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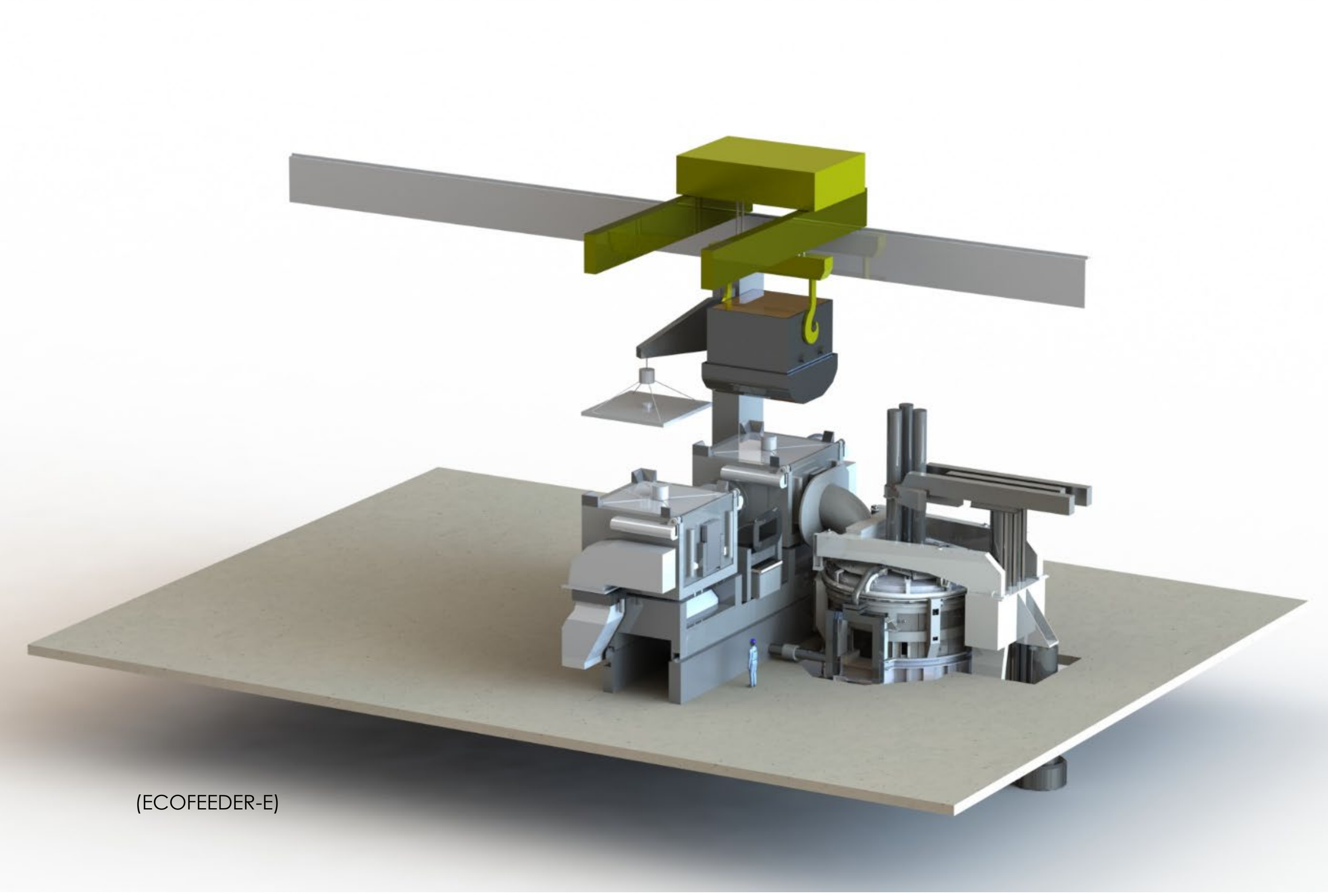

(ECOFEEDER-E)

Customer information

As we all know, there are many roads leading to Rome. In this sense, we ask you to put aside the prejudices about scrap preheating and to openly address this issue. Without doubt, scrap preheating can bring maximum profit and still meet environmental requirements. With this in mind, we ask you to read the following article.

Clesid Lorber SAS
53, rue Sibert
F-42400 Saint Chamond
clesid.com | +33 477 5742 97

eco-e AG
Kantonsstrasse 155a
CH-8807 Freienbach
+41 55 280 60 66 | eco-eag.com

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Preface

The following explanations, suggestions and comments are seen in the optic of the use of a scrap and DRI preheating installation with the aim to maximise the efficiency of energy input and to minimise the disturbing effects and impact to the environment, man, and atmosphere.

1 Possibilities of Energy Saving

There are various areas of energy savings possible, some are applicable without big modifications, others are linked to a major change of the installation. Some became obsolete because further findings contradicted them, others have not found maturity yet, so for example the scrap preheating.

1.1 Burn-off of Pollutions

The burn-off of pollutants and reactions is commonly known, and the issue cannot be solved reasonably, whether in open roof charging nor in single-chamber or coherent-chamber shaft furnaces. As soon as cold scrap is loaded into a container where the reigning heat is capable to ignite the evaporating pollutants the containing energy is lost, respectively heat up the surrounding air or the off-gas stream.
The possible energy saving by controlling the burn-off of the pollutants can be up to about 50kWh/t scrap.

1.2 Preheating

1.2.1 DRI

Typical ranges of DRI chemistry are 90 – 94% iron, whereof about 83-89% metallic iron, and 6-9% of iron oxide, 0.8 to 2.5% carbon, 2.8 – 6% gangue, 0.005-0.09% phosphorous, and 0.001 to 0.03% sulfur. Hot DRI is added to the melt and results in an energy saving of up to 150kWh/t liquid steel. It further gives a benefit to an improved slag foaming.

1.2.2 Scrap

Scrap preheating is offered in various concepts and technologies.

- The oldest technology is the one where scrap is preheated in the transportation basket (**basket preheating**). Here the energy saving is in the order of 30kWh/t scrap.
- Another scrap preheating concept is the **conveyor belt scrap preheating.** The energy saving results are discrete, the dust retention is in the order of 50% which is important. According to the supplier there is no need for reheating the off-gas after the preheating zone (not measurable number of dioxins or furans at the stack due the dilution of the off-gas and the continuous supply of pollutants).
- The scrap preheating in a vertical shaft at side or above the furnace is available from different suppliers and with different brands.
    - The first single chamber **shaft-furnace** for steel scrap has been built by Fuchs. These shaft furnaces were working quite well, however, they had an environmental problem as the pollutants produced, right after charging the scrap into the shaft, were measurable at the chimney.
    - The single-chamber shaft technology was continuously improved, and the environmental problems solved, however, the overall energy savings have dropped massively as the total energy input (between energy delivery and chimney) had to be reduced by the endeavours for the off-gas cleaning.

- Coherent-chamber shaft furnaces and two vessel pre-heating could not solve this problem either.
- Two separated chambers with independent atmospheres can solve this problem. The **ECO-E technology** with a common off-gas suction but with an individual heat transfer in the containers can take advantage of the burn-off of the pollutants. The compounds produced during this burn-off in the first chamber are then incinerated at the second chamber after reheating the off-gas. The assumed additional 50kWh/t energy gain, and the absence of hard cooled elements like fingers near the furnace allow to reduce the direct energy input compared with any other shaft furnace. The benefit of the higher preheating temperature of the scrap reduces the melting time which also reduces the energy input for burners and arcing, thus the power-on time. On the other hand, the power off times is extended by the travelling times for the ECOFEEDER car, and the charging process of the scrap (open roof, tilting the container and closing the roof again). During this charging procedure energy is lost by radiation and convection. This energy loss can be saved with the installation of the ECOFEEDER-M. The ECOFEEDER-M is like ECOFEEDER-S equipped with two independent containers, however, with a closed scrap feeding. That needs a modification of the furnace. For new installations it is advisable to install an ECOFEEDER-M.

1.3 Energy balance and Consumption figures

Consumptions figures characterize the process. All carbon-based consumptions, the oxygen and gas consumptions, the energy input of hot metal, DRI/HBI, the electric energy input and the effect of the preheated scrap are balanced against the energy contained in the hot metal, the slag, the cooling water, the energy loss due to electrical resistance and finally the energy in the off gas.
Important for evaluating an energy balance is the understanding of the system boundary.

Assuming the tightest boundary, we have the following situation:

- Input: Electric energy, chemical energy, material at normal conditions (0°C)
- Output: steel, slag, cooling water, electric losses, and off gas

Let us keep the chemical energy (C, CH_4 and O_2) constant (to keep the off-gas amount constant), steel and slag enthalpy are constant, energy exit by cooling water is constant too – so enthalpy of material and electric energy are variable (electric losses are a function of the electric input, so basically variable too but with a very little influence).
Thus, the higher we preheat the material the less electric energy we need, right?
Assuming an ideal heat exchange from off gas to scrap or DRI we could expect a maximum material temperature of approximately the 900°C (off gas temperature at the 4th hole 1100°C and material temperature 0°C and unlimited time). The scrap preheating, however, is far away of being an ideal heat exchanger. Off-gas temperature measures at existing shaft furnaces have shown a heat transfer to the scrap of 45 kWh/t. We do not know whether this represents the maximum or not. The amount seems ok, maybe modern installations reach 60kWh/t.
Preheating with two separated chambers with different atmospheres, however, allows to get out twice as much. How that?

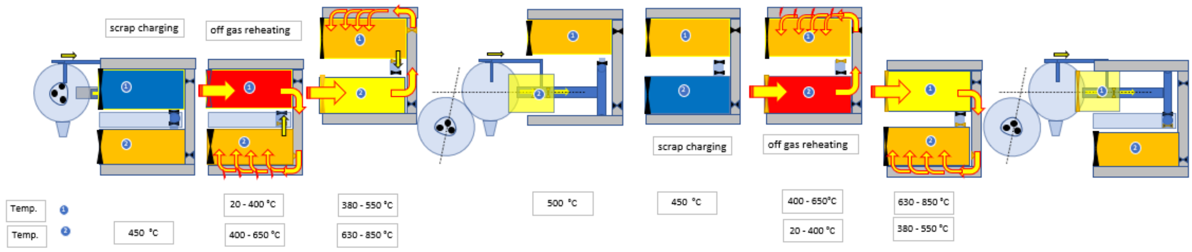


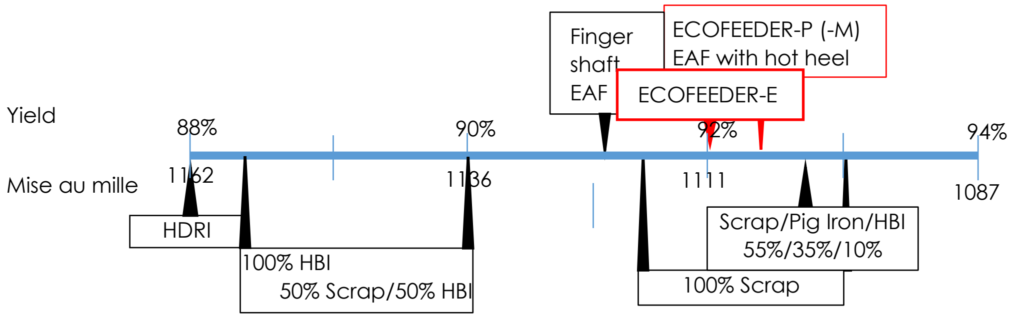
Figure 1 / temperature evolution

With the temperature evolution from 20°C to 400°C and from 380°C to 700°C and finally from 650°C to 850°C the ideal preheating temperature can be reached and by that, the electric energy can be reduced by about 115 kWh/t. A side effect of this procedure is that the burned pollutants in the off gas are cracked when reheated after warming the scrap (20°C to 400°C) and the base elements of the cracked compounds are burned. Another side effect is that the exiting temperature after the two containers is at level of about 600°C which is ideal for DRI preheating.

1.4 Yield

Yield = liquid steel / scrap load; 'mise au mille' = 1000 x scrap load /liquid steel

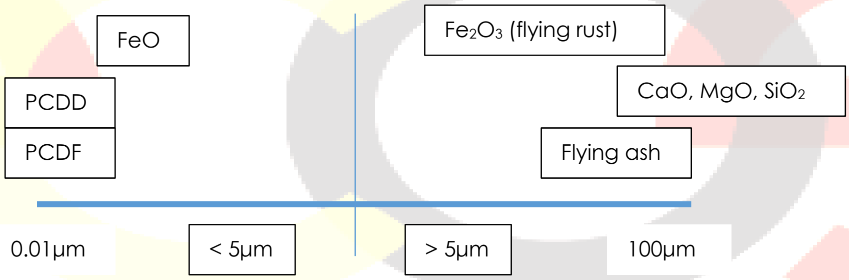
Yield may be influenced by melting at an open arc and by the interaction at the slag-steel interface. The scrap melting in an open arc produces a big number of FeO molecules in the high temperature nucleus. This FeO is emitted and mixes with the off gas, until the electric arc is covered by foaming slag.
Installations with a high share of flat bath operation report an increase in yield of up to 2.5% compared to traditional furnaces and the same scrap qualities.
At installations with shaft furnaces an increase of yield of up to 2% can be observed. This is probably due to the shorter open melting times.
Another reason for higher yields is the existence of a hot heel. With a continuous loading of warmed scrap, a hot heel of about 50% of the tapping capacity seems to be ideal, as the newly added scrap sinks into the liquid bath and a flat bath operation can be maintained. On batch loading the existence of a hot heel may also help, but here the preheating temperature is more important. The hotter the scrap the shorter the melting time, and as a consequence a lower emission of FeO.
One important fact, probably the most important factor for yield differences is the efficiency of oxygen lancing. Lancing into the steel bath produces a high amount of FeO which goes into the slag, lancing into the slag produces dust! So, having an accurate and fine tuneable oxygen lance (see eco-e, 'optical oxygen lance 'the lance with an eye for the bath level') gives probably the highest yield.
Yield can also be positively influenced by adding coarse carbon onto the slag during refining, (FeO in the slag & C (coarse carbon) → Fe and CO by 'slow burning' carbon).



1.5 Dust (particulate matter)

Dust (during open arcing) = FeO (from arcing) and flying Fe_2O_3
Dust (during flat bath operation) = CaO, MgO, SiO_2 and FeO

Dust is produced by the violent expansion of the atmosphere around the arc (ionisation) or by the impact of the jet into the slag surface (kinetic action). The dust produced during the burn-off of the pollutants and reactions is different than the dusts produced in the furnace (here above).
The dust produced during burn-off of the pollutants is a mixture of fine grain dust (mainly Fe_2O_3 (flying rust)) and molecules produced when burning (PCDD/PCDF, NOx, HCL, etc.). At the open furnace, this dust is falling out.
The dust produced during open arcing is also a mixture of fine grain dust (mainly Fe_2O_3 (flying rust)) and FeO as micro dust. This dust is part of the off gas and evacuated through the dedusting system.
The dust produced during flat bath operation is more like sand, however, as it is produced in a closed container which is under slight negative pressure it will be sucked out together with the off gas.
The off-gas amount is a function of the imported gaseous media and the air inlets. The fallout of dust is depending on the local gas speed. The gas speed in vertical shaft systems is constant. Therefore, almost no dust is remaining in the scrap, thus the filtering effect is nil.
The evolution of the gas speed at the ECOFEEDER is different. Here, the cross section of the container is more the 10 time larger than at the fourth hole, thus the gas speed slows down immediately, and the dust can fall out.



1.6 Maintenance and wear material

The two containers are made of reinforced refractory concrete with a steel shell. They are intended to be understood as wear items and shall be replaced after a campaign by newly lined containers. Another wear item is the reheating chamber with the burners.

The production does not have to be stopped for maintenance. The production can continue without any disturbance through the existing off gas duct which is also the emergency position in case of any disturbance with the ECOFEEDER. The automation system also includes fault and error indication and supplies immediate on-screen maintenance advice.

1.7 Adjacent Installations

Combined systems such as exhaust gas cleaning are modified. The primary suction system (EAF) is separated from the building exhaust system (hall roof). Due to the cleaning effect of the horizontal containers, the dust load is reduced by approx. 50%, which leads to lower disposal costs and lower energy costs for the exhaust fan. A new fan is intended for scrap preheating, as a higher suction pressure with lower suction power is required.

2 Production

2.1 Costs

Well. using the available resources are certainly the best way to save costs, and heat is an undeletable resource at the production of steel. Heat is easy to transform into electric energy, only it needs to be available constantly. Fluctuations and instable temperatures as they arise at the electric furnace render the transformation into electric energy almost impossible, unless you use a kind of heat battery – heat exchanger from gas to liquid, tank storage of the hot liquid or steam and then use the steam for the transformation. The efficiency factor of this chain is unfortunately rather poor. Moreover, as the hot and dusty gas is quickly sticking the heat exchanger, there is a constant need for maintenance. Altogether probably not the best solution.

The ECOFEEDER, however, offers both the bread and the butter. As explained above, the energy in the off gas coming from the furnace is used for heating the material at the same time the off gas is partially dedusted. Then, the gas is reheated by the burners (only during warming the cold scrap) or by the 2^{nd} step preheating and leaves the ECOFEEDER at an almost constant temperature of 600°C (fluctuation when moving the containers). By then, this gas is containing only CO_2, some steam (H_2O) and some free oxygen, without toxic or other disturbing compounds, and is almost dust free. Temperature fluctuations can be flattened by addition of ambient air, to low temperatures can be raised by use of the burners. This gas can be used to produce electricity via an ORC process.

The production costs are reduced by the gain of the preheating, respectively by the savings on electric energy input. Further the dust which remains in the containers flows back to the furnace which reduces the addition of slag builders and raises the yield as some of the dust is FeO (see yield here above). Then, consequently, there is less dust going to the dedusting station which lowers the cost for cleaning as there are less filter bags needed in the flow. The cost for the fan energy is reduced as well.

2.2 Time

The hotter the scrap, the shorter the melting time. There is a balance between the time where heat is needed for preheating and time where heat is produced while melting down the scrap, but anyhow this time is massively shorter than time needed to melt cold scrap. This gain can either be used to raise the production or used for operating the furnace at times when energy costs are low.

2.3 Gain

Well, as seen here above, the yield can be considerably increased by two effects, first the reduction of the times with open arcs (boring phase) and second by the back-feeding of the dust settled in the containers. Shorter melting times also result in smaller losses, shorter heat impact to panels, thus less cooling loss per ton.

2.4 Risk

There is no risk when installing an ECOFEEDER on an existing furnace (no revamp needed). The furnace can be operated during the hole erection period. Only the rails, the by-pass off-gas duct and the junction boxes for the electric, and the cable schlepp must be prepared before placing the ECOFEEDER. Foundations for the rails can be made during the normal operation respectively during the usual maintenance periods of the furnace.

2.5 Erection

The ECOFEEDER is workshop assembled with junction boxes on each unit and a cable schlepp connection with the hoses for the media (gas, oxygen, hydraulic, water) and cables for electric power and the communication.

3 Efficiency

The ECOFEEDER is a very efficient installation. Thanks to the integrated re-heating of the off gas after a first use, combining the elimination of the dioxins and furans as well as other disturbing compounds in a new but proven procedure with the preheating of scrap, it also allows to reach high preheating temperatures without holding elements near the furnace, a fact which is certainly most welcome to the maintenance department. The electrical energy input is reduced to the maximum and the installation security is at the level of the traditional and well approved melting procedure.

Furthermore, it allows to continue with the traditional melting as well as it offers the highest possible scrap preheating rate at an affordable investment especially when it comes to an addition to the existing furnace without need for major modification of the same.

4 Scrap

4.1 Triage / Separation

The separation of arising scrap in different categories is standard. The following scrap classes are listed (some classifications (E… according to the European steel scrap specification), numbers according to Institute for Scrap Recycling Industries (IRSI)):

Spec.	Description	Thickness	Dimensions [m]	Bulk density [t/m^3]	Corresponds to
E1	Old thin scrap	<6mm	1.5x0.5x0.5	≥0.5	HMS2
E3	Old thick scrap	≥6mm	1.5x0.5x0.5	≥0.6	HMS1
E2	New thick scrap (production)	≥3mm	1.5x0.5x0.5	≥0.6	
E8	New thin scrap (production)	<3mm	<1.5x0.5x0.5	≥0.4	
E6	New thin baled scrap	<3mm	packaging	≥1.0	
E40	Shredded old scrap	-	95% <0.2; 5% <1	≥0.9	IRSI: 210,211
E5H	Homogenous steel turnings	-	-	≥0.7	IRSI: 219
E5M	Mixed steel turnings	-	-	≥0.7	IRSI: 221
EHRB	Old scrap (rebars, profiles)	-	1.5x0.5x0.5	≥0.5	
EHRM	Old scrap (mech. pieces and components)	-	1.5x0.5x0.5	≥0.6	
E46	Incinerator scrap	-	-	≥0.8	
208	Bundles (baled and sheared)	-	0.9x0.6x0.6	1.1	
209	Dealer bundles	-	0.9x0.6x0.6	0.9	
231	Bonus (plate and structural)	≥6mm	0.9x0.6x0.05	>1.0	236
207	Busheling (new scrap)	-	1.2x0.6x0.012	1.2-1.4	
213	Tin Can bales	-	1.2x0.9x0.6	0.8-0.9	
259	Cast iron (old scrap)	-	0.9x0.4x0.1		263
	DRI	4-20mm	-	1.9 (3.6)	-
	HBI	-	0.1x0.02x0.05	4.8	-

	Pig Iron	-	0.9x0.15x0.15	3.2	-
4	Railroad (plates, connections)	-	0.9x0.45x0.02	2.4	5
27	Railroad (rails)	-	1.2x0.17x0.05	2.4	28,29
2	Railroad (wheels)	-	1.0x0.45x0.15	1.6	3
-	Gipsy scrap	<6mm	-	>0.2	-
-	Gipsy scrap bundles (baled and sheared) *)	<6mm	1.0x0.7x0.7	>0.55	-

*) suitable for ECOFEEDER-P   +) with DRI preheating (ECOFEEDER-M & ECOFEEDER-S)   ++) ECOFEEDER-M & ECOFEEDER

However, the buying department buys the scrap according to different criteria than the melt shop manager would do it. The melt shop manager must live with what is around.

4.2 Packaging

Street scrap, the cheapest scrap available, has usually a density below 0.4t/m³. To use this kind of scrap in scrap preheating it must be bailed. The experience made with a baler shear was very positive. The achieved density was around 0.55t/m³ which is ideal for the ECOFEEDER-P (pusher type). The prepared package size was approx. 1.0x0.7x0.7m.
By compacting and shearing loose material the loading time of the baskets can be reduced, and the filling of baskets can be optimised which results in a higher charge per basket, and this means less baskets and thus less energy loss per heat. Less power off times and shorter tap-to-tap times can result in a higher production or shorter production times.
This is valid for open roof charging and for scrap preheating. Additionally, in scrap preheating the advantage of a more homogenous geometry which is achievable by compacting facilitates the heat transfer.

4.3 Selection

The combination of different scrap qualities and densities according to an elaborated recipe can raise the efficiency and lower the energy input as well. Layers of different densities may accelerate melting in an open roof charging and can intensify the preheating effect in scrap preheating, especially in horizontal preheating.

5 Frequently Asked Questions

Can I use all kind of scrap?

Yes, all kind of scrap can be used, provided they are within the guaranteed limits for weight, length, width, and thickness. However, note that scrap with a higher density needs a longer preheating time and some modifications regarding the container height, i.e., the cover needs maybe to be adjustable.
Example: occurrence: AC EAF 90t tapping weight, furnace diameter 5.8m, P_{on} 31mins, scrap density 0.55t/m³.
The ECOFEEDER was designed based on this information: P_{on} 31mins- 4mins refining = 27 mins / melting time/basket 9mins → 3 baskets with 33t scrap each, (yield 0.91), volume of the scrap +10% = container 66m³, width (according to the furnace max 4.1m) 4.0m, length (according to the location max 4.1m) 4.0m, corresponding height = 4.12m. Now, the scrap supply has changed. New situation: density 0.9t/m³, P_{on} = 36 mins. Melting time/basket 16mins → 2 baskets (yield = 0.91), volume of the scrap 60m³, same width and length, corresponding height = 3.78m, resulting gap: 0.34m

This gap is acceptable, however, if the gap would be bigger, then there are various possibilities: e.g., lift the bottom plate by 30 cm, add a layer on the cover, or modify the supports of the cover to lower it.

What is different compared to the traditional shaft furnace?

The big difference is that the ECOFEEDER has two independent scrap preheating containers with different atmosphere and different temperatures, while the shaft furnace basically has one chimney type containment where the scrap is hold by energy consuming finger or other kind of holding or pushing elements. Another not less important fact is, that the energy which is applied for eliminating the contaminations in the off-gas acts in a separate chamber and goes to the atmosphere while at the ECOFEEDER this energy is going into the scrap for preheating purpose. There are a lot of other differences but those are the major ones.

What do you mean with 'incineration of the toxic compounds?

Scrap, which is covered with paint or a surface coating, or is protected by an oil film, or contains grease, or has a plastic coat, or is isolated by resins is polluted. When heating-up these pollutants are evaporating and form compounds like PCDD known as dioxin or PCDF known as furan and other combinations of hydrogen, chlorine, and carbon. These compounds are cracking at higher temperatures and reformate when cooling down. When such scrap is brought to the furnace, these vapours are heated up to the self igniting point and burn off – usually this is so sudden, that the base elements of the compounds are incinerated. If not, the reformatted compounds are falling out around the furnace.
In a shaft furnace this happens differently. The cold scrap is cooling down the off gas to a level where self ignition is not anymore possible. The compounds are carried on by the off gas and would be measurable at the stack. To avoid that, the off gas must undergo a special treatment, the reheating (cracking) and shock cooling to avoid the reformation.
At the ECOFEEDER basically the same happens as at a shaft furnace: the off gas carries the compounds on. Now, by reheating the off gas the compounds are cracked, and the residence of more than 2 secs in the hot atmosphere incinerates the base elements this is called incineration.

Where is this incineration practiced?

The cement industry has the same problem, they are firing the rotation furnace with garbage and oxy-gas burners. With that they can get the temperature of approx. 1300°C. The off gas remains in the furnace for about 5 secs. The dioxin and furan produced when burning the garbage is cracked the same way and the elements are incinerated during their way through the furnace. Documentations with measurements give proof of this procedure.

How do you prevent the burn-off when charging cold scrap into the hot container?

At the reigning temperatures in the containers (max. about 900°C) the self-igniting temperature of the compounds is not reached. Additionally, it takes a time until the cold scrap reaches the temperature where evaporation of the pollutants starts. By that time, the cover is again on the container and melting has started.

How can the off-gas flow at the container entrance be directed?

There is no need for directing the off-gas stream. The off gas enters the container by the entrance gate, gets through the scrap to the surface and is sucked to the exit of the container. By that way, the off gas loses its energy and volume.

How do you prevent the preheated steel to stick on the ground plate of the container?

Usually, scrap does not melt at the targeted temperatures, but to prevent thin material to stick-on onto the bottom plate in case of occasional melting one could add some calc stone (CaO) before charging the scrap into the container. Occasional melting can occur near the entrance of the off gas and more often with light scrap than with heavy stuff.

Do you need more personal to manage the ECOFEEDER?

No, the automatics are controlling the system, the exit temperatures, pressures, and the oxygen content of the off gas are giving information about the state of the preheating. The operators are controlling the melting process and are giving the order to load the scrap into the furnace.

How intensive is the maintenance?

Basically, there is no special maintenance required. The containers can be exchanged easily and be maintained at the area designated for. The burner chamber is equipped with a manhole and a trap to empty the accumulated dust. In case of an unexpected incident, the ECOFEEDER can be placed in the middle position and production can go on until the damage is repaired.

What are the expectations in respect to the Return-on-Investment ROI?

It is difficult to say without having checked the layout and the requirement, but based on the important gain possible, a ROI below one year seems feasible. It is depending on many factors and assumptions, so that an exact prediction can only be made after close examination.

How long is the realisation time (order to start-up)?

From the date of an order being in force to the start-up we are estimating the following schedule: approximately 3 months for the basic engineering, 6 to 7 months for the detail engineering, 6 months for the fabrication, 4 months for the workshop erection of the ECOFEEDER and 1 month for the commissioning, thus about 21 months from the date when the order is in force to the start-up of the installation.