Heat Recovery for the EAF of Georgsmarienhütte, Germany

Energy Savings vs. Heat Recovery

The target of any optimization for an EAF or other industrial furnace is either to increase product quality or lower energy consumption. If you look at the various ongoing discussions the current focus is clearly on energy reduction. There has been a lot of progress in minimizing the input of primary energy like slag management, optimized charging schemes or intelligent furnace control systems (i.e., EFSOP).[1]

The new cooling system at GMH, including the first element of the waste gas duct, was completely designed as an evaporative cooling system. This paper analyzes the project characteristics as well as the opportunity for similar heat recovery in EAFs in North America.

How great this progress is and will be is still undetermined; however, a large amount of the energy supplied to the EAF will be lost in the offgas and cooling water of the respective process. When you view heat recovery, you should view it as a secondary option behind reducing the energy input. It is better to use 1 kWh less, than to recover 1 kWh.

Figure 1 explains that the energy contained in the offgas of an EAF adds up to at least 25% (for furnaces with optimized use of chemical energy) or up to approximately 30%, making offgas by far the biggest source for heat recovery. This doesn't apply to all types of mill equipment. For example, large walking beam reheating furnaces typically measure cooling water as the biggest energy loss.

From an economical standpoint, you must weigh whether a project to reduce energy consumption is too costly when compared to achieving the same amount of overall energy savings by implementing heat recovery. If your EAF operation has been recently modernized, it becomes more difficult and expensive to make even slight improvements in the operating efficiency. At this point, the biggest potential for efficiency improvement in the EAF is heat recovery from the offgas.

Temperature Level as the Determining Aspect for Technology — The typical modern EAF has a water-cooled waste gas duct that cools the offgas to approximately 600°C while heating the cooling water from approximately 20°C to around 40°C, and sometimes from 70°C to 90°C. When offgas temperatures are below 600°C, a quench tower is typically used to cool the waste gas to approximately 200–250°C. The heated water is cooled, and the energy is released into the atmosphere.

In consideration of 40°C cooling water, there is not a low cost modern technology that can reverse the cycle and return the water to 20°C and reuse the energy. If the cooling water has a temperature of around 90°C, it might be used for heating purposes. If the following two conditions are fulfilled, then there is a perfect use for waste gas energy:

- No other source of hot water in the plant.
- There is a demand for heating all year.

In many plants, you will find a greater hot water supply than demand. The geographical location of a plant and seasonal demands can make the supply and demand gap even wider. Figure 2 shows a very typical hot water demand in a steel plant in Central Europe. Some plants need a constant supply of hot water for uses such as preheating feed water for a nearby power station, but these plants are the exception.[3]

The Best Method for Heat Recovery

Steam Generation Using Tenova iRecovery — There are several reasons why steam production is the best operating practice for flexible heat recovery. For example:

- Steam can be used for many purposes (i.e., process steam, heating, compressor operation and power generation).

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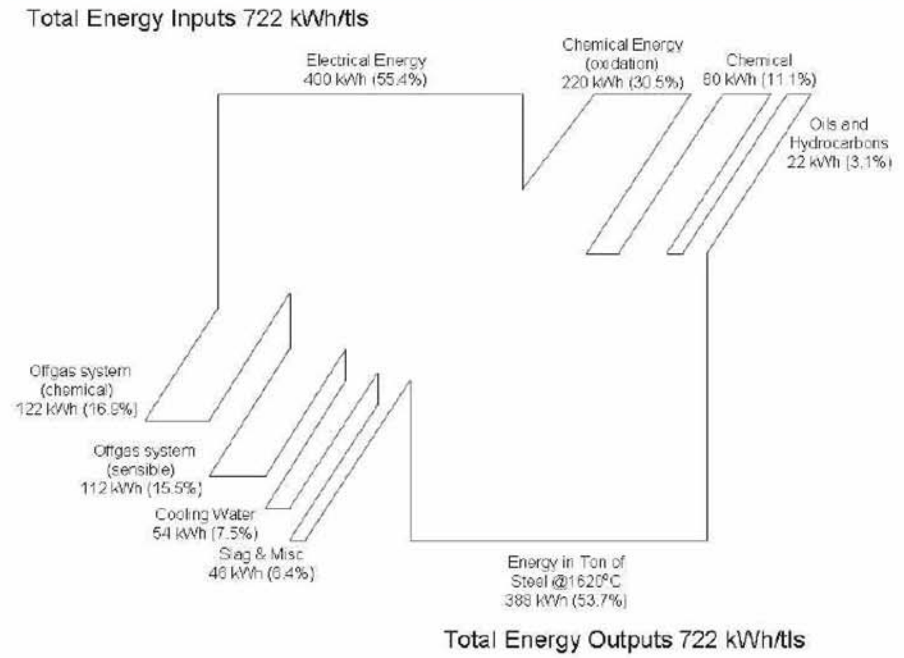
- Wide temperature range (similar to offgas temperatures, steam temperatures can be variable).
- Relatively easy to transport.
- Water is an inexpensive and non-toxic base.
- Proven technology.

The technology used to turn waste gas energy into steam is Tenova iRecovery. An iRecovery waste gas duct is a tube-tube construction that looks very similar to a conventional cooling duct.

The main difference between an iRecovery and a conventional cooling system is that pressurized water at the boiling point is led through the piping. The chosen temperature-pressure combination is determined by the required steam parameters at the plant. Typical values are between 13 bar/192°C and 28 bar/230°C. Higher pressures are used to run steam turbines.

Figure 1



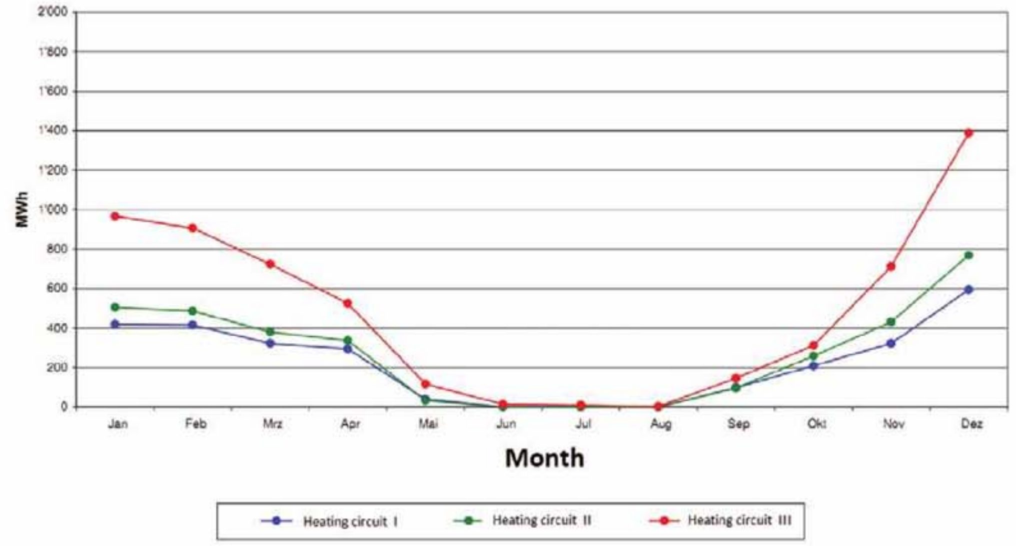
Energy balance for modern EAF practice.[2]

The nearly boiling water absorbs the energy from the waste gas by evaporation. The physical process of evaporation consumes much more energy than heating water for, i.e., 20° more.

An iRecovery system is designed for partial evaporation of the water; typically no more than 5–12% will be evaporated under normal operation conditions, which means there is spare capacity in the cooling system.

Figure 4 demonstrates that an iRecovery with a steam weight content of 12.5% in the return stream requires approximately 35% less water than cold water cooling. This means smaller piping and smaller pumps are required.

Figure 2



Demand for hot water in a European steel plant.

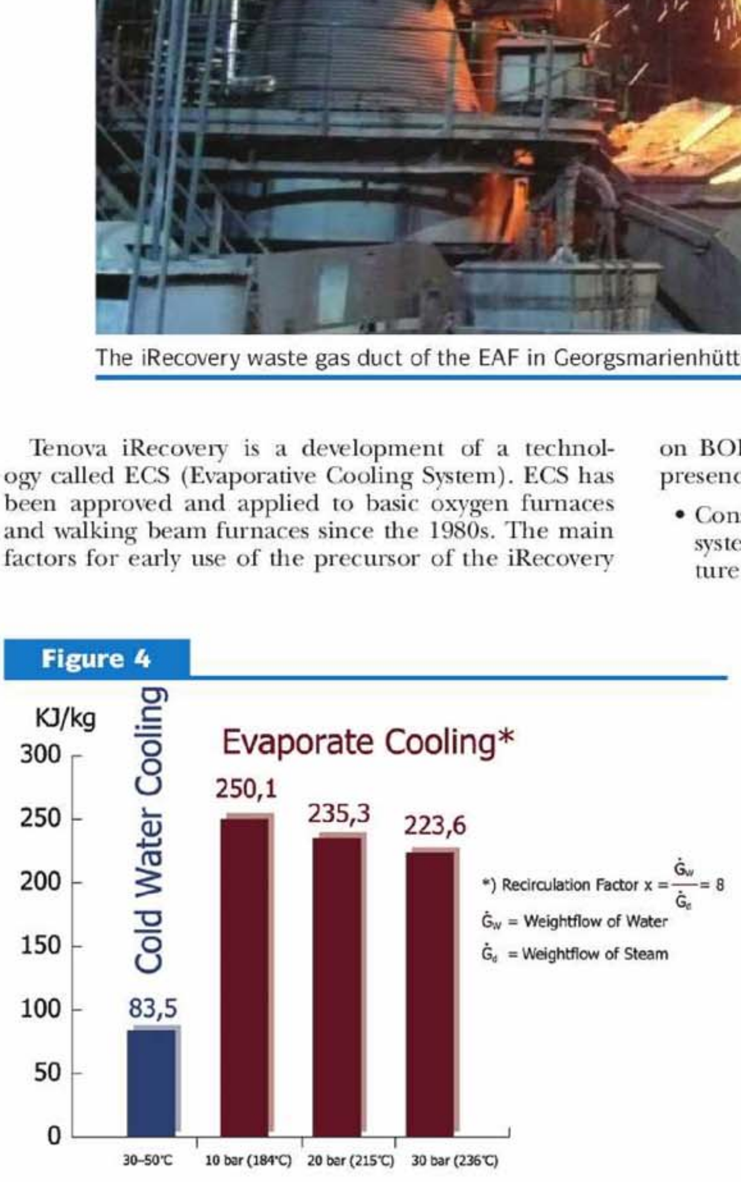
Figure 3

The iRecovery waste gas duct of the EAF in Georgsmarienhütte, Germany.

Tenova iRecovery is a development of a technology called ECS (Evaporative Cooling System). ECS has been approved and applied to basic oxygen furnaces and walking beam furnaces since the 1980s. The main factors for early use of the precursor of the iRecovery on BOF vessels and large reheating furnaces was the presence of stable operating conditions due to:

- Constant temperature in the complete cooling system (saturated steam has the same temperature as water).
- Fewer problems with corrosion and other chemical reactions due to a closed system with clean boiler water.
- Robust at energy/temperature peaks.
- Robust at interruption of water supply (closed system with nearly zero losses unless steam is taken out).

Figure 4



*) Recirculation Factor $x = \frac{\dot{G}_W}{\dot{G}_d} = 8$

$\dot{G}_W$ = Weightflow of Water

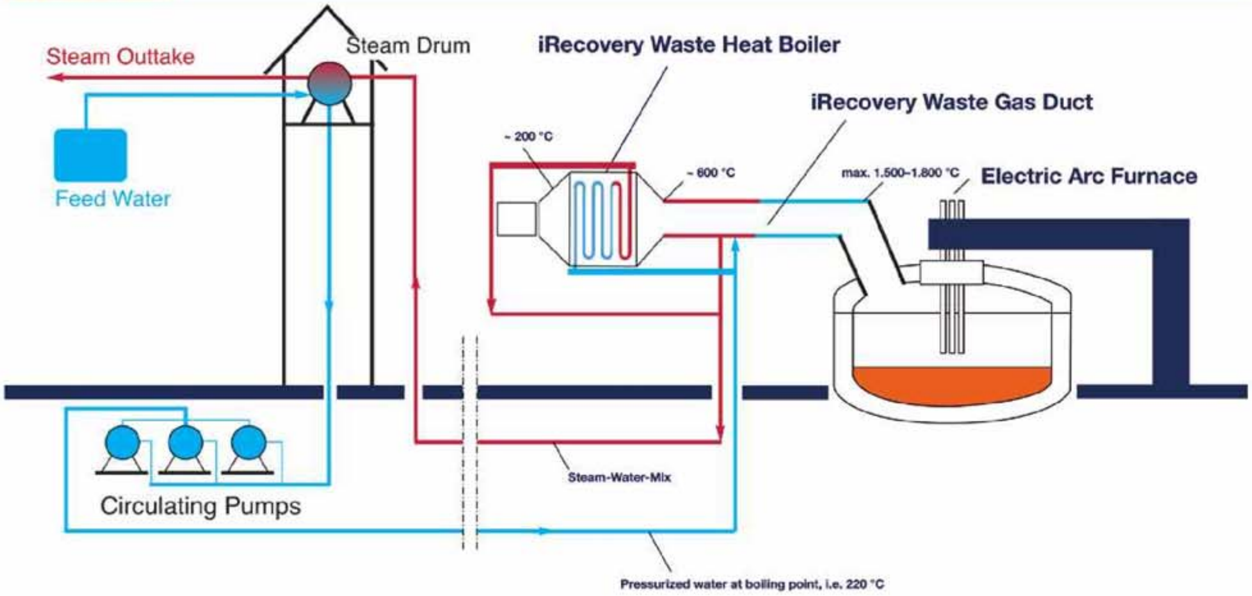
$\dot{G}_d$ = Weightflow of Steam

Comparison of cooling capacity between water and evaporation.

Heat recovery is the main driver behind today's growing importance of iRecovery technology used on other types of furnaces, such as electric arc furnaces. iRecovery benefits for the EAF other than heat recovery are viewed as secondary advantages.

iRecovery waste gas ducts work with radiation heat transfer, which is efficient down to approximately 600°C. Below this temperature, heat transfer by convection becomes more effective. In other words, a waste heat boiler must be used to recover the energy between around 600°C and a filter inlet temperature of 180–250°C. Due to the extremely high dust load of EAF waste gas, the design of the waste heat boiler must be planned very carefully; solutions for similar situations can be found at waste

Figure 5



Scheme of two-stage heat recovery for an EAF.

incinerators. Figure 5 provides a schematic illustration of the two stages of EAF heat recovery.

The Georgsmarienhütte EAF Heat Recovery Project

Challenges — Georgsmarienhütte GmbH (GMH) operates a 140 t/h DC EAF and is located in Georgsmarienhütte, Germany. A unique feature of this EAF was the existing duct cooling system: When GMH switched from blast furnace steel production to EAF steel production in 1994, some of the main parts of the cooling system from the former blast furnace were kept in place and used for the new EAF. Since the former BOF was equipped with ECS, the newly built EAF began operating using a used ECS from the 1980s. Only the first section of the ECS duct had been upgraded in the 1990s to use conventional cold water cooling. However, the steam produced was not used for any purpose due to its semi-continuous production; a boiler house was used to supply steam to the vacuum degassing system and other minor steam consumers in the plant.

In 2007, GMH decided to replace the cooling system after almost 25 years of continuous operation, including the time it was used for the BOF. The cooling system had deteriorated considerably.

At the beginning there was a lot of excess steam: an average production of 20 t/h of steam compared to an average demand of 7 t/h for vacuum degassing. This is not atypical; typically, a VOD consumes only a third of the steam that can be obtained from the corresponding EAF.

Although the project was already economically profitable with this value, the question remained how to use the remaining steam. In the past year, GMH has made additional steps to increase the steam demand:

- The iRecovery is now connected to the plant heating network, which consumes (depending on temperatures) 4–7.5 t/h during winter.
- 3 t/h steam are sold to a nearby air separation plant.
- 2 t/h steam are used for feed water preheating and keeping the boiler house in a hot standby mode.

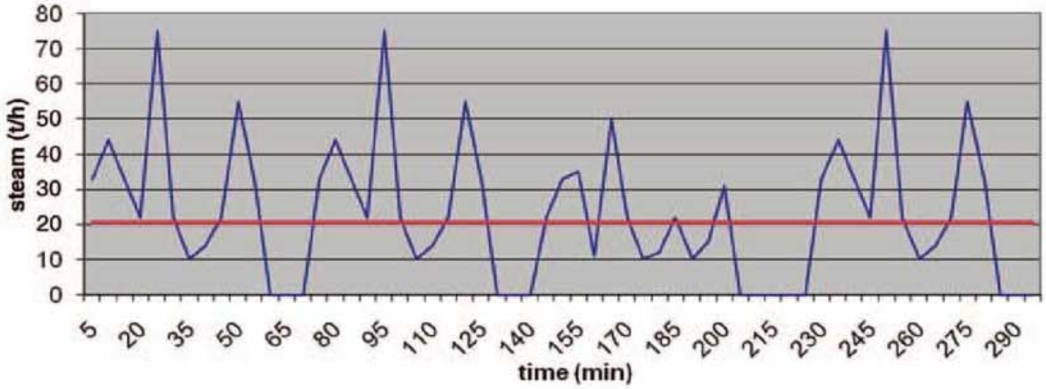
In the wintertime, most of the steam is consumed; during summer, there are still approximately 8 t/h excess steam, which is also not atypical. This, combined with a survey of more potential for heat recovery, is the basis on which to evaluate the possibility of power generation.

One main challenge was to smooth out the steam output and efficiently handle the energy peaks. Figure 6 shows a simplified timeline for steam production during four EAF heats with a different melt type during the third cycle. The short time peaks of 75 t/h are more than three times the average steam production of 20 t/h.

Usually, energy peaks are reduced in the waste heat recovery process by releasing some energy. However, a cooling system is being used at GMH, and each energy peak must be transformed reliably in the form of steam.

The normal EAF operating process creates gaps of 10–20 minutes power-off time, which leads to practically no steam production. The vacuum degassing system is the meltshop's main steam consumer and operates in its own batch mode asynchronous to the EAF. Additionally, the vacuum degassing system follows the EAF on a one-cycle delay; when the EAF shuts down, there is one EAF

Figure 6



Simplified timeline for EAF steam production.

tap waiting for the vacuum degasser. GMH required a guarantee of enough steam for this situation.

This requirement was achieved by a couple of design elements:

- The whole iRecovery was designed slightly bigger than required for cooling purposes. Therefore, the additional amount of water had an excess stored energy capacity.
- Two Ruth buffers were built into the system. Ruth buffers are large pressure vessels that store energy in hot water, converting the water to steam when the pressure drops.
- Sliding pressure between 13 bar and 20 bar.[4] During the EAF power-on time, the pressure rises with the effect that a part of the absorbed energy heats the water that would evaporate at the lower temperature. During the power-off time, the pressure will sink, leading to evaporation, although no new energy is brought into the system.
- Variable temperature of feed water. The typical feed water temperature for boiler systems is 105°C. In the GMH system, the temperature moves between 105°C and 159°C during the peaks of the power-on time. Energy is used to heat the feed water, thus leading to less energy required for evaporating the feed water in the steam drum during lower energy output of the EAF.

Table 1

Main Operating Numbers

Plant type	iRecovery waste gas duct for EAF 140 t/h
Project start	October 2007
Commissioning	January 2009
Maximum steam production	75 t/h
Average steam production	20 t/h
Steam parameters	Saturated steam, sliding pressure 13–20 bar
Steam buffer capacity	8 t
Main steam consumer	VOD, Ø 7 t/h

As a result of these actions, 8 t of steam is buffered at the end of each melt.

Facts and Figures — Table 1 presents an overview of the main operating numbers of the project.

Power Generation as Future Perspective — The boiler house at GMH has reduced its consumption of natural gas for the vacuum degassing to almost zero, resulting in economical success of the project for GMH.

Initially, an average of 13 t/h steam seems feasible for power generation. However, a list of typical factors exist at GMH which are common for power generation from waste heat in steel plants in general:

- The amount of available steam fluctuates (as discussed earlier).
- The demand for process steam is the main priority; the use of process steam is more economical than power generation and activation of the boiler house for process steam. This leads to a nearly unpredictable availability of the excess steam, while steam turbines need constant operation to guarantee their efficiency.
- An EAF shuts down more frequently, compared to regular power stations, plants for petrochemical processes and waste incinerators. Standard power-generation steam turbines require a lot of energy for starting and stopping.
- Another important point is that steam can be buffered (as already discussed), but *superheated* steam can't be buffered. Efficient power-generation steam turbines require superheated steam; this means an external superheater would be necessary for EAF power-off periods. The superheater would have to be powered by either gas, oil or coal, which is an additional cost.

When searching for a solution to these problems, Organic Rankine Cycle (ORC) turbines are an interesting alternative. The organic working fluid has a lower energy density with relatively big mass flows, leading to a much lower rpm value; this leads to a relatively simple system design with an excellent partial load factor. The steam is not led through the turbine but transfers its energy to the ORC fluid via a heat exchanger; therefore, no superheated steam is required.

The nominal efficiency of an ORC turbine is lower than the nominal efficiency of a steam turbine with the same capacity. Due to its better partial load factor, the effective efficiency at the discussed operation environment is at least equal to a steam turbine. This, combined with the automated start-stop procedure and the nearly unmanned operation, makes ORC turbines a highly interesting option for all scenarios with noteworthy amounts of excess waste heat.

References

1. Doug Zuliani, Vittorio Scipolo and Carsten Born, "Opportunities to Reduce Operating Costs, Increase Productivity and Lower GHG Emissions in Electric and Oxygen Steelmaking," *Stahl und Eisen*, Vol. 129 (2009), No. 9, S10–29.

2. Doug Zuliani, Vittorio Scipolo and Joe Maiolo, "Opportunities for Increasing Productivity and Lowering Operating Costs While Reducing GHG Emissions in Steelmaking," *AISTech 2010 Conference Proceedings*, Vol. I, p. 61.

3. R. Granderath, "Intelligente Abwärmenutzung als Teil jedes Feuerungskonzeptes, " *Gaswärme International 5-2009*.

4. In this special case, the existing steam network didn't allow going above 20 bar. Generally speaking, this is a low value. ◆

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DID YOU KNOW?

Stainless, Specialty Imports Finish 2010 Nearly 70% Above 2009

Total stainless imports reached **662,695** tons in year-to-date (YTD) December 2010, a 69.6% increase compared to the comparable year-ago period, according to the latest report from the Specialty Steel Industry of North America (SSINA). Total specialty imports (comprising stainless steel, alloy tool steel and electrical steel) reached 842,055 tons through the same period, a 70.4% increase compared to the comparable year-ago period.

Imports increased 170.1% between July–December 2009 and July–December 2010. The largest exporting countries were Germany and Italy.

Data included in the SSINA report reflect U.S. consumption, imports and import penetration for YTD December 2010 compared to the same 2009 12-month period for major specialty steel product lines, as well as for total stainless steel and total specialty steel.

YTD December 2010 **stainless steel sheet/strip** imports were 387,564 tons, a 76.4% increase compared to YTD December 2009. U.S. consumption was 1,250,105 tons through the same period, a 29.6% increase, while 12-month import penetration was 31.0%, an 8.2% increase from 2009.

YTD December 2010 **stainless steel plate** imports were 97,414 tons, a 92.1% increase compared to YTD December 2009. U.S. consumption was 258,881 tons through the same period, a 44.0% increase, while 12-month import penetration was 37.6%, a 9.4% increase from 2009.

YTD December 2010 **stainless steel bar** imports were 108,621 tons, a 46.4% increase compared to YTD December 2009. U.S. consumption was 218,319 tons through the same period, a 48.9% increase, while 12-month import penetration was 49.8%, a 0.8% decrease from 2009.

YTD December 2010 **stainless steel rod** imports were 24,306 tons, a 68.4% increase compared to YTD December 2009. U.S. consumption was 65,391 tons through the same period, a 78.0% increase, while 12-month import penetration was 37.2%, a 2.1% decrease from 2009.

YTD December 2010 **stainless steel wire** imports were 44,790 tons, a 41.0% increase compared to YTD December 2009. U.S. consumption was 57,587 tons through the same period, a 36.2% increase, while 12-month import penetration was 77.8%, a 2.6% increase from 2009.

Through YTD December 2010, imports of ***total stainless steel*** (comprising the foregoing product lines) were 662,695 tons, a 69.6% increase compared to YTD December 2009. U.S. consumption was 1,850,283 tons through the same period, a 35.0% increase, while 12-month import penetration was 35.8%, a 7.3% increase from 2009.

YTD December 2010 **alloy tool steel** imports were 85,046 tons, a 125.9% increase compared to YTD December 2009; U.S. consumption and import penetration were not calculable.

YTD December 2010 **electrical steel imports** were 94,314 tons, a 43.7% increase compared to YTD December 2009. U.S. consumption was 196,549 tons through the same period, a 1.0% decrease from YTD December 2009, while 12-month import penetration was 48.0%, a 14.9% increase from 2009.

Through YTD December 2010, imports of ***total specialty steel*** (comprising stainless steel, alloy tool steel and electrical steel) were 842,055 tons, a 70.4% increase compared to YTD December 2009. U.S. consumption was 2,100,227 tons through the same period, a 31.9% increase, while 12-month import penetration was 40.1%, a 9.1% increase from 2009.