Use of Soderberg electrode paste in Briquettes

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ABSTRACT

Use of Soderberg in Briquettes in Latin America has been proven in different types of furnaces and alloy production with excelent results. Present paper deals with market data and technical reasons for such performance. Paste softening was also investigated in SiMn and FeMn furnaces resulting in a suggested model by which a layer of partially melted paste is stablished depending on slipping and temperatures inside column. Even in a variety of softening conditions, as expressed by upper paste level descent caused by slipping, electrode performance is good in practical conditions investigated and probably in general ferroalloy production as suggested by market performance. With briquettes electrode performance is much less dependent on softening of paste and turns operation simpler in most cases. Briquette usage development should consider paste feeding automation, tranport logistics, hot air blower devices and product formulation developments for specific operations.

1. INTRODUCTION

Present paper deals with results collected on many years of experience of Carboindustrial S.A., an Elkem Carbon company, with production, development and use of Soderberg Electrode paste in briquettes supplying the Latin American market.

Soderberg Electrode Paste is fed into smelting furnaces column in different forms: cylinders or polygonal blocks and briquettes. Blocks and cylinders are moulded into pieces in medium to large dimensions related with differente electrode sizes. Briquettes are extruded into uniform dimensions (6x12x13 cm for instance) and produced semi-continuously to be used in any type of electrode diameter.

Briquettes used to be associated with smaller diameter electrode columns and low power small furnaces. This situation has been changing in the last years, specially in Latin America´s market, where a strong influence of Japanese technology had taken place with its traditional use of briquette type paste in ferroalloy production.

The advantages of using briquettes are related to lower production cost, transport logistics, possibilities of automation on feeding and to minimizing electrode segregation. New processes like hollow electrode operation and composite electrodes for Si metal production also require the use of paste in briquette form. In order to meet such market demands Carboindustrial had to adapt its production facilities and develop concepts for paste control and use in ferroalloy clients. In next chapters we will look into such developments presenting the general market experience and performance, industrial plant development, transport and feeding system to electrodes and recently developed concepts for electrode formation with briquettes.

2. MARKET OVERVIEW

From an average production of electrode paste of 45000 tons/year in the last 10 years at Carboindustrial, briquette sales have increased in Latin America from 50% ot total production to nearly 80%.

Table 1 shows general performance results in terms of specific paste consumption and average number of ruptures/year according to technical assistance records. Only briquette operating furnaces are listed .

table I

alloy type	#furn.	MVA	KA/el.	el. diam. m	paste cons kg/ton alloy	ruptures av. #/year
FeMn	2	30,0	70	1,35	10	3
	2	9,0	30	0,8	15	3
SiMn	4	9,0	32	0,8	25	4
	2	15,0	50	1,06	22	<1
	10	4,5-6,5	30	0,6	28	2
FeSi75	3	18-30		1,1-1,35	45-50	<1
	4	15,0		1,06	60	<1
	3	24,0		1,25	55	1
	3	18-35		1,1/1,35	45-50	<1
	1	15,0		1,06	60	<1
Si metal	2	19-30		1,0-1,3	90-110	2
SiCa	2	9–11		0,9	80	2
	1	21,0		1,1	60	<1
	1	18,0		0,95	75	1
CaC2	1	50,0		1,35	12	0
	1	12,0		0,8	25	0
	1	10,0		0,7	22	0
FeCr	1	16,0		1,2	25	0
FeNi	2	15,0		1,35	70	2
Cu slag	1	10,0	7	1,3	10	0
phoshate	2	6,0		0,5	5	0
Tin smelt.	1	5,0	24	0,6	10	3
	50					

In order to supply such a diversified demand, different types of paste formulations have been developed: from metal free, pure petcoke based pastes to different mixes of petcoke, anthracite and metalurgical cokes dry aggregates.

3. INDUSTRIAL PLANT CONCEPT

Production of different paste types in industrial scale required a new plant concept to be applied, investing in its flexibilization through:

- Introduction of computer controlled batch type raw materials feeding. Precise dry aggregate particle size control, plasticity and mechanical properties charachteristics have been made possible on industrial scale.

- Briquette production machines had been developed to handle high temperature softening pitches and special paste formulations.

A new stocking yard automated pile conveyor distribution system was also developed in order to store different briquette specifications according to client needs.

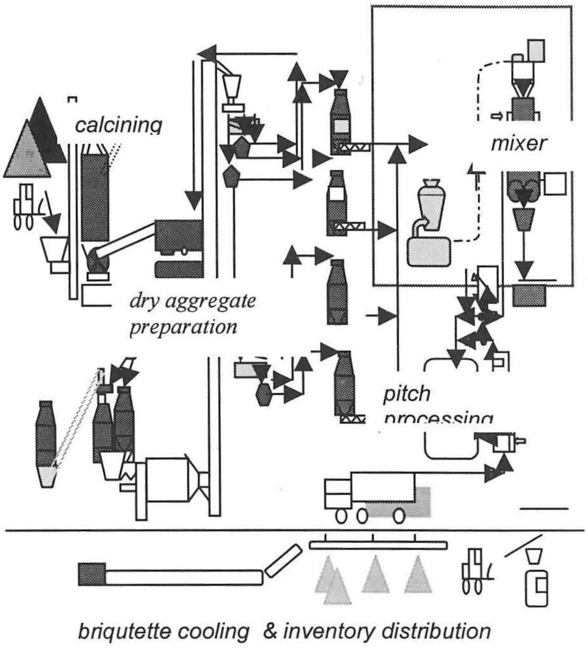

Figure 1- Shows production flux scheme and computer controlled system.

- All dry aggregate processing is conveyed to process silos (fig.1). A computer controlled PLC (fig2) feeds dry aggregate components according to specific formulations , to a pneumatic transport system and, finnally, to a high intensive mixer where pitch is added to form the paste. Briquettes are extruded, cut, cooled in water tank and conveyed to different piles depending on type of paste produced.

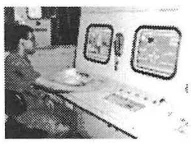

Figure 2 - Computer control room.

- ISO 9002 procedures are applied along all process which is certified by DVN

- ISO 14000 certification has also been achieved in terms of environmental policies and practices.

4. PASTE SUPPLY LOGISTIC

The Brasilian Internal market for briquettes is supplied in bulk transportation by trucks. Transport distances are usually larger than 1000 km. normally in hot climate with temperatures ranging from 25 to 35 -40°C.

Carboindustrial has developed the use of higher softening point paste in order to avoid paste plastic deformation and sticking together of briquettes. It is now a common practice to have the briquette paste in silos in lower or upper furnace levels which in turn are used to fill, with discharge vibrators, feeding recipients into the electrodes.

Use of bigbags for export markets turned out to become more reliable and practical, allowing normal containerization with up to 21 tons per 20´dry box.

Direct feeding of electrode columns with big bags has also been used with success in some plants.

Further automation of briquette feeding can be developed with silos and conveyors depending of each plant characteristics.

5. BRIQUETTES COLUMN OPERATION CRITERIA

Electrode columns operating with blocks or cylinders should mantain a solid paste level able to keep a constant pressure at softening paste level in order to allow for a uniform distribution of paste in the column section and the cooling of paste between fins.

Electrode columns with briquettes do not count with pressure of solid paste as a softening mechanism. On the other hand, briquettes naturally cool down the whole column section forming an homogeneous and low temperature/high viscosity paste volume at the softening paste level which is usually positioned 2 to 3 m. above contact plates. Fig. 4 shows a normal briquette column with indicated main operating levels and defining the high viscosity layer as the volume of paste between 80°C and 100°C isotherms.

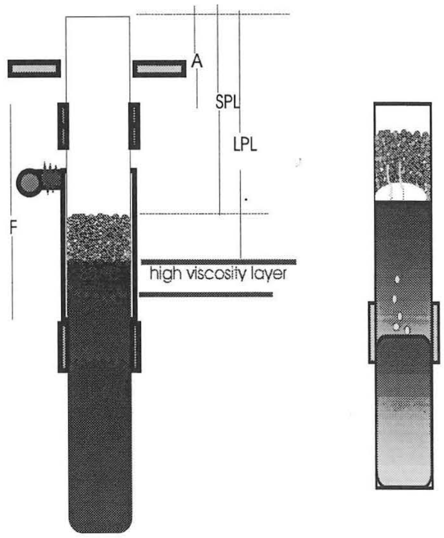

Fig.4 – Normal operating column and bridging.

The position of these isotherms will define how stable is the high viscosity layer. Steeper temperature gradients associated with low liquid paste level would generate unstable high viscosity layer and tendency to segregation with volatiles from baking zone going up inside the column. Blocks and cylinder s columns are more sensitive to such problem. Softening paste level kept at 2–3m through appropiate heating of upper column and regular paste feeding in the electrode column would guarantee a stable high viscosity layer and minimize possibilities for segregation.

Briquettes should be less sensitive to lower liquid paste situations due to its continuous cooling of whole column section.

Main disavantage with briquettes could be the formation of bridges during column operation like in fig.4. Bridging will stop the cooling of liquid paste from new solid material flow. Heating of paste will decrease viscosity of the liquid paste upper layers and migh give rise to the begining of a segregation process if bridging is not destroyed.

6. BRIQUETTE SOFTENING STUDY.

In order to better understand the briquette flow behaviour in the column, measurements were made of the relationship between slipping and upper briquette level descent. Such measuring used a simple device with a steel plate positioned on the upper paste surface attached to a cord whith weights registering the relative movement of the paste surface in relation to the casing as in fig 5.

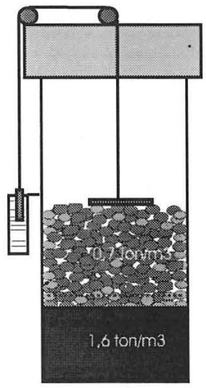

Fig. 5 – measuring device scheme.

Measurements were made during normal furnace operations at Ferroligas Maringá-SP, Brasil in SiMn and FeMn furnaces. Operational results were collected in the period of tests in order to evaluate the effect of flow behaviour with electrode formation and performance.

7. –RESULTS

Collected measurement results are presented and following furnace operation data and typical graphicals were obtained

a) furnace 1

transformer	6,5 MVA
power applied	4MW
el. diameter	800 mm
alloy	FeMn (75%Mn)
current/phase	25 kA
paste consumption	9 kg/m. ton alloy
sp. power cons.	2750 kwh/ m. ton.

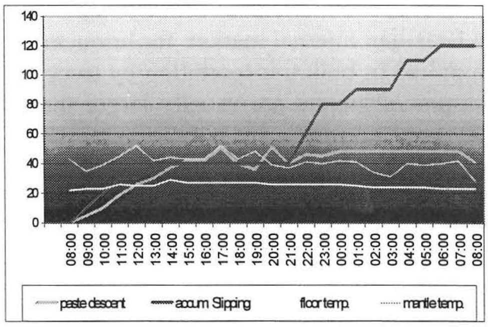

Fig. 6 : Paste descent x slipping furn 1 el. 1 july 9th, paste lowers with mantel temperature levels above 40°C but stabilizes with higher slip increments

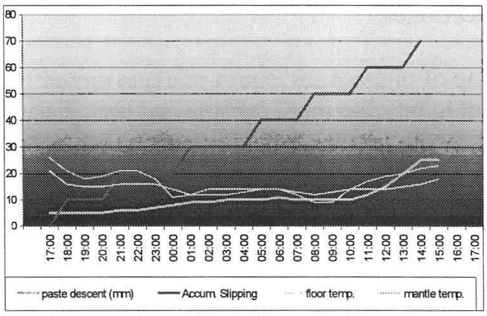

fig. 7 –furn.1/el.1, july, 13 th. paste descent restricted due to low temperature inside column even with high slipping; starts moving as temperatures raises.

b) Furnace 2

transformer	6,5 MVA
power applied	5.0 MW
el. diameter	860 mm
alloy	FeMn (75%Mn)
current/phase	30 kA
paste consumption	11kg/m. ton alloy
sp. power cons.	2850 kwh/ m. ton.

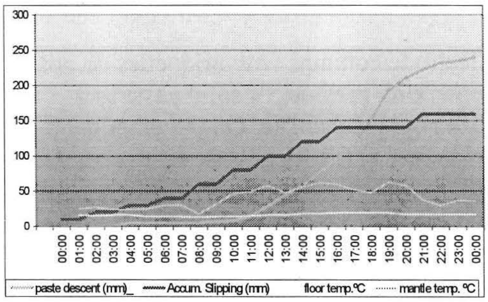

fig.8- furn 2 el.1 18th july-Higher column temperatures promotes enhanced paste descent.

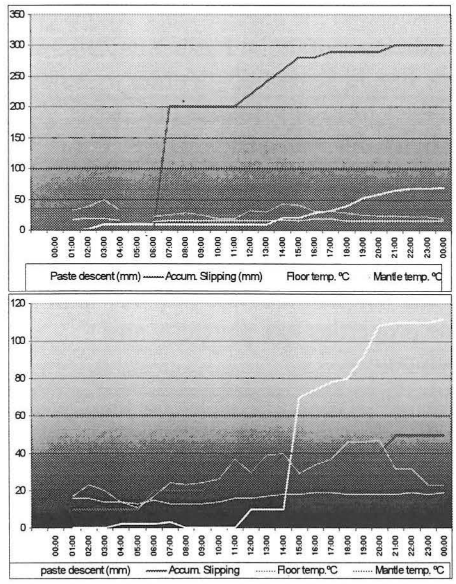

fig.9 –Furn.2 el. 1 20th and 21st, july, high slipping but paste lowers in column only next day when column temperatures are raised with decreased mantle fan air flow

c) Furnace 3

transformer	2,5MVA
power applied	2 MW
el. diameter	500 mm
alloy	FeMn (75%Mn)
current/phase	17 kA
paste consumption	14kg/m. ton alloy
sp. power cons.	2800 kwh/ m. ton.

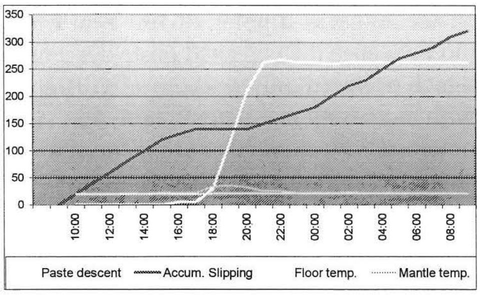

fig 10 –Furn 3 el. 1, august 1st.- Peak hour slight increase in temperatures triggers paste descent

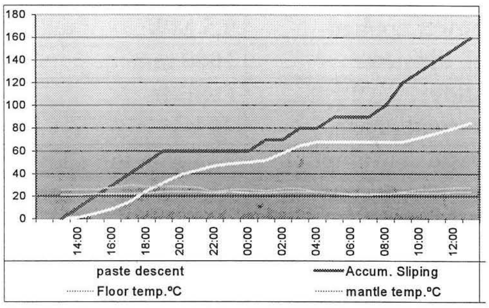

fig 11 –Furn 3, el 3, august 6th . paste descent follows slipping pattern but with delay time to react. Reference temperatures also influencing softening of paste.

d) furnace 4

transformer	15 MVA
power applied	8.5 MW
el. diameter	1060 mm
alloy	FeSiMn
current/phase	45 kA
paste consumption	20 kg/m. ton alloy
sp. power cons.	3450 kwh/ m. ton.

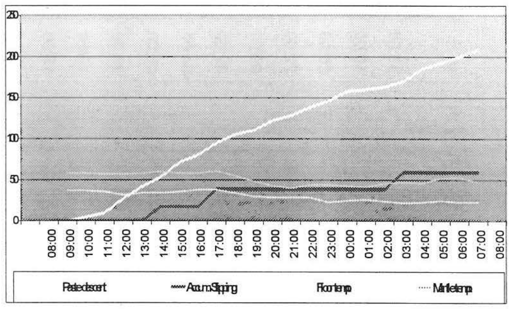

fig. 12. Furn.4 El. 2 , 7th of june. Paste descent above accumulated slipping shows more fluid behaviour in heated column.

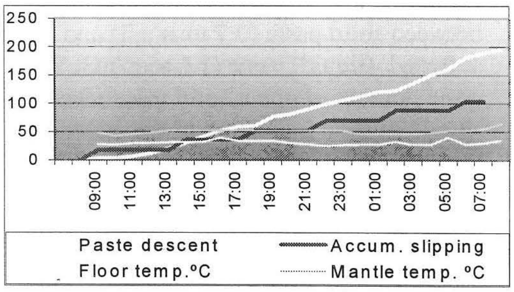

Fig 13 – Furn.4 El 3 , june 10th. Normal expected behaviour in heated column.

e) Furnace 5

transformer	15 MVA
power applied	9,5 MW
el. diameter	1060 mm
alloy	FeSiMn
current/phase	48 kA
paste consumption	20 kg/m. ton alloy
sp. power cons.	3356 kwh/ m. ton.

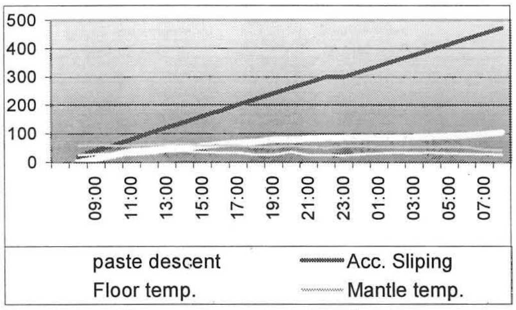

fig. 14- Furn 5, el. 2, june 18th. Restricted paste descent due to high accumulated slipping.

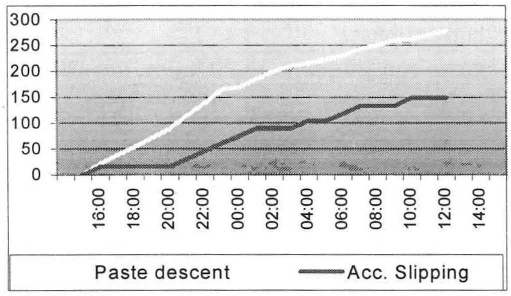

fig. 15 – furn 5 , el 2. Paste moves during peak hours catching up for previous restricted descent.

8. –RESULT ANALYSIS

Soderberg Paste charged in briquettes lowers into electrode column upon slipping due to the difference in apparent density between solid paste (0.7 tons/m3) and softened (liquid) paste (1.6 tons/m3. Such paste descent of upper solid paste level should give an indication of the softening mechanisms which will be important in order to understand the formation of bridges and the control of column operation.

Analysis of results obtained shows that relationship of paste descent and slipping during SiMn and FeMn normal operations is not a direct one. Many other factors will intervene and the present work would give an indication of them. Further development work should be carried in order to isolate variables like temperatures and paste plasticity for instance.

In all cases we can detect a significant lead time between slipping and paste descent. This delay would be dependent mainly on column temperatures and possibly in other paste properties like plasticity and conductivity.

In our experiments we could classify the results in two main types: measurements done on smaller furnaces (# 1,2 and 3), and measurements performed on furnaces 4 and 5. Furnaces 4 and 5 are equiped with heating of the mantle air meanwhile furnaces 1,2 and 3 do not have such equipment.
In smaller furnaces, figures 6 to 11, paste softening is strongly dependent on ambient and upper column temperatures. Figures 6 and 7 give the impression that the paste descent movement rather follows the temperature measurements than amount of electrode slipping. During shut down periods like characterized in fig. 10, under winter temperatures of 10ºC , switching off cooling fans would increase column temperatures and produce a strong movement of paste catching up with previous amount of slipping. Fig. 9 shows an accumulated slipping of 300 mm which did not cause the expected paste descent which occurred only next day (fig. 10), with increasing mantle temperatures obtained with charge lowering and fan shutdown during energy peak hours.

In furnaces 4 and 5, with larger electrode diameters and air heating device, the relationship of slipping and paste descent is more clear. Paste softening is more pronounced (fig 12 and 13) due to higher column temperatures. The softening expressed in terms of paste descent will depend more in the amount o slipping: an higher accumulated slipping would produce a lower paste descent value. Subsequent lower slipping would produce bigger paste descent values as in fig.14 and 15.

One main result to be noticed is in relation to electrode performance during measurements period. The operating parameters tables show good performance in relation to electrode consumption and no rupture events. All operation procedures have been standard for the furnaces in question. Even with such a variety of paste behaviour in relation to softening and paste descent interaction with slip, the formation of electrode in the columns was good, resulting in excelent specific consumption figures during that period. The operation of column at Ferroligas Maringa includes a careful slipping increment control using 10mm increments whenever possible and dayly regular feeding of paste together with paste descent control

9. SOFTENING MODEL.

Softening of briquettes in the electrode column should depend more strongly on paste properties like plasticity and green conductivity than softening of blocks and cylinders due to absence of pressure from heavy solid paste pile. Above results show that briquettes softening, following slip, requires a time period to attain complete melting and produce a lowering of the upper solid level inside the column.

The accumulation of slipping increments during furnace operation could produce a correspondent layer of paste in a partially melted condition or briquette surface melted condition.

This layer will eventually subside into the total melted condition provided thermal homogeneity is reached in the briquettes

An upper solid paste level will then descent in the column. The rate of descent will depend on many factors like upper column temperature distribution and paste properties. Figure 16 illustrates above described situation.

Heating of paste in the liquid state can produces swelling in the range of 200-300 °C (*1*), in briquette operation this swelling could eventually produce some small effect in the upper descent of paste.

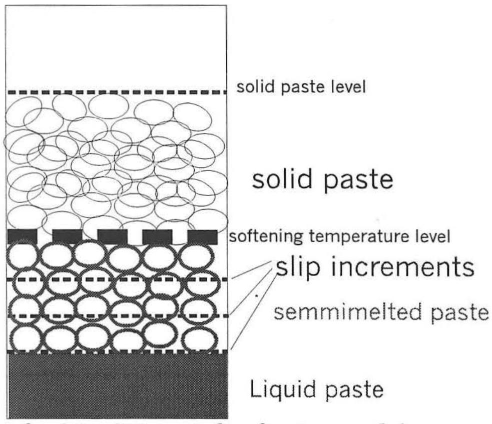

fig.16 – Suggested softening model

As confirmed by the practice at Ferroligas Maringá, the formation of bridges with briquettes is more likely to occur in lower diameter electrodes and during winter low temperatures. This should be associated with an increased width of partially melted paste layers and eventual abnormal coooling and heating cycles at the upper partially melted briquettes forming a bridge. Such abnormal cooling situations could arise after shutdowns, after forced slipping and irregular electrode operation situations. In the case of Ferroligas Maringá, decrease of cooling fan air flow in smaller furnaces produced a better heating of the column and increased briquette flow .

Normally, bridges are controlled through measurements of solid paste upper level: if after one shift the paste has not lowered in the column, a mechanical impact (15 to 20 kg.) is applied or cooling fans are switched off. The later procedure could be very damaging to the column paste and is not recommended.

10. DISCUSSION AND CONCLUSIONS

Our results indicate that solid briquette paste level descent inside the column is not a direct result from slip. Smaller than expected paste descent does not mean that a bridge has been formed. The routine use of mechanical impact is adopted in many companies in order to prevent the formation of bridges. Such procedure could best apply to smaller diameter electrodes and cooler columns. In electrode diameters larger than

1m. and heated columns, such events are more rare and only a check is made in terms of solid paste level.

Possibilities to bridge formation with briquettes are smaller with bigger diameter electrodes and heated columns. The operators will decide on the need to adopt special procedures in relation to this problem. The use of the simple device suggested in this paper to measure upper solid paste level could be useful to give an idea of the specific furnace behaviour in relation to paste descent and softening conditions.

We think that more important to successfull briquette electrode column operation is the paste formulation, regular charging of paste in the column, small slipping increments and control of temperatures in the upper parts of it through air fan heating or hot air blowing.

In our experience the use of briquettes in a wide range of furnaces, alloy and operating conditions has been very positive. Its main advantage being the formation of an stable homogeneous layer of high viscosity paste over all the electrode column section minimizing possibilities for segregation. Such advantage, in our opinion, is far more important than the risk of bridge formation. Even in case of problems arising from heterogeneous conditions to soften the paste and eventual formation of bridges, the briquette column system is self healed by paste softening mechanisms with minor consequences for the formed electrode quality. Basically, interruption of paste flow will produce temperature increase and briquette column descent will occur restoring high viscosity layer and normal operation conditions before much damage is caused to electrode formation.

During our test period at Ferroligas Maringa a great variation of softening behaviours have been detected with possibilities for bridging in small furnaces. Even so, the electrode formation and its operational performance were not affected by such variations: no ruptures occurred and specific consumptions were normal.

The successful use of briquettes in a wide variety of operational conditions without special column controls seems to indicate that good electrode formation with briquettes is less dependent on paste softening conditions than with blocks or cylinders.

Our experience also shows that in colder columns like in FeNi and Cu slag Soderberg operations, briquettes could promote a more stable and reliable operations working with low liquid paste levels. In hotter columns like in FeSi and Casi operations briquettes allow for simpler column control and minimize segregation. In Si metal Soderberg production with composite electrodes, briquettes are mandatory and further research should bring higher quality electrode paste for such applications.

Briquette usage could be developed in the following main technological directions:

a) Development of paste formulations for critical applications.
b) Improvement of green paste conductivity as pointed out in (2).
c) Development of electrode automated feeding systems.
d) Promote use of hot air blowers to heat inside electrode columns in association with briquettes.

11. ACKNOWLEDGEMENTS

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