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Investigation of "Simultaneous Coke Quenching and Coal Preheating Through Solid Media

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From C. Lin

Subject Investigation on "Simultaneous Coke Quenching and Coal Pre-heating through Solid Media".

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Date: October 12, 1978

Copies to:
C. Lin
B.W.H. Marsden
J.E. Schuster

To: Mr. N.H. Keyser

N.H.K. OCT 13 '78

From: V. Beaucaire

Subject: Investigation of "Simultaneous Coke Quenching and Coal Preheating Through Solid Media"

Reference: D2-002-001 (RD-78-4)

Attached is C. Lin's report on simultaneous coke quenching and coal preheating using a solid intermediate for heat transfer.

The solid-to-solid heat exchange approach to preheating coal might be workable, but I doubt that it would ever be truly practical. Charlie points out several possible difficulties. I think over-all slow heat transfer and the potential for leaving inerts in the coal blend would be the most difficult to overcome.

Re alternatives, aside from the waste gas approach, there is also Akgun's idea of merging dry-quenching and more-conventional coal preheating systems. Since these latter technologies already exist, a good initial approach would be to talk with people who are more knowledgeable, i.e., Wilputte or Koppers.

V. Beaucaire

meo

IS-5018-1-E

INTEROFFICE CORRESPONDENCE

Date: September 27, 1978

Copies to:
V. Beaucaire
B. Marsden
J. Schuster

To: N. H. Keyser

From: C. Lin

Subject: Investigation of "Similtaneous Coke Quenching and Coal Preheating Through Solid Media"

Reference: D2-002-001 (RD-78-4)

Summary

This memorandum outlines the study of "Similtaneous Coke Quenching and Coal Preheating through Solid Media." Various ideas have been initiated and studied by the research staff. Only one idea seems still reasonable and maybe feasible to try further -- use of coke breeze and ceramic balls as a heat carrier to obtain heat from red hot coke to preheat coal. However, this idea requires lots of capital spending, even in the initial stage. This is the reason why only theoretical study is mentioned here. Further experimental or pilot plant work had better be consulted with a construction company, like Wilputte.

Objective

The objective of this study is to evaluate the possibility of using solid media as the heat conductors to preheat coal by heat from incandescent coke normally lost during coke quenching. Preheating coal before charging to coke oven increases the so-produced coke productivity and its quality. The elimination of water quenching means avoidance of thermal shock thus improving coke quality further. The economical value is somewhere in the order of 10 million dollars annually (See Appendix).

Detail

Simultaneous coke quenching and coal preheating through direct contact had been tested in the laboratory. The result was poor -- coal lost part of its volatile matter and could not make coke anymore. The reason is simple -- incandescent coke is just too hot to be the heat carrier to preheat the coal. The only way to avoid the deterioration of coal's coking properties is through some other lower temperature heating media. Inert gas has been used as quenching and heat exchanging media for years in Russia. However, gas handling facilities are both expensive and hard to take care of. The coal preheating system has been adapted by various major U.S. steel mills, but it requires extra heating sources, such as, coke oven gas, or natural gas.

Part of these difficulties may be able to be solved by solid-solid heat exchanging technique. The ceramic ball using the shale oil process to preheat shale powder can be adapted here. Ceramic balls are supposed to be strong enough to handle and have been used successfuly by major oil companies for years. The purpose of using both coke breeze and ceramic balls is (1) to reduce the heating temperature while still preserving most of the heat, (2) feasibility to be separated after heat exchanging, and to avoid contamination. The so-proposed procedure is as follows:

> "In the beginning, coke is quenched by coke breeze. After coke is separated by screening, ceramic balls will be heated by thus "heated" coke breeze. Finally, coal is preheated by these ceramic balls (Figure 1)".

Ceramic balls at this time have a temperature no more than 800^{0}F and have less chance to damage coking properties. Ceramic balls and coke breeze can be recycled over and over again. None of these steps in so-proposed procedure can be omitted. These steps would ensure a better separation among coal, coke, and heat carriers. There is an alternative - use of nut to substitute ceramic balls (Figure 2). The ratio between ceramic balls and the coal will be 2 or 3 to 1 by weight. The amount of heat furnished by ceramic balls can be adjusted by the total amount of ceramic balls and coke breeze. During winter time, more ceramic balls and coke breeze are needed. Since coke has more than enough heat to preheat coal, the extra heat can be eliminated anytime by spraying water onto the recycling coke breeze.

A. <u>Major Equipment and Supply</u>

Kilns (2 or 3): for mixing
Screening Device: (1,100^{o}F)
Screening Device: (600^{o}F)
Screening Device: (300^{o}F)
Ceramic Balls: (3/4" diameter) 40 Ton
Coke Breeze: 36 Ton
Nut (1" x 1/2" Coke): 36 Tons
Belts and Elevators

B. Heat Balance

The theoretical working diagram is as shown in Figure 1 and Figure 2. A calculated example is included.

Major Difficulties

1. This is a multimillion dollar project. Even the pilot plant test may need a fortune.

2. Hot screening coke and coke breeze at 1,100° F will have pollution problems and may involve some technical difficulties.

3. During preheating, coal is partially exposed to air, even with the help of some gadget designs. The rate of coal oxidation can be exponentially increased as temperature goes up. Further test is needed if we want to know the extent of coking property deterioration.

4. The volume of kilns is determined by the rate of heat transfer. From previous experience and over-simplified calculation, ten to fifteen minutes may be enough to complete the heat transfer in each mixing. Additional test is needed to verify it.

5. No other company has done a similar thing before. We would be No. 1 to try. We are a relatively small size steel mill. "Is it worth it for us to pursue this work further?" is the question.

C. Lin

C. Lin

CL/ey

Attachments

Disadvantage: Broken ceramic balls may damage coke quality.

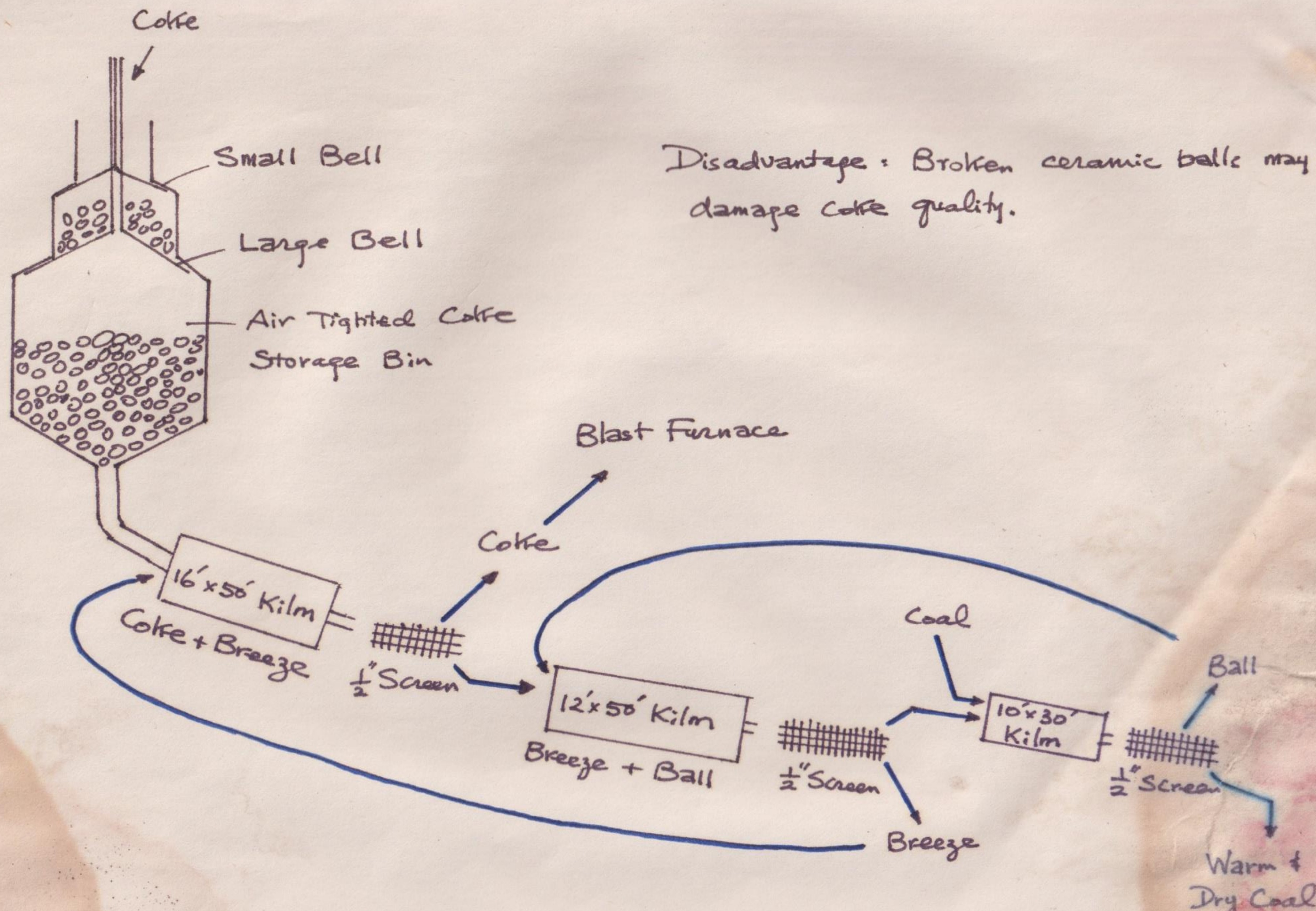

Figure 1. Ceramic Balls and Coke Breeze as Heat Carriers.

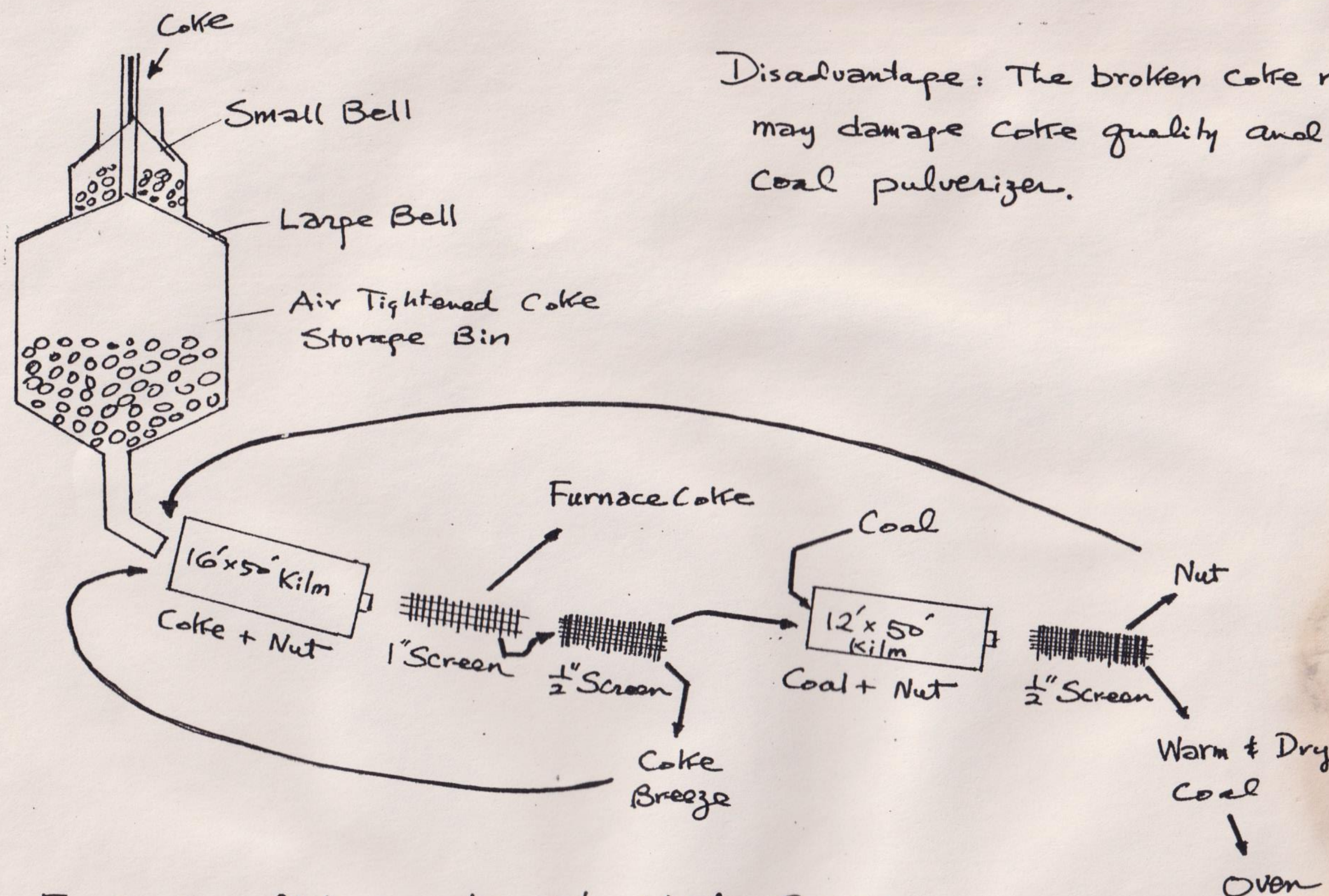

Figure 2. Nut as the only Heat Carrier.

Disadvantage: The broken coke nut may damage coke quality and the coal pulverizer.

Example: Summer time, coal with 5% moisture.

17 Ton coal (per oven) ⟶ 12 Ton coke

Specific heat of coke (or coke breeze) = 0.265 Cal/deg-gm
" " " coal = 0.315 Cal/deg-gm
" " " ceramic ball = 0.16 Cal/deg-gm

Coke initial temperature = $2000^{\circ}F$
Coal initial temperature = $70^{\circ}F \longrightarrow 20^{\circ}C$

Step I 12 Ton Coke at $2000^{\circ}F$ +
24 Ton Coke Breeze at $700^{\circ}F$ (from Step II)

$$12 \text{ ton} \times 2000^{\circ}F + 24 \text{ ton} \times 700^{\circ}F = 36 \text{ ton} \times X$$

$$X = \frac{24,000 + 16,800}{36} = 1133^{\circ}F$$

Step II 24 Ton Coke Breeze at $1050^{\circ}F$ (or $565^{\circ}C$) +
24 Ton Ceramic Ball at $220^{\circ}F$ (or $105^{\circ}C$) (from Step III)

$$24 \text{ ton} \times 0.909 \times 10^{6} \text{ gm/ton} \times 0.265 \text{ cal/deg-gm} \times 565^{\circ}C$$
$$+ 24 \text{ ton} \times 0.909 \times 10^{6} \text{ gm/ton} \times 0.16 \text{ cal/deg-gm} \times 105^{\circ}C$$
$$= 24 \text{ ton} \times 0.909 \times 10^{6} \text{ gm/ton} \times (0.265 + 0.16) \text{ cal/deg-gm} \times X$$

$$X = \frac{149.73 + 16.8}{0.425} = 391.8^{\circ}C \text{ or } 737^{\circ}F$$

Step III 24 Ton Ceramic Ball at $700^{\circ}F$ or $370^{\circ}C$ + 17 ton coal
with 5% moisture at $20^{\circ}C$

$$24 \text{ ton} \times 0.909 \times 10^{6} \text{ gm/ton} \times 0.16 \text{ cal/deg-gm } (370^{\circ}C - T)$$
$$= 17 \text{ ton} \times 0.909 \times 10^{6} \text{ gm/ton} \times 0.315 \text{ cal/deg-gm} \times 0.95$$
$$\times (T - 20^{\circ}C) + 17 \text{ ton} \times 0.909 \times 10^{6} \text{ gm/deg-gm} \times 0.05 \times$$
$$(80 + 536) \text{ cal/deg-gm}$$

or

$$1420 - 3.84\ T = 5.087\ T - 101.74 + 522.75$$

$$8.927\ T = 998.99$$
$$T = 111.9^{\circ}C \text{ or } 240^{\circ}F$$

<u>Appendix</u>

The Economical Value of "Simultaneous Coke Quenching and Coal Preheating through Solid Media".

<u>Pre-assumption</u>

(1). 1600 ton coke production per day (133 push per day) at $100/ton.

(2). 2500 ton hot metal production per day at $200/ton.

(3). Coal contains at least 8% moisture before charging into oven.

(4). Coke Plant can only push 150 push per day due to the limitation of coke plant facility.

(5). From previous calculation, coke has more than enough heat to preheat coal.

(6). From W. Mc Henry's paper,* the preheating of coal can boost up at least 25% in coke heating rate and raise coke strength 10%.

Economical Value

(1). <u>Heat Saving During Coking</u>

$$8\% \times 17 \times 0.909 \times 10^{6} \text{gm} \times 133 \times 365 \text{ day/yr} \times 600 \text{ ca/gm}$$

$$\times \frac{1}{252} \frac{\text{BTU}}{\text{cal}} = 1.43 \times 10^{5} \text{ million BTU/year.}$$

If each million BTU costs $2.00 and the heating efficiency

is 66% then $\frac{3}{2} \times 1.43 \times 10^{5} \times \$2 = \$0.43$ million/year

(2). <u>Increasing in Coke Productivity Due to 2 Hour Oven Time Saving (12%).</u>

$$\frac{1}{3} \times \$100 \times 12\% \times 1600 \text{ ton/day} \times 365 \text{ day/yr}$$

= $2.34 million/year (ASSUMES 1/3 PROFIT)

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* W. Mc Henry, R. Land and A. Sellers, "Design and Operation of No.2 Battery Coal Preheating Plant at Gary Works", Ironmaking Proceedings, <u>36</u>, 1977

(3). Increasing in Blast Furnace Productivity and Coke Rate Reducing Due to Better Coke Stability

In Inland Steel Company, Each percentage raise in coke stability will increase 1 to 1.5% in productivity and lower 0.5% in coke rate.

Increasing in coke stability due to dry quench = 2.

Increasing in coke stability due to preheating coal and enlengthening of coking time = 10. (ONLY 12% PRODUCTION INCREASE DUE TO PUSHING LIMITATIONS.)

12 x 0.5% x 1600 ton/day x 365 day/year x $100

= 3.50 million/year

Assume one third of the increase in productivity will be profit.

$\frac{1}{3}$ x 2500 ton/day x 365 day/year x $200 x 12 x 1.0%

= 7.3 million/year

Total Saving = 0.43 + 2.43 + 3.5 + 7.3

= 13.57 (million/year.)

Appendix

The Economical Value of "Simultaneous Coke Quenching and Coal Pretreating through Solid Media".

Pre-assumption

(1). 1600 Ton Coke production per day (133 push per day) at $100/Ton.

(2). 2500 Ton Hot Metal Product per day at $200/Ton

(3). Coal Contain at least 8% moisture before charging into oven.

(4). Coke Plant can only push 150 push per day due to the limitation of coke plant facility.

(5). From previous Calculation, coke has more than enough heat to pretreat coal.

(6). From W. Mc Henry's paper*, the pretreating of coal can boost up at least 25% in coke heating rate and raise coke strength 10%.

---

* W. Mc Henry, R. Land and A. Selters, "Design and Operation of No. 2 Battery Coal Pretreating Plant at Gary Works", Ironmaking Proceedings, 36, 1977

Economical Value

(1). Heat saving during Coking

$8\% \times 17 \times 0.909 \times 10^6 gm \times 133 \times 365 \text{ day/yr} \times 600 \text{ Cal/gm}$

$\times \frac{1}{252} = 1.43 \times 10^5$ Million B.T.U.

If each million B.T.U. costs \$2.00 and the heating efficiency is 66%, then

$\frac{3}{2} \times 1.43 \times 10^5 \times \$2 = \$0.43$ Million / year

(2). Increasing in Coke productivity due to 2 ~~hour~~ hour oven time saving (12%)

$\frac{1}{3} \times \$100 \times 12\% \times 1600 \text{ Ton/day} \times 365 \text{ day/year}$

$= \$ 2.34$ Million/year

(3). Increasing in Blast Furnace Productivity and Coke Rate Reducing due to better Coke Stability

In Inland Steel Company, each percentage raise in coke stability will increase 1 to 1.5% in productivity and lower 0.5% in coke rate.

Increasing in coke ~~rate~~ stability due to dry quench = 2

Increasing in coke stability due to ~~Pret~~ pretreating coal and enlengthening of coking time = 10.

12 × 0.5% × 1600 Ton/day × 365 day/year × \$100
= 3.50 million/year

Assume one third of the increase in productivity will be profit.

$\frac{1}{3}$ × 2500 Ton/day × 365 day/year × \$200 × 12 × 1.0%

= 7.3 million/year

Total Saving = 0.43 + 2.43 + 3.5 + 7.3
= 13.57 (million/year.)