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EFFECT OF THE COKING COAL QUALITY ON THE COST OF STEEL PRODUCED IN TURKEY.

Abdullah ÇOBAN
Deputy Director Isdemir (Iskenderun Iron Steel Co), TURKEY

SUMMARY

The effect of the quality of coke on coke rate at T.D.C.İ has been studied since 1981 in order to improve the quality of coke, a team work was organised. The importance of the quality of coke and saving would be gained has been tought to starting from the ordinary workers up to top level managers. The short and long terms tergets have been defined, great effort has been put to reach these targets sistematically.

These works have mainly been concentrated at İsdemir, where while the quality of coke has been improved, it was noticed that the coke rate has been decreased from 782 kg/ TSHM in 1981 down to 535kg/TSHM in 1990. Due to the bottleneck in coal supply in Kardemir, the quality of coke produced there has not been reached to the target level. Therefore, the required level of saving has not been achieved there . Althought the other raw materials have been the same at Kardemir and İsdemir, the main reason for not being able to reach the resired level was found to be the difference in the quality of cokes produced.

In both steel works, the necessary target studies have been defined. At the and of the above mentioned studies about 50 million US$/ year saving has been achieved. About the same amount of saving can be saved, has been shown in the future, if the necessary actions has been evaluated.

TÜRKİYE'DE ÜRETİLEN ÇELİĞİN MALİYETİNE KOKLAŞABİLİR KÖMÜRÜN KALİTESİNİN ETKİSİ

ÖZET

T.D.Ç. işletmelerinde çelik üretimine üretilen kokun kalitesinin etkisi 1981 den beri incelenmiştir. Bu tarihten itibaren, kokun kalitesini artırmak amacıyle bir grup çalışması yapılmıştır. Öncelikle, kok kalitesinin önemi ve kazandıracağı tasarruf işçiden en üst düzey yöneticiye kadar öğretilmiştir. Kısa ve uzun vadeli hedefler belirlenerek, sistematik bir şekilde bu hedeflere ulaşılmaya çalışılmıştır.

Bu çalışmalar İsdemir'de yoğunlaştırılmış, kokun kalitesi artırılırken, buna paralel olarak da ton sıvı hamdemir başına kok sarfiyatı 1981'de 782 kg iken 1990'da 535 kg'a kadar düşürülmüştür. Kardemir'de, kömür tedarikindeki darboğaz nedeniyle kok kalitesi istenilen seviyeye yükseltilememiştir. Bu nedenle de istenilen tasarruf sağlanamamıştır. İsdemir ve Kardemir karşılaştırıldığında, diğer hammadde girdileri aynı olmasına rağmen, kok kalitesinin artırılamamasının Kardemir'de istenilen hedefe ulaşılamamasının asıl sebebi olduğu görülmüştür.

Her iki müessede kok kalitesini daha da iyileştirmek için yapılması gerekli çalışmalar ve hedefler belirlenmiştir. Bu çalışmalar sonunda yılda 50 milyon US$ tasarruf edilmiştir. Bu kadar daha tasarrufun sağlanabileceği de gösterilmiştir.

INTRODUCTION

There are three integrated steel plants in Turkey. Kardemir and Isdemir are state owned sister companies producing long products. Erdemir is privetaly owned plant producing only flat products.

The production of Kardemir remained almost constant during the last 10 years while Isdemir and Erdemir showed remarkable increase in production, reaching from $420X10^3$ tonnes up to $1.775X10^3$ tonnes and $1.815X10^3$ tonnes respectively [1].

Total steel production including in EAF in Turkey reached up to $7.931X10^3$ tonnes in 1988 while it was $2.505X10^3$ tonnes in 1980. In parallel to steel production, the amount of coking coal consumption has increased fnom $2.591X10^3$ to $4.611X10^3$ tonnes between 1980 and 1988. During this period, imported coking coal demand increased from $951X10^3$ tonnes to 3.048X103 tonnes with increasing steel production while domestic coking coal consumption remained almost constant, being about $1.600X10^3$ tonnes. This is due to the fact that the domestic coking coal production could not be increased above the level of approximately $3.600X10^3$ tonnes between 1980 and 1990, its consumption in integrated steel plants was almost 45 % of the production values during the above period. Although some rehabilitation and modernisation projects for increasing the production up to $4.500X10^3$ tonnes per year in 1994 under operation, domestic coking coal production has not been sufficient in the past and will not be enough in the future. Therefore , Turkey will continue to import coking coal with an increasing trend and remain as an international coal importer.

1. IMPORTANCE OF THE QUALITY OF COKING COAL.

The amount of domestic and imported coking coking coal consumed between 1980 and 1988 and to be used till 2000 at each integrated steel plants in Turkey is indicated in details in **Table. 1** and **Table. 2** respectively.

	KARDEMİR		İSDEMİR		ERDEMİR		TOTAL	
	IMPORT	DOMESTIC	IMPORT	DOMESTIC	IMPORT	DOMESTIC	IMPORT	DOMESTIC
1980	0	849	691	95	260	696	951	1640
1981	0	854	330	393	321	750	651	1997
1982	0	848	709	267	504	657	1213	1772
1983	0	911	884	353	733	554	1617	1818
1984	0	891	1095	180	969	568	2064	1639
1985	62	769	1641	63	646	585	2349	1417
1986	347	731	1754	223	926	631	3027	1585
1987	192	928	2072	44	831	608	3095	1580
1988	220	970	2099	0	729	593	3048	1563

Tablo.1 : DOMESTIC AND IMPDORTED COKING COAL CONSUMPTION OF TURKEY SINCE 1980 (X 1000 Tonnes)

The figures in **Table.1** indicate the actual amount of coking coal consumed whereas in that of **Table.2** are calculated by taking into account of the future projection of domestic coking coal production, easiness of its distribution to these plants and the projection of the necessary improvements of the quality of coke to be produced by adjusting the percentage of imported coking coal to be used in coal blending.

	KARDEMİR		İSDEMİR		ERDEMİR		TOTAL	
	IMPORT	DOMESTIC	IMPORT	DOMESTIC	IMPORT	DOMESTIC	IMPORT	DOMESTIC
1988	220	970	2099	0	729	593	3048	1563
1990	420	980	2360	0	1120	745	3900	1725
1995	585	875	2280	300	1445	965	4310	2140
2000	544	816	2570	500	4020	1500	7134	2816

Tablo.2 : DOMESTIC AND IMPDORTED COKING COAL DEMONDS FOR INTEGRATED STEEL PLANTS TURKEY SINCE TİLL 2000 (X 1000 Tonnes)

As can be seen from the **Table.1** that until1985 coke was only produced from the domestic Turkish coking coal which is high volatile coking coal with very high ash content ranging from 13 % to16 %. The percentage of this domestic coking coal used in Isdemir has been desreased steadily since 1981 from 54 % down to 11 % in 1986 and 0 % in 1988. The percentage of domestic coking coal in Kardemir was 68 % in 1986 and 81 % in 1988.

1.1. THE RELATİON BETWEEN COKE RATE AND COKE QUALİTY.

The relation between coke rate and coke quality of Kardemir and Isdemir is given in **Table.3.**

	COKE QUALITY				COKE RATE (Kg/THM)			
	İSDEMİR		KARDEMİR		İSDEMİR			KARDEMİR
	M_{40}	M_{10}	M_{40}	M_{10}	BLAST FURNACE			BF (Avarege)
					No.1	No.2	No.3	
1981	61.7	10.6	69.8	11.2	734	694	-	942
1982	65.4	8.5	73.1	10.1	653	622	-	1043
1983	76.8	6.9	71.2	10.3	636	626	-	1024
1984	75.6	7.3	71.6	10.5	668	635	-	990
1985	76.2	7.4	75.1	9.3	636	580	564	958
1986	77.9	7.2	77.9	8.1	640	587	540	812
1987	81.6	6.8	76.8	8.2	580	550	538	815
1988	81.3	7.2	76.1	8.6	545	574	527	768
1989	79.5	7.9	68.9	11.2	582	608	542	760
1990	77.7	8.1	69.8	10.5	543	521	537	-

Tablo.3 : DEPENDENCE OF COKE RATE THE QUALITY OF COKE CONSUMED.

KARDEMİR and ISDEMİR are of being sister companies, the both consume the same or similiar quality of raw materials. Iron ores suplied from the same mines, pellet is obtained from the other sister company called Div-pellet, Ferro allages are bought generally from the some suppliers by TDÇİ General managements for both steel

plants. Other auxilary raw materials are of same or, similiar qualities. Futhermore, Kardemir has been in operation since 1937 so that the experience gained and the knowledge obtained in Kardemir is expected to be more than that of in Isdemir. The only main reason causing the much higher consumption of coke per ton of hat metal must be attributed to the difference in the quality of coking coal or coking coal blend.

As it is seen clearly, the coke rate is directly dependent on the quality of coke used in Isdemir and Kardemir. It is very sensitive when the quality of coke is worse than the optimum level, it reflects the minor changes in the quality of the coke, decreases suddenly if there is any small improvement in coke quality and visa versa.

It is necessary to be mentioned here the fact that the M_{40} and M_{10} values are not the only parameters such as the ash, S and alkaline contents, porosity, size, size distribution, reactivity, after reaction strength.,etc are of equaly important parameters in determining the quality of coke, therefore, these parameters must be taken into account in evaluating the quality of coke.

Since it was not the aim of this paper to study the effect of the individual properties of coke on the coke rate, the details of the quality of coals and coke are not given, M40 and M10 values are chosen just to be able to compare the quality difference between the coke produced at Kardemir and Isdemir.

It can also be concluded from the results indicated in Table. 3 that the quality of coke produced at Isdemir increased sharply and reached to the quality level of world standards, whereas the coke quality of Kardemir's needs to be further improved.

In order to reduce the coke rate at Isdemir down to an optimum level (450-500 Kg/THM),the other parameters, apart from the coke quality, is needed to be considered. In Kardemir the prime importance has to be given to the improvement of the quality of the coke produced.

2. HOW MUCH MONEY CAN BE SAVED BY REDUCİNG THE COKE RATE DOWN TO OPTİMUM LEVEL AND HOW CAN THİS BE ACHİEVED.

As mantioned above, the other canditions are needed to be considered at Isdemir in order to reduce the coke rate further. On the other hand, at Kardemir the prime attention has to be paid on the quality of the coke produced. In any of these cases whatever the action has to be taken, is to be taken without any delay.

2.1. COST REDUCTION TARGET İN TDÇİ.

It was stated that coke quality has been shown to have played a major role in the performance of Blast Furnace operation, and the main parameter to be cansidered in reducing the coke rate.

In the beginning of 1981, coal blending used to be based on the amount of coal present at the coal stok- yard. The percentages of coals to be added into the blend were calculated according to their weight percentage present in the stock. Nobody use to pay any attention of their quality. Almost nobody was aware of the importance of quality ofthe coal, coal blending, coke quality and the role of coke in the blast furnace, but for the coal supplier (trader) who took the advantage of selling any type of coal they can provide cheaply. without bothering of their quality because they were aware of the fact that at Isdemir there were nobody with enough knowledge without the coal and evaluation of the results they obtained. This was hard to accept but was true, because managers, engineers, foremans were usually brought from Kardemir or trained at Kardemir where the only coking coal used for coke production was the domestic Zonguldak high volatile coking coal with inferior coking properties and high as content. Therefore, it was difficult to blame them having little knowledge about the quality of coke.

Sice 1981 prime attention have been paid to the improvement of the quality of coal imported. It was started from the training of the people involving with the sampling and sample preperation. All the necessary stantards were translated, the importance of the sampling was thought them starting from the ordinary workers up to chief en gineers and manager responsible from the quality control deparment of Isdemir. Education have been given theoriticaly and practicaly. All the necessary equipments for the sampling,

sample preperation, analysis of the coking coals, coke and the other raw material and semi finished and finished products have been supplied. It was a good team work on the quality control procedure took place at Isdemir. It showed its effect, and in a very short time, it has started to pay back. Every body in this team have been proved of seeing results of their effort returning. The results given in **Table. 3** are some of indicating parameter of their achievement. It is also necessary to mention here the fact that as soon as this quality control team took the responsibility and realised the importance of the quality control, it also showed its effects on the raw material suppliers, especially on the coal supliers, and persuaded them that they cannot sell coking coal with improper coking properties as a prime coking coal.

This has been the one of the main reason in reducing the coke rate from 734 Kg/THM down to 540 Kg/THM or less at Isdemir.

At present, hot metal production of Isdemir is 2.450 million Tonnes per year. The difference between the coke rates in 1981 and in 1990 is (734-540) 194 Kg/THM.

The amount of coke saved is (2450x194) : **475300 Tonnes/year**
The amount of coking coal necessary to produce

475300 tonnes of coke $\frac{475300}{0.77 \times 0.85}$: **726203 Tonnes/year**

where; 0.77 and 0.85 are the figures indicating the coke and metallurgical coke yields, respectively.

Imported coking coal price (F.O.B.) in 1990	:	**52.00 US$/Ton**
Freight cost from USA	:	**9.95 US$/Ton**
Total cost assuming coal is imported from USA	:	**59.95 US$/Ton**
How much money saved per year is (59.95x726203)	:	**43535870 US$/Ton**
The amount of hot metal production at Kardemir	:	**600000 Tonnes/year**

The difference between the coke rates in 1981 and 1990 (942-760)	:	**182 Kg/THM**
The amount of coking coal necessary to produce 109200 Tonnes of metallurgical coke (109200/077x085)		**:166850 Tonnes/year**
Total cost assuming coal is imparted from USA	:	**59. 95 US$/Ton**
Transportation cost from Isdemir to Kardemir	:	**12. 15 US$/ Ton**
The cost of coking coal to Kardemir	:	**72. 10 US$/ Ton**
The amount of money saved every year in Kardemir (106850x72. 10)		**: 7693200 US$/year**
TOTAL SAVİNG (ISDEMİR+KARDEMİR) (43535870+7693200)		**:51229070 US$/year**

This results clearly proved the importance of the quality control and the achievement of the quality control team of Isdemir. It is therefore, necessary to define the next step or steps to be taken to reduce further down the coke rate at Isdemir and Kardemir.

2.1.1 PROCEDURE TO BE FOLLOWED FOR REDUCİNG THE COST OF STEEL AT ISDEMİR.

It was stated above that the quality of coke produced at Isdemir has been improved steadily since 1981 and reached to the quality level of the world standard by the affort of the quality control team of Isdemir.

In order to reduce the cost of steel production without reducing the quality of coke, centain amount of cheap coking coal with inferior properties, weakly coking coal, and even non-coking coal can be added into the coal blend by applying the follawing technologies [2].

1- SELECTİVE CRUSHİNG
2- BRİQUETTE CHARGİNG
3- PREHEATING
4- PROPER TENDER SPECİFİCATİON AND CONTRACT CONDİTİONS.

First three technologies are well known technologies found well application in many integrated steel plants in the world. The stamp charging and Jumbo Coking Reactor technologies are also well known technologies to suit the above mentioned purposes, it is difficult to apply them at Isdemir since it requires new design or new installation.

The principles of these technologies have been well publisized, thus the details are not given here.

It is worth mentioning here that to produce consistent quality of coke at Isdemir, it is necessary to prepare a proper tender in which the detailed properties describing the coking coals required are well defined and the primium and penalty conditions are indicated clearly, avoiding any missunderstanding so that the coal trader and supplier cannot penatrate into the tender spesifications otherwise they find the way of obeying the tender specifications but giving coals with inferior coking properties. This can also be achieved to a certain extend by making mid-term or long-term contracts with the coal supplier therefore the basic blend componet can at least be quarantied.

On the other hand, there is much to be done on the blast furnace side of Isdemir to reduce the coke rate down to the level of world standarts. These problems can mainly be solved under the following subheadings :

a) Increasing the capacity of the steel plant up to a level which the hot metal produced from the three blast furnaces even if they are working at 100 % or over of their nominal capacity.

b) Injecting pulverised coal to all or some of the three blast furnaces present at Isdemir.

a) Increasing the capacity of the steel plant :

The present given nominal capacities of these furnaces are much less than the modern blast furnaces. with the some diameter and volumes, of the other countries. Due to the bottle-neck which is present at the steel mill of Isdemir the actual capacities of these blast furnaces have not been tested property. After conducting a number of tests at Number. 3 blast furnace it was found out thatthe

nominal capacities of these blast furnaces are far more than their given project capacities. These tests also showed that although its project capacity is given as 3000 THM/day, it was quite easy to produce over 4000 THM/day without improving the quality of the coke, iron ore, sinter and pellet charged, increasing the hot blast temperature and addition of any coal tar, oil and/or pulverised coal.

The results obtained during these tests when the number 3 blast furnace is operating under or over its project capacity are given in **Figure. 1**

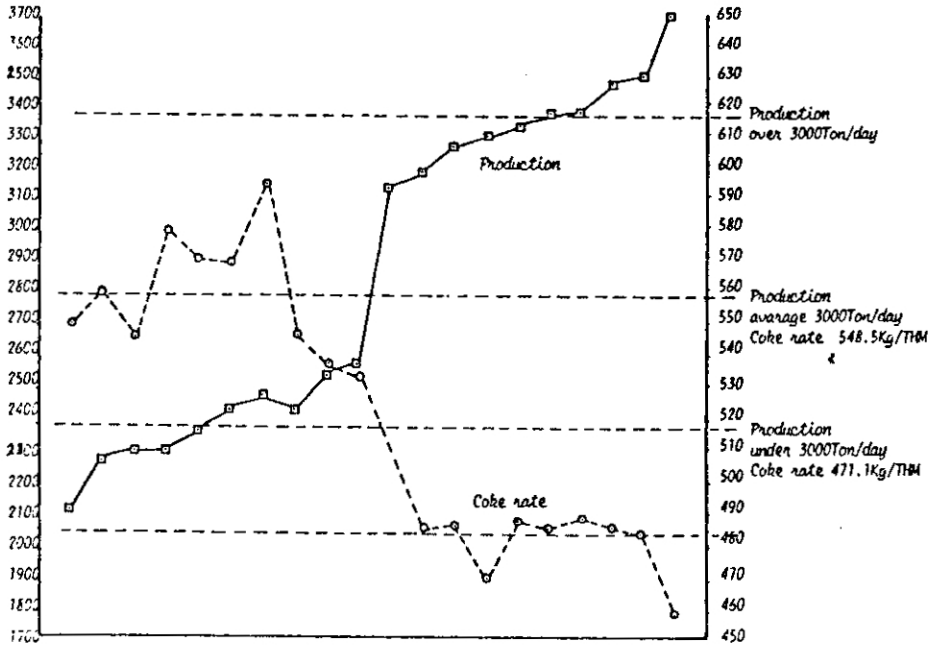

Figure. 1. THE EFFECT OF INCREASING PRODUCTION ON COKE RATE.

This figure clearly indicates that the coke rate decreases with the increase in hot metal production. When the hot metal production is under or around the project capacity (3000 THM/day orless) the coke rate is found to be around 550 Kg/THM, when it exceed this level it decreases suddenly cames down to 475 Kg/THM and almost stays constant betwen 3100 THM /day and as the production increases further the coke rate decreases again above the 3700 THM /day level the coke rate comes to a minimum level that of the standard, 450 Kg/THM.

The results given in this figure are definetly indicating the fact that in order to reduce the coke rate down to the minimum coke rate level accepted as world Standard (450 Kg) without injection, it is necessary to operate these blast furnaces above the given project capacity, this is also showed that proving that given project capacity is not indicating the real nominal capacity of these blast furnaces.

It also proves that it is more than necessary to operate these blast furnaces well above their given project capacity, whatever bottlenecks are present must be avoided very soon.

It can, therefore, be said that by increasing the production over their project capacity, the coke rate can be reduced down at least to 475 Kg/THM, this also means that 65 Kg of coke/THM can further be saved at Isdemir.

The amount of coke saved per year will be (2450x65)	:	**475300 Tonnes/year**
The amount of coking coal to be saved (159250/0.77x0.85)	:	**243316 Tonnes/year**
The total cost saving is going to be (243316x59.95)	:	**14586765 US$/year**

b) Pulverised Coal Injection :

This technology has been improving gradually during the last decade and proving itself being the one of the best method of replacing the expencive coke by non-coking cheap coal. It also enlarges the variety of coal can be utilised for steel production and reduces de

pendence of steel producers on expensive coking coals with limited reserves in the world. The amount of pulverised coal can be injected into blast furnaces without reducing the production and causing any other problem have reached recently up to 200 Kg/THM. The avarege injection rate is around 120 Kg/THM with a coke replecement ratio of about 0.80 Kg coke/Kg coal injection coal [3].

The replacement ratio (coke/coal) can possibly be calculated from the formula given below :

$$\text{The replacement ratio} : 148\text{-}0.666 \left(\frac{\text{ash \% in coal}}{\text{ash \% in coke}} \right)$$

assuming weakly coking Armutcuk coal 12.5 % ash content is in A. jected and the avarege 11 % ash content of the coke used in Isdemir blast furnaces using, abuve formula :

$$\text{The replacement ratio is going to be} : 148\text{-}0.666 \left(\frac{12}{11} \right) : 0.76 \text{ coke coal}$$

Assuming :

The price of this coal is : **50 US$/Ton**

The price of coke is : **100 US$/THM**

120 Kg of coke (25 % percent of the coke rate) is replaced the injected coal :

The amount of money saved per ton : **7.8 US$/THM**

Or hot metal calculated from the **Figure. 2**

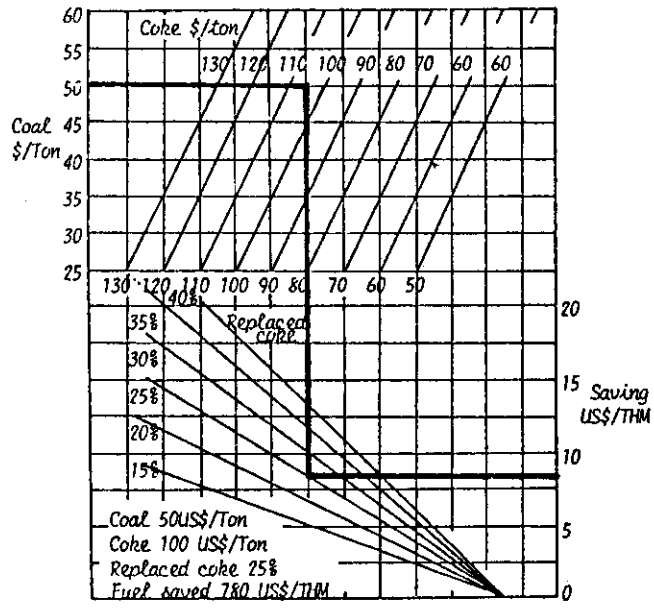

Figure. 2: THE SAVİNG İN US$/THM

The total amount of saving is going to be : **19110000 US$/year**

Finally it can be concluded, that by improving the operation efficiency of the three blast furnaces and injecting pulverised coal into them it is possible to save about
(14586765+19110000) : **33696765 US$/year**

This means that by reducing the coke rate and injecting readily available cheap weakly or non-coking coal the cost of steel can further be reduced (33696765/2450000) about 13.75 US$/THM at Isdemir.

2.1.2. REDUCİNG THE COST OF STEEL AT KARDEMİR

As mentioned above the problem in reducing the cost of steel at Kardemir is totally different than that of in İsdemir. The piority has to be given to the improvement of the quality of the coke produced at Kardemir. This can be achieved by adjusting the quality of

coking coal blends to be charged in to the coke ovens presents at Kardemir.

In order to improve the quality of coke, coking coal or coals with suitable properties, which have to be compatible with the domestic Zonguldak coking coal, is to be defined and imported especially for Kardemir.

The coals to be imported should have opposite properties to that of Zonguldak coking coal. It has to be low volatile coking coal with very low ash content and certain amount of medium volatile bridging imported coal is also needed to be added into the blend. As it is given in **Table.3** the quality of coke has been improved since 1985 after using the imported coking coal in the blend, due to the fact that the amount and the quality of the imported coals have been used in Kardemir was not sufficient in quantity and was not suitable in quality of the coke as much as it was expected. Due to this difficulties, it has still been possible to reduce the coke rate from 958 Kg/THM down to 760 Kg/THM since 1985.

It can finally be said that by adjusting the properties of the blend to a desirable level, the coke rate at Kardemir can be reduced at least down to the present level of Isdemir, which is less that 550 Kg/THM. This means that, coke rate can easily be reduced from 750 Kg/THM down to 550 Kg/THM, about 200 Kg/THM can be saved.

The total saving will therefore, be in
Kardemir (600000x200 $x10^{-3}$ x72.10) : **8652000US$/year**

3.CONCLUSİON.

It was intended to show above the importance of quality control system in a plant.The quality control department has to work as a proper team well educated and feeding the reliable informations, obtained by applying the proper standards, from the ordinary workers level up the managers and the results achieved are fed-back following the same line in opposite directions.The applications of the quality control team work at Isdemir since 1981 has proved their importance by reducing the coke rate from 734 Kg/THM down to 540 Kg/THM.

It has also shewed that there is much to be done at Kardemir and Isdemir, but the problems and their solutions are different so that the different prescriptions has to be given. These prescriptions have been well defined.

In order to improve the effect of the quality control team of Isdemir together with that of Kardemir, it seams necessary to exchange time to time the informations gathered and experience a chived with the other quality control team of the other domestic or international company involving in the proda ction of similiar materials.

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