicles and Tier 3 applies to years 2006-2008. The Tier 3 rules are quite stringent but can be met without exhaust after-treatment systems. The latest requirement, Tier 4, could not be implemented until low sulfur (15 ppm, which is down from 500 ppm) diesel fuel became widely available in the U.S. in 2006.

Starting in 2008 and continuing through 2015, EPA Tier 4 emissions standards will be phased in by off-road diesel engine manufacturers. Tier 3 and Tier 4 standards together require that emissions of particulate matter (PM) and nitrogen oxides (NOx) should be further reduced by about 90 percent. As an example, for engine horsepower between 75 and 750 hp, Tier 1 limits NOx to 6.9 g/bhp-hr (or 9.2 g/kWh) compared to Tier 4 limits of 0.30 g/bhp-hr (or 0.40 g/kWh), *i.e.*, a 95.6 percent reduction.

The EU standards for off-road vehicles are described in terms of stages rather than tiers. Under pressure from engine and equipment manufacturers, the EU Stages I and II have been harmonized in part with

U.S. regulations, and EU Stages III and IV are harmonized with U.S. Tier 3 and 4. Hence, the European Stage IV standards for the larger off-road engines call for 0.4 g/kWh NOx (i.e., the same as U.S. EPA limits) by 2014. Again, this is a dramatic reduction from previous levels.

Valtra tractors now use *Cu*proBraze CACs and radiators. (Photograph courtesty of Valtra Inc.)

The Japanese 2008 standards are similar in stringency to the U.S. Tier 3 (2006-2008) and EU Stage III-A (2005-2007), but they are not harmonized with U.S. and EU regulations. The Central Environmental Council of Japan's Ministry of Environment (MoE) is also considering "aftertreatment-forcing" standards with implementation dates around 2010.

A concise summary of emissions standards for off-road diesel engines is provided by DieselNet at www.dieselnet.com/standards/us/nonroad.php.

*Cu*proBraze and Off-Road

*Cu*proBraze technology is enjoying great success in off-road equipment with regard to both radiators and CACs. The arguments for *Cu*proBraze resemble those outlined in Part I for on-highway trucks, but the technology is taking hold much faster for a variety of reasons.

The durability of heat-exchangers for off-road vehicles is even more important than for on-highway trucks. Agricultural and construction equipment is typically subject to harsh environments. When dirt, dust and debris accumulate in the fins of the vehicles' heat exchangers they must be power-washed out. To withstand this, fin designs must be robust, and this favors the use of copper and brass over the less-dense aluminum. Soldered copper and brass heat exchangers were preferred in these applications even before *Cu*proBraze was an option. As such, *Cu*proBraze is considered an upgrade of an existing technology rather than a change in technology. In many cases, the introduction of *Cu*proBraze has prompted equipment manufacturers to switch from aluminum back to copper and brass.

The Finnish Radiator Manufacturing Company (www.FinnRadiator.com) is pioneering the development of *Cu*proBraze heat exchangers for off-road vehicles. It is already supplying *Cu*proBraze heat exchangers to leading OEMs of agricultural tractors, terminal tractors, multipurpose machinery, piling rigs and other types of off-road equipment.

One customer is Valtra, a worldwide brand of the AGCO Corporation, which is based in Duluth, Georgia (USA). AGCO is the third-largest manufacturer of agricultural equipment in the world. "We are already familiar with the superior performance of *Cu*proBraze heat exchangers," says Ilpo Ahola, manager of Front-end Installations at Valtra Suolahti. "We are now using *Cu*proBraze CACs in all of our N-Series and T-Series tractors."

Numerous other large OEMs in the U.S., Europe, Japan, China and Russia are actively pursuing *Cu*proBraze technology for off-road applications [6].

Locomotive Emissions

The U.S. EPA has targeted locomotives for stringent emissions reductions as well. On March 14, 2008, a regulation was signed to further restrict emissions from locomotives. The EPA Tier 4 standards for locomotives ultimately will apply to Model Years 2015 and beyond, limiting NOx to 1.3 g/bhp-hr and PM to 0.2 g/bhp-hr.

In addition to stringent Tier 3 and Tier 4 standards, the 2008 EPA legislation calls for tougher standards for remanufactured Tier 0 to Tier 2 locomotives. These new regulations apply to locomotives dating back to 1973 model years. Since many locomotive diesel engines are remanufactured, the new regulations are having a significant impact on both the railroad industry and the environment.

In Europe, locomotives must adhere to off-road emissions standards. The Stage III/IV standards cover railroad locomotive engines as well as marine engines used for inland waterway vessels. In effect, the EU off-road standards place stringent restrictions on locomotive emissions comparable to the U.S. EPA emissions standards for locomotives.

The Final Rule was published in the U.S. Federal Register [7]. Table I summarizes the model years and emissions standards for locomotives.

A concise summary of emissions standards for off-road diesel engines is provided by DieselNet at www.dieselnet.com/standards/us/loco.php.

*Cu*proBraze in Locomotives

For locomotives, weight is much less of a consideration than durability and volume. Locomotives require huge onboard heat exchangers. In retrofit or upgrade applications, it is often necessary to squeeze more cooling capacity into a smaller space and the heat exchangers may need to operate at temperatures higher than those required in the past. The increased durability of brazed copper and brass along with the increased cooling capacity of serpentine-fin designs make *Cu*proBraze a natural choice for locomotive applications.

For this reason, interest in *Cu*proBraze for locomotives is intense and growing. Major OEMs such as MotivePower, a Wabtec Company (Boise, Idaho), Siemens AG Transportation Systems (Erlangen, Germany), and Bombardier Transportation (Västerås, Sweden) are already using *Cu*proBraze technology in locomotive applications. Railways from India to Africa to North America and Asia are examining this technology or already upgrading their locomotives with *Cu*proBraze heat exchangers.

In many cases, *Cu*proBraze replaces older plate-fin heat exchanger technology. The *Cu*proBraze brazing process provides rugged joints between the fins and tubes. These components are as durable as soldered plate-fin heat exchangers but more efficient and hence also more compact.

Young Touchstone, a Wabtec Company in Jackson, Tennesee (USA) and a leader in the development of *Cu*proBraze heat exchangers, also manufactures mammoth *Cu*proBraze locomotive radiators with core face areas up to 3 meters long by 1.5 meters wide. According to Sales & Marketing director Mike Sprenger, "In the past several years, OEMs have shown increasing interest in the benefits of this technology. We have successfully tested cooling systems with our customers and are now experiencing the initial waves of demand for *Cu*proBraze. With many heavy-duty applications now in production, we are preparing for additional customer demand in all of our global markets."

Table I — Line-Haul Locomotive Emission Standards. Units are given in g/bhp-hr. (Table courtesy of DieselNet.com.)

Tier	Model Year	Date	HC	CO	NOx	PM
Tier 0[a]	1973-1992[c]	2010[d]	1.00	5.0	8.0	0.22
Tier 1[a]	1993[c]-2004	2010[d]	0.55	2.2	7.4	0.22
Tier 2[a]	2005-2011	2010[d]	0.30	1.5	5.5	0.10[e]
Tier 3[b]	2012-2014	2012	0.30	1.5	5.5	0.10
Tier 4	2015 or later	2015	0.14[f]	1.5	1.3[f]	0.03

a – Tier 0-2 line-haul locomotives must also meet switch standards of the same tier.
b – Tier 3 line-haul locomotives must also meet Tier 2 switch standards.
c – 1993-2001 locomotive that were not equipped with an intake air coolant system are subject to Tier 0 rather than Tier 1 standards.
d – As early as 2008 if approved engine upgrade kits become available.
e – 0.20 g/bhp-hr until January 1, 2013 (with some exceptions).
f – Manufacturers may elect to meet a combined NOx+HC standard of 1.4 g/bhp-hr.

Power Generator Emissions

Large stationary diesel engines are typically used to generate electricity and operate compressors and pumps in power and manufacturing plants.

The U.S. EPA proposed standards for stationary diesel engines in 1979 but they were never finalized, so regulation remained at the state and local level for decades until a lawsuit was filed against EPA in 2003 by an environmental advocacy group. As a result, in June 2006 the EPA adopted emission regulations mandating that most new stationary diesel engines meet the Tier 1-4 emission standards for mobile off-road engines.

Emissions regulations for stationary diesel engines are published in Title 40 Chapter I, part 60 of the Code of Federal Regulations (CFR) [8].

A concise summary of emissions standards for stationary diesel engines is provided by DieselNet at www.dieselnet.com/standards/us/stationary.php.

New Technology

As noted, the U.S. Environmental Protection Agency, the EU Council of Environment Ministers and the Japanese Ministry of Environment have passed stringent laws regulating emissions from diesel engines. Consequently, major diesel engine and equipment makers continue to research new technologies to reduce emissions from diesel engines. Environmental agencies and ministries in other countries are developing their own emissions standards or adopting the U.S., EU or Japanese standards. In some case, international unions or industry associations are also developing emissions standards.

The International Copper Association, Ltd. (ICA)

The International Copper Association, Ltd. (ICA) is the leading organization for promoting the use of copper worldwide. The Association's 38 member companies represent about 80 percent of the world's refined copper output. ICA's mission is to promote the use of copper by communicating the unique attributes that make this sustainable element an essential contributor to the formation of life, to advances in science and technology, and to a higher standard of living worldwide.

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

Footnotes and References

(continued from Part I)

6. *CuproBraze Executive Report* Number 55, "OEMs Reach for Brazed Copper Brass."
7. The Final Rule for locomotives published in the U.S. Federal Register, Vol. 73, No. 88, 6 May 2008, pages 25098 through 25352 and can be accessed online via www.gpoaccess.gov/fr/retrieve.html.
8. Title 40 Chapter I, part 60 of the Code of Federal Regulations (CFR) applies to stationary diesel engines and can be accessed online via www.gpoaccess.gov/cfr/index.html.

Many OEMs are adopting *Cu*proBraze technology as part of the solution for clean diesel engines. *Cu*proBraze heat exchangers offer compactness, durability and temperature resistance. They are ideally suited for cooling new clean diesel engines, particularly locomotives, stationary power plants and off-road equipment, which use very large heat exchangers to cool high-horsepower engines.

This *Cu*proBraze heat-exchanger assembly is for a locomotive application. (Photograph courtesy of Young Touchstone.)

"We expect interest in *Cu*proBraze to expand globally as OEMs strive to meet Tier 3 and 4 off-road emissions standards in the U.S. and corresponding EU standards for various engine classes," says Nigel Cotton, Automotive Manager of the International Copper Association. "We are especially pleased by the surge of interest in *Cu*proBraze for locomotive and stationary gen sets. As *Cu*proBraze proves itself in these demanding applications, we expect that more OEMs will move forward with plans to use *Cu*proBraze technology in other off-road and highway applications."

Young Touchstone's Michael Sprenger agrees that, in the long run, OEMs will realize that *Cu*proBraze makes good sense for off-road and locomotive applications. "We are anticipating a second wave of demand in all of our markets. Research is ongoing for both engine-cooling radiator applications and air-to-air CAC applications. As OEMs of all types seek to meet Tier 3 and 4 off-road emissions standards for new locomotive, mining, petroleum, and generator set applications, interest in *Cu*proBraze continues to grow. The pendulum is very definitely swinging toward *Cu*proBraze in these heavy-duty markets." ■

Valtra tractors are transported by rail from the tractor works in Suolahti, Finland to the harbor. Locomotive and tractor OEMs are are working hard to meet tough diesel emissions standards. (Photograph courtesy of Valtra Inc.)

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