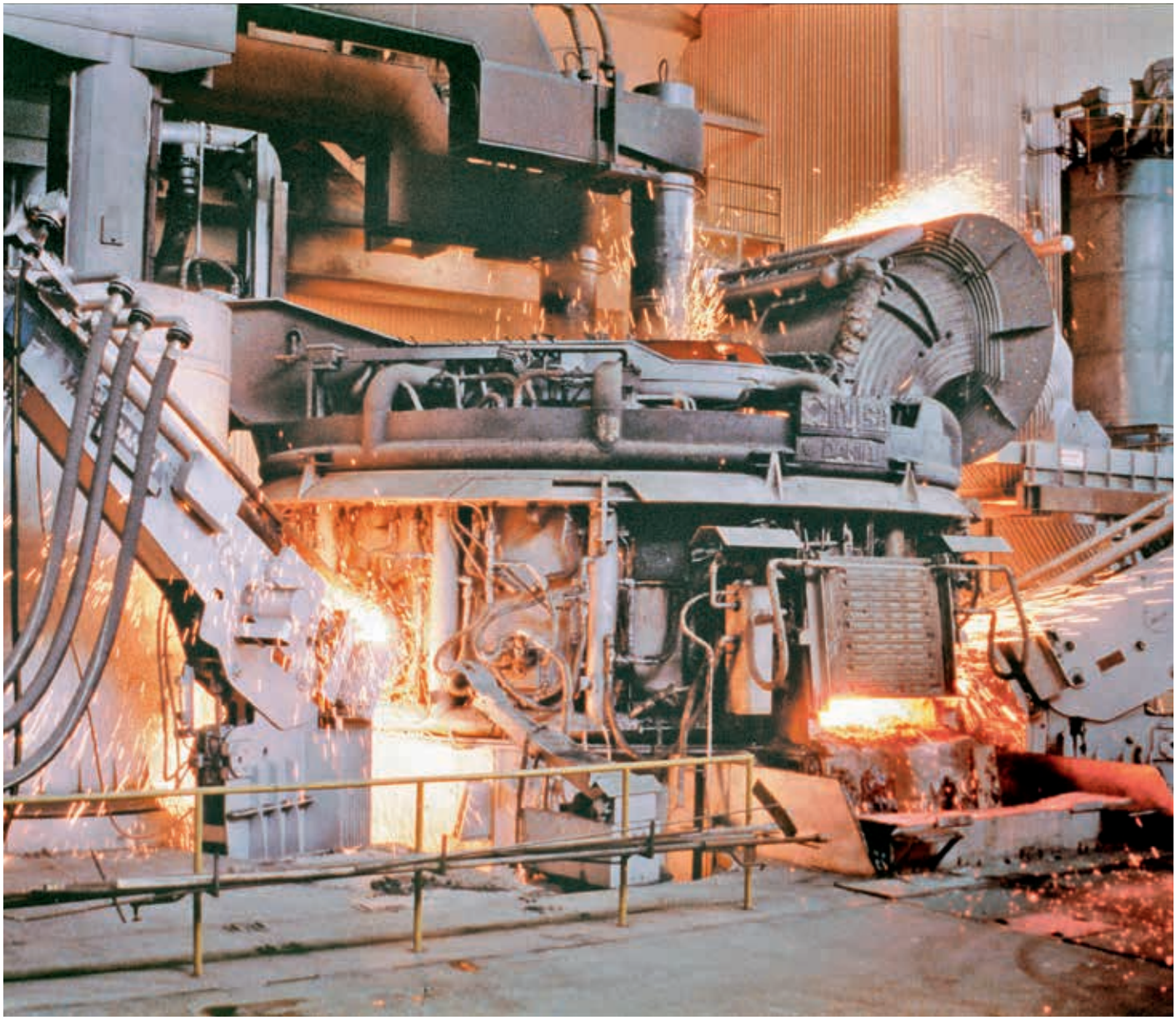


Causing a stir

ArcSave® increases productivity and lowers costs in electric arc furnaces

LIDONG TENG, AARON JONES, MICHAEL MEADOR, HELMUT HACKL – ArcSave® is a new generation of ABB electromagnetic stirrer (EMS) for electric arc furnaces (EAFs) that helps to improve safety, increase productivity and reduce costs. The first ArcSave system was installed in 2014 on a 90 t arc furnace. The hot test results show that it has stabilized the arcs and enhanced the heat and mass transfer in the arc furnace process. This results in a faster scrap melting rate, a lowering of the slag superheat during arcing, a more homogenous melt bath, a higher decarburization rate and a higher free opening frequency of the eccentric bottom tapping (EBT). ArcSave has also reduced the tapping temperature and tapping oxygen in the steel, which brings a higher scrap yield and saves ferroalloy consumption in the downstream ladle furnace operation. The lower energy consumption, short tap-to-tap time and consistent furnace operation greatly increase the productivity and operation safety.

ABB has been committed to the development of new electromagnetic products to improve quality, productivity and safety in the steel business over 70 years.

ABB has been committed to the development of new electromagnetic products to improve quality, productivity and safety in the steel business over 70 years. The first electromagnetic stirrer for electrical arc furnaces (EAF-EMS) was delivered in 1947 to Uddeholms AB in Sweden and since then more than 150 units have been installed worldwide. Recently, a new generation of EAF-EMS – ArcSave – has been developed by ABB to fulfill the requirement for a stronger stirring power in the EAF process for both plain carbon and high-alloyed steel production.

The main difference ArcSave makes to the EAF is the intensity of convection in the melt bath.

In July 2014, the installation and commissioning of the first ArcSave was completed on a 90 t AC EAF at Steel Dynamics, Inc. (SDI) in Roanoke, United States. SDI is a company with a tradition of improvement using the best technology available. In order to remain competitive, SDI believes that every ton of steel has to be produced as efficiently and safely as possible. For this reason, SDI entered into the project with ABB to install ArcSave on the EAF.

Stirring principles

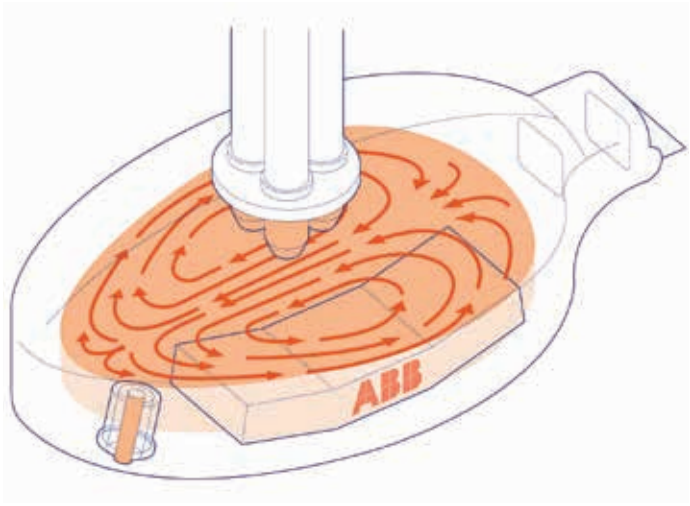
The ArcSave stirrer was placed under a nonmagnetic (austenitic stainless steel) steel plate bottom → 1a. Low-frequency electric current in the stirrer windings generates a traveling magnetic field that penetrates the furnace bottom and generates physical forces in the molten steel → 1b. Stirring can be customized to match the needs of different EAF process steps such as scrap heating, homogenization, melting of alloys, decarburization (reduction of carbon content), deslagging and tapping.

The designed average melt velocity induced is around 0.5 m/s. → 2 shows a simulated example of the horizontal cross-section of the mean flow pattern for the horizontal plane about 25 cm below the melt surface in a 150 t EBT tapping EAF. It can be seen that the flow is slightly asymmetric. However, com-

Title picture
Electromagnetic stirrers are essential for the efficient operation of arc furnaces. ABB's new generation of stirrer – ArcSave – has been in operation for a year in a steelworks – what are the results so far?

1 Arc furnace at the SDI site

1a Showing the ABB stirrer mounted underneath



1b Furnace top view schematic showing the stirrer underneath and flow patterns

pared with the more localized bottom gas stirring via porous plugs, the EMS creates a global circulation in the arc furnace bath and thereby provides a more efficient mixing of the complete bath melt. This mixing effect accelerates the homogenization of the temperature and chemical composition of the steel, as well as that of the chemical reactions between steel and slag.

The complete ArcSave system comprises the electromagnetic stirrer, a frequency converter, a transformer and a water station → 3. It has the following features:

– No physical contact with the steel melt
– Normal refractory lining can be used
– The stirring direction can be reversed by changing the current direction
– Very little maintenance is required

The hot test results from SDI show significant process benefits have been achieved due to the improved kinetic conditions for heat and mass transfer with ArcSave. It is worthwhile to examine these benefits in detail.

Arc heating efficiency and energy saving

Due to the homogenization, the temperature gradient in the melt with EMS is reduced to only 25 percent of what it was before. This means that the EMS reduces the melt surface superheat and the heat from the arc zone is quickly transmitted to the melt bulk. The decrease in surface superheat will reduce heat losses to the furnace wall and roof, and thereby reduce electricity consumption. Simultaneously, the stirring will increase the scrap melting rate and decarburization rate and therefore save furnace process time, which also reduces the heat loss. In the ArcSave test at SDI, the total energy saving includes the chemical energy decrease from the lowered consumption of natural gas, carbon and oxygen, and the reduction of FeO in the slag. The total energy saving is about 14 kWh/t, which is equivalent to 4 percent of the total. Because of the higher power input efficiency and higher heating efficiency, ArcSave reduces the power-on time by around 5 percent.

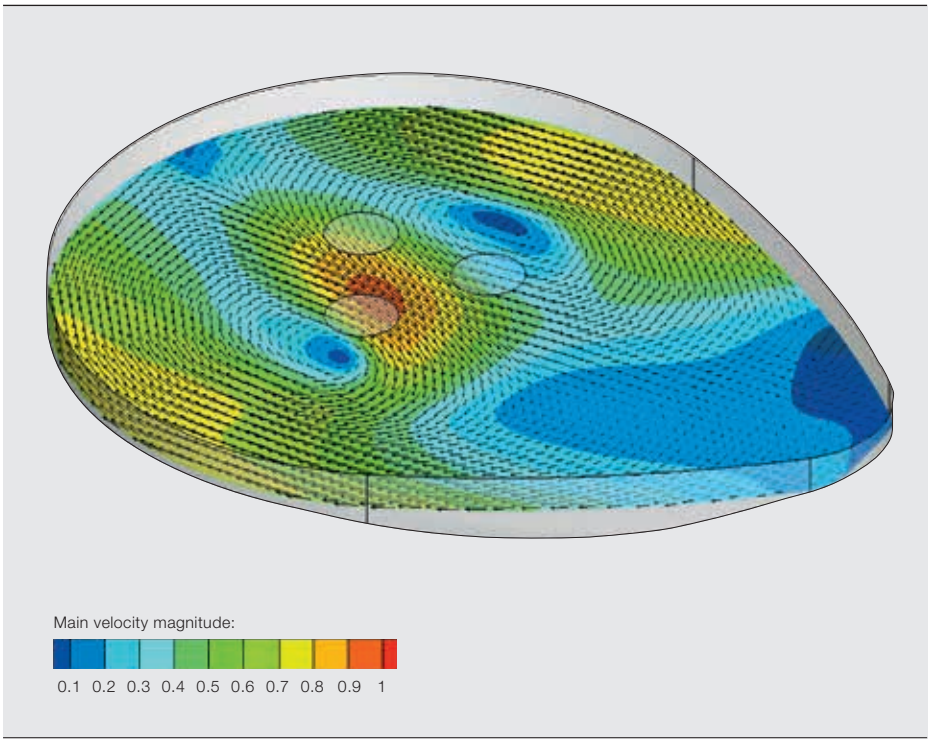
> At SDI, the total energy saving is about 14 kWh/t, which is equivalent to 4 percent of electrical energy saving.

Scrap melting

The main difference ArcSave makes to the EAF is the intensity of convection in the melt bath. The forced convection in-

EAF bath stirring can push the carbon-oxygen reaction closer to the equilibrium value. It is also seen that the Fe_2O_3 content in the slag is reduced by 2.5 percent.

2 Melt flow pattern created by electromagnetic stirring [1]



duced by electromagnetic stirring will enhance the melting of larger scrap pieces and bundles, contribute to a homogenous temperature and composition distribution, and make scrap stratification less significant. Without stirring there is only the very low convection caused by the difference of densities.

Stirring also reduced electrode stabilization time (by some 10 percent) after bucket charging at SDI → 4a. In addition, it has been found that the EMS stabilized the arc by melting big scrap bundles faster and by reducing scrap caves for a three-bucket melting period is reduced by about 50 percent with ArcSave → 4b. The reduced current swings result in higher power input and, therefore, increased productivity.

A homogenous temperature distribution in the melt bath also gives a hot EBT and smooth tapping without delays and makes it possible to obtain an exact tapping temperature for the different steel grades.

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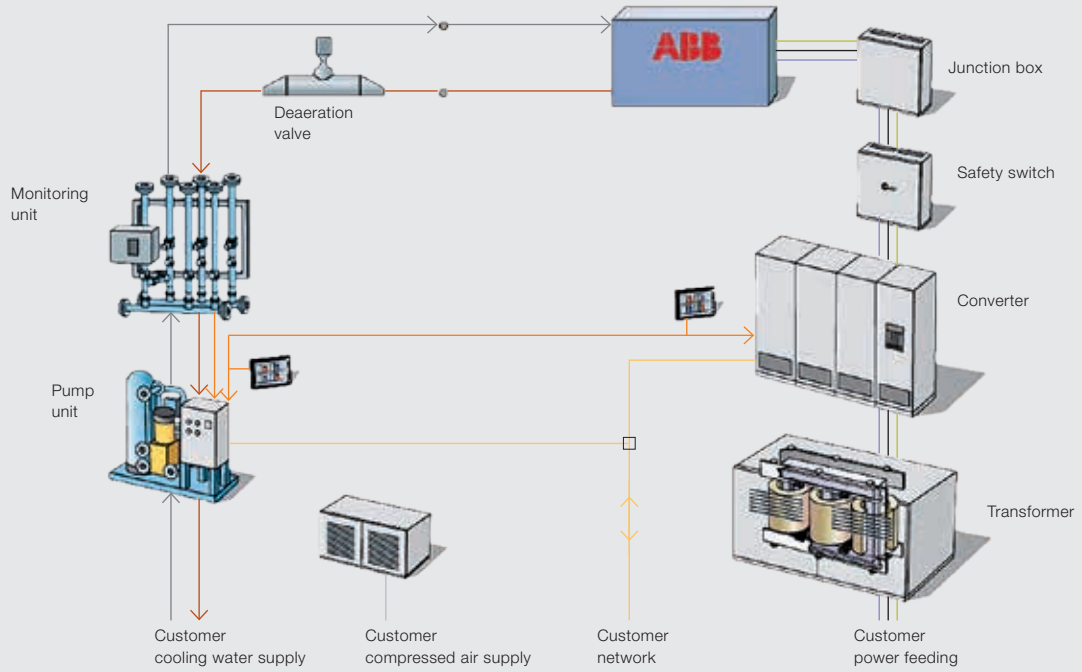
Decarburization and O_2 yield

After the scrap is completely molten, the refining period starts. This mainly involves decarburization by injecting oxygen. This injection creates a highly turbulent reaction zone where carbon from the bulk metal can react with oxygen or FeO. If the steel carbon content is high, the decarburization reaction rate is determined by the rate of oxygen supply. However, if it is lower than a certain level, the rate of carbon transport to the reaction zone would consequently normally be lower, as

ins (surges in scrap movement in the melt that disturb process continuity). The standard deviation of current chang-

3 System overview of ArcSave



would then be the decarburization reaction rate. But ArcSave facilitates carbon mass transfer to the reaction zone and can double both these rates and reduce oxygen consumption – by 5 percent at SDI.

Steel deoxidation

It is known that EAF bath stirring can push the carbon-oxygen reaction closer to the equilibrium value [2]. This has been proven by the test results from SDI, where the tap oxygen was reduced from 618 ppm to 504 ppm, with a slight tap carbon increase. These results indicate that ArcSave makes it possible to reach lower carbon and oxygen levels at the same time. It is also seen that the Fe_2O_3 content in the slag is reduced by 2.5 percent with ArcSave. This, according to the materials balance calculation, gives a 0.2 percent steel yield increase, which reduces scrap and conversion cost.

> ArcSave facilitates carbon mass transfer to the reaction zone and can double the decarburization reaction rate, and reduce oxygen consumption.

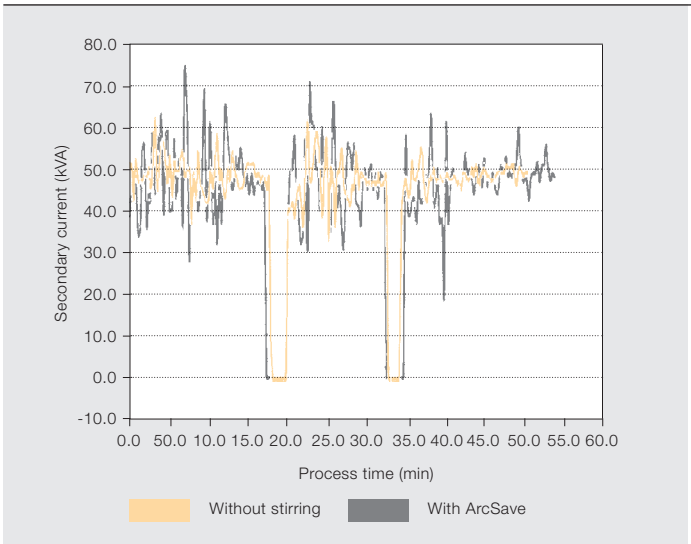
Steel yield

Besides the FeO reduction in slag, another big contribution to the steel yield increase is the reduction of metallic scraps in the dumped slag – it is found that the scrap in the recycled slags is reduced by about 40 percent. This gives some 0.6 percent steel yield increase in the EAF. The reason for the reduction of steel droplets in the slag with stirring is under investigation, but the intensive slag/metal interaction and the more homogeneous slag with ArcSave are possible causes.

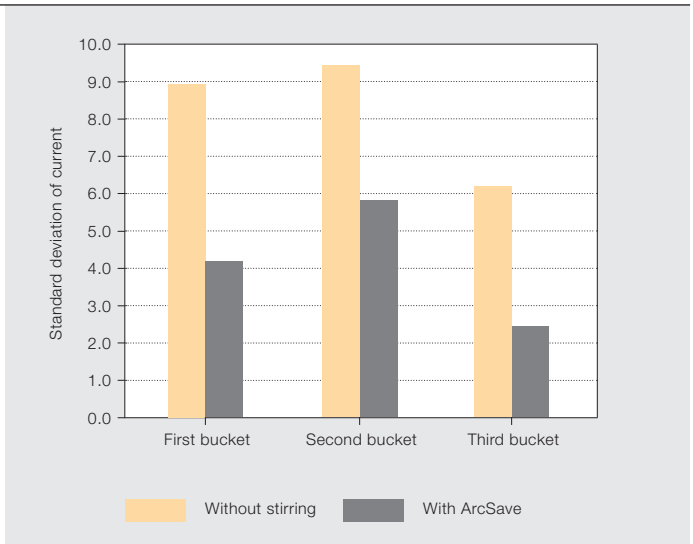
Yet another contribution to the steel yield increase is the metallic yield increase due to lower tap oxygen in the steel.

Vortex formation and slag carryover

Theoretically, an EBT hole should result in slag-free tapping. However, slag carryover is always evident in the tapping ladle, the main reason being vortices in the later stage of the tapping. Water modeling results show that vortex formation can be suppressed by the stirring force from ArcSave. The slag thickness in the tap ladle was measured by the aluminium-



4a Comparison of the electrode secondary current without stirring and with ArcSave. The current swings were reduced using ArcSave.



4b Standard deviation of current change for a three-bucket melting period. It is reduced by about 50 percent with ArcSave.

steel pole method. The results show that the carryover slag amount is reduced by 50 percent with ArcSave.

Furnace refractory

Six months of hot test results at SDI show that stirring with ArcSave reduced furnace refractory repairs by some 15 percent. The superheat reduction is probably the main contributor to this since the most critical refractory damage is in the slag-line area. The reduction of the FeO in the slag and the oxygen in the steel also helps. A third contribution to reduced refractory wear is the lowered tap temperature – down by 14 °C without affecting the ladle furnace arrival temperature → 5.

Process reliability and safety

Safety and reliability are always of great importance for EAF operation. The positive effects of ArcSave on the EAF process discussed above will have a significant impact on improving process reliability and safety. ArcSave decreases the tap temperature and reduces the superheat in the hotspots area, and increases the EBT free opening ratio, thereby increasing furnace safety.

The following process disturbances could be decreased or eliminated with the aid of ArcSave:

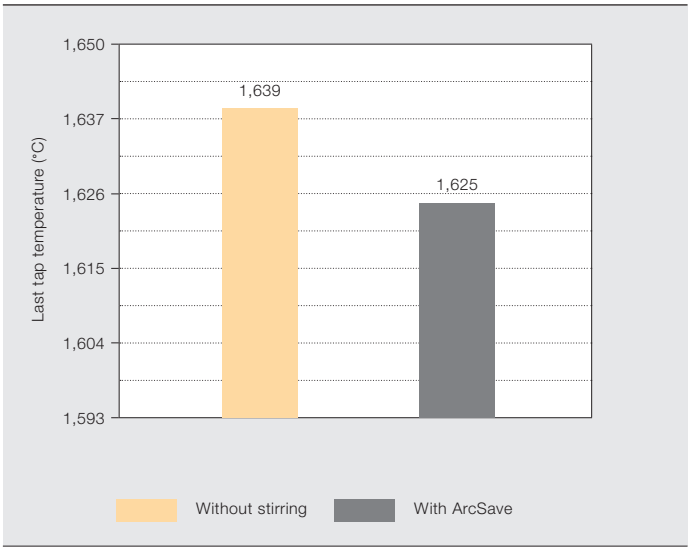
- Scrap cave-ins
- Residual non-molten big scrap or pig iron
- Carbon boiling-out (sudden boiling phenomena in the melt) – a significant topic if charging with pig iron
- Off-target tapping weight and temperature
- Low EBT opening ratio → 6

Safer, quicker and cheaper steelmaking

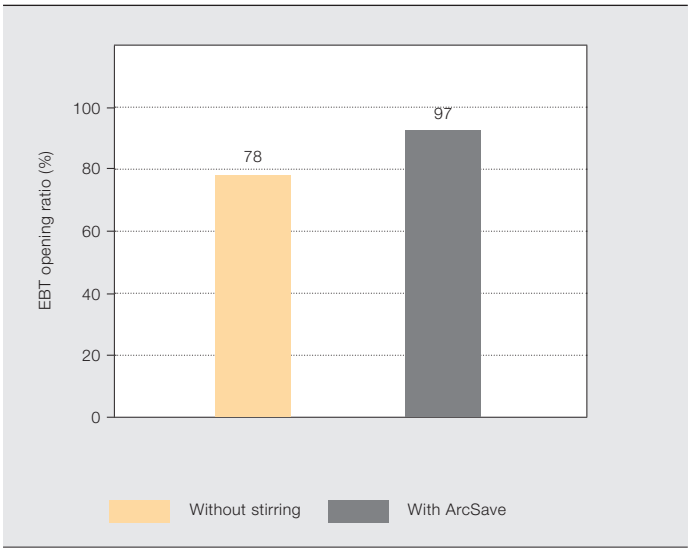
The review of results from the SDI plant has shown that ArcSave has produced multiple benefits for the steelmaker → 7. ArcSave helps the melting process make liquid steel more safely, quicker and with lower cost. ArcSave improves the heat and mass transfer of the EAF process; speeds up the scrap meltdown; accelerates the homogenization of the temperature and chemical composition of the steel bath; forces the metal/slag reactions closer to the equilibrium state; increases the decarburization rate; and improves the operation safety, reliability, and productivity. The

The review of results from the SDI plant has shown that ArcSave has produced multiple benefits for the steelmaker.

5 Change of tap temperature after ArcSave



6 Change of EBT opening frequency after ArcSave. High EBT opening frequency is beneficial for operation safety and productivity.



7 Process benefits summary

Process items	Benefits
Total energy	- 3~5%
Electrode	- 4~6%
Power on time	- 4~6%
Oxygen	- 5~8%
Deoxidants	-10~15%
Steel yield	+ 0.5~1.0%
Productivity	+4~7%

Six months of hot test results at SDI show that stirring with ArcSave reduced furnace refractory repairs by some 15 percent.

impact of ArcSave will be particularly significant in those EAFs requiring a productivity increase.

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