Iron Making
Prof. Govind S Gupta
Department of Materials Engineering
Indian Institute of Science, Bangalore

Lecture – 06
Iron Making

Here I would like to mention something about the PCI injection rate. So, now-a-days, in fact, in some of the furnace PCI injection has gone up to 250 kg per ton of hot metal. And so, now a days, the blast furnace they operate at a very low coke rate which is around 300 kg per ton of hot metals.

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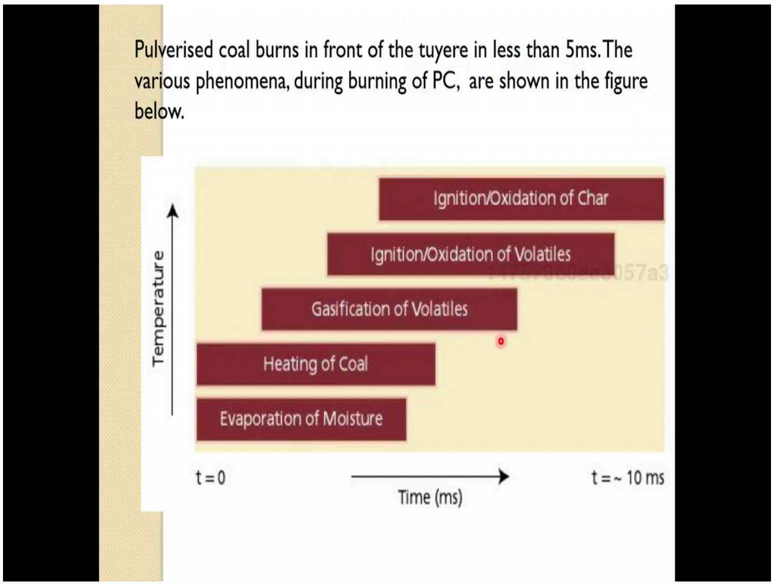

So, that is a significant improvement with the PCI.

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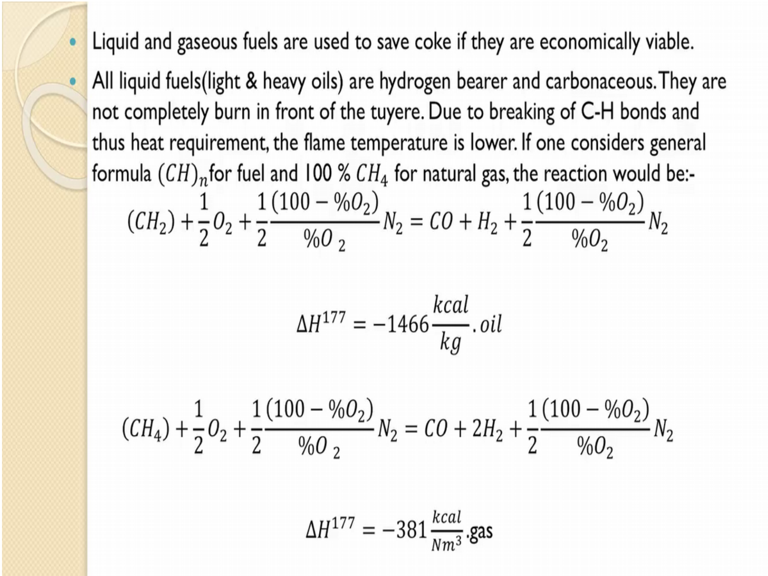

So, but besides PCI we can have this, Liquid and gaseous fuel and previously, liquid fuel was quite common. Because due to the availability and economical fit it; they were quite cheap actually and comparison to coke and other.

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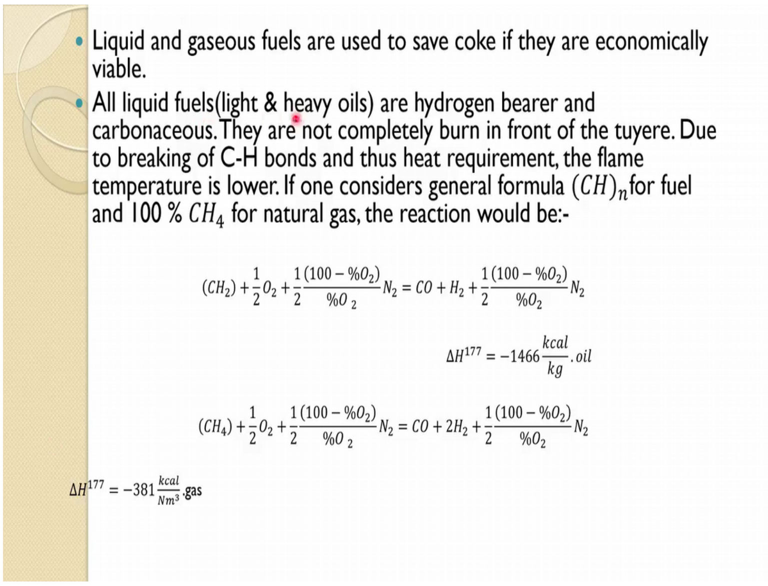

So, just to say, so, economical is ever more viable. So, all liquid fuel light and heavy are hydrogen bearer and carbonaceous and have carbon and hydrogen bonds. So, for which to break it; you need the heat and to do that they are not completely burn in front of the tuyere. The time with they have actually. So, the flame temperature always is lower when we use the liquid fuel. So, you have been do not consider general formula like CH 2 to of this type of fuel and 100 percent methane for natural gas.

The reaction would be something like that; where this is the oxygen and remaining. Because we are doing this in terms of presence of air with quite a lot 80 percent nitrogen is there, depending if it is a entries oxygen blast or what. So, the you can write the balanced equation and the enthalpy for the reaction; for natural gas which is mostly comprising with methane.

Similarities you can write this equation; where, hydrogen and CO is forming. Look at this product the product actually CO and hydrogen. So, this is highly reducible. So, reducing power of this is increasing due to the hydrogen and hydrogen is much much stronger reducing agent than carbon monoxide.

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Flame temperatures of some blast furnace fuels, °C

Blast temperature °C	$\%O_2$	Carbon	Fuel oil	Natural gas	Coke-oven gas
900	21	2295	1315	671	518
900	25	2510	1360	651	505
1100	21	2458	1443	768	583
1100	25	2667	1497	740	566
1300	21	2621	1570	866	648
1300	25	2825	1598	830	627

So, some the flame temperature or some of the fuels is given heat here. So, flame temperature is very important; it is usually it is around between 2000 to 2200 that is the I am to keep it; so, but depending on the other condition. So, if the blast gas temperature is about 900 and oxygen; so, which is just a normal air and carbon is the fuel. So, let us suggest only PCI injection is there. Then your flame temperature would be around 2295.

Now, instead of Carbon, if you are using fuel oil; see how much decrease in the flame temperature, very low. And Natural gas, it is even lower. Coke-oven gas is even lower.

So, probably these are not even correct to use it. Let me probably create more problem more volume and things in the blast furnace.

So, one had to look at the whole chemistry and the volume of it and then, must you have the right combination or right fuel. And when you increase the, this blast temperature; you can see the flame temperature of all of those increases.

But again, the flame temperature of natural gas in turn when using natural gas as a fuel or coke oven gas is hardly reaches more than 800 off like that. So, these are really not a very good choice for the fuel. They can be combined with some other.

So, many times you use the oxygen rich blast which usually increase the flame temperature, fueling all is ok. So, this gives an idea about the flame temperature. So, flame temperature that is the highest sort of temperature which is prevailing in the, raise variation or in the cavity region. And that is where the flame temperature comes into picture.

Now, we talked about the pre heating blast temperature Blast Air.

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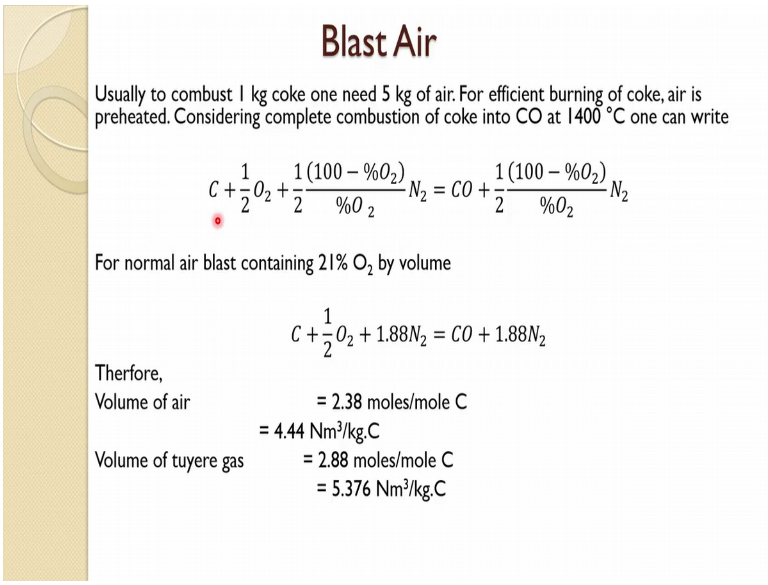

So, this is about the, if you do not pre heat; then, to combust 1 kg coke. You need actually 5 kg of air that is a huge volume and remember in this 5 kg of air 80 percent is your nitrogen, which takes away the sensible heat and other thing and it is a increases the fuel rate. They are the coke rate and which really you do not want. So, it is always good to heat it, heat the blast air for the reducing the concrete and efficient warning of the coke.

So, air is preheated and considering the complete combustion of coke at 1400 degree Celsius, one can I can write the chemical equation for that. And if normal air blast because had 21 percent oxygen. So, that and then, one can get the moles of nitrogen. This gives the volume about 4.44 Normal meter cube per kg carbon and a tuyere gas volume comes to this.

So, volume also reduces and that way.

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If t_b and t_f are the blast and flame temperatures in °C respectively,

$$2300 + 540 + 4.44 * 0.333 t_b = 5.376 * 0.338 t_f$$

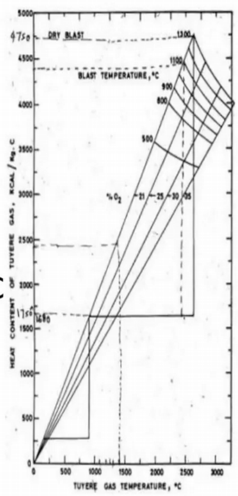
where,

2300 = heat of combustion of C to CO, kcal/kg.C

540 = heat content of carbon at 1400 °C, kcal/kg.C

0.333 = heat capacity of air, kcal/Nm^3. °C

0.338 = heat capacity of tuyere gas, kcal/Nm^3. °C



And this tells you how you can get the flame temperature. And so, the end the tuyere gas temperature. So, this is the blast temperatures, which like preheating the blast. So, t b is the blast temperature and t f is the flame temperature. So, for this case about the blast air, when we are doing at 1400 on complete combustion of it; it is preheated there is a sort of a correlation why which you can calculate the flame temperature.

So, 2300 so, here it is showing the heat of combustion of carbon 540 is showing the heat content of the carbon at 1400 degree please ok.

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If t_b and t_f are the blast and flame temperatures in °C respectively,

$$2300 + 540 + 4.44 * 0.333t_b = 5.376 * 0.338t_f$$

where,

2300 = heat of combustion of C to CO, kcal/kg.C

540 = heat content of carbon at 1400 °C, kcal/kg.C

0.333 = heat capacity of air, kcal/Nm³. °C

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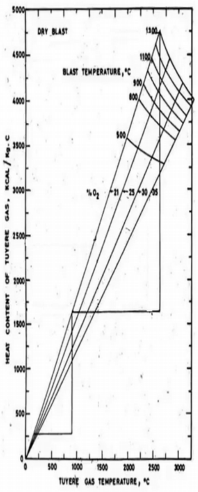

So here, we can have a sort of a correlation between the blast temperature and the flame temperature which is given below. So, t b is the blast temperature and t f is the flame temperature. So, 2300 is a heat of combustion of carbon to CO in kilo calories and 540 is heat content of carbon at 1400 degrees Celsius in kilo calories and 0.33 is the heat capacity of air in kilo calories for normal meter cube and 0.338 is the heat capacity of the tuyere gas and this adjoining figures.

So, that how? So, if you know the blast to temperature, from these you can calculate the flame temperature. So, our voice forces you can have it; if you need a particular flame temperature. So, what sort of preheating of the blast needed, you can do that and this adjoining figure is showing about the tuyere gas temperature is nothing it is a flame temperature and the blast temperature.

So, these are the blast temperature curve. And this is actually the percentage of oxygen. So, oxygen enrichment if you put it. So, 21 percentage of presenting the normal air and this is the enrichment with a of the air with oxygen. And from that one can easily calculate, what about the heat content of the tuyere gas (Refer Time: 10:25) the flame temperature ok, temperature or the heat content of the gas or the blast temperature that gives an idea how to control the flame temperature was changing on these variables.

And because this is very important of flame temperature for burning of the coal and produce producing, the reducing gases at the right temperature which had to go up to the top.

So, this is an important parameter.

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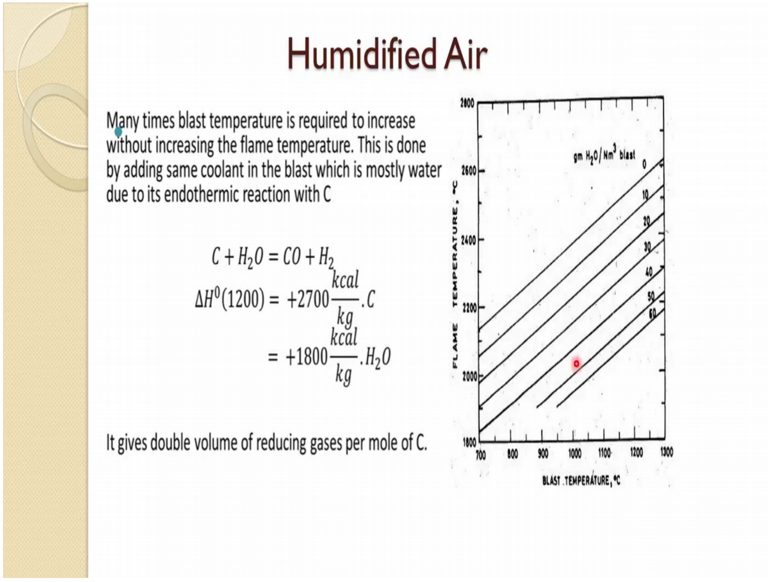

Similarly, many times to increase the reducing capability of the cases or even reduce the sometime temperature to humidify the air. Humidification means you somehow add some water into it in the air. So, many times blast temperatures required to increase without increasing the flame temperature. So, this is then by adding some coolant in the blast which is mostly water due to its endothermic reaction.

But here one thing must be remember, you do not add water directly in the pre heated; air because that water has to evaporate and we will consume the heat and it will reduce the blast temperature. And other problem also comes.

So, usually what you, do you, put this water in this top when you are sending the cold air during that time you do it. And with that it is you who modified it and it comes and from this, you can see you are really getting a double volume of the reducing cases CO and hydrogen, when you put the water from the one.

So, you are reducing powers increases and because it takes the heat and return reacts and this also reaction or the water subtraction and as you can see, as you increase the powder content, your flame temperature decreases or you can have a blast temperature decrease to maintain the same flame temperature if you want to maintain a 2000 degree flame temperature.

So, either you can put 20 percent water at this pre preheating or you can preheat the blast temperature can be up to 800 and 30 percent. So, like this you can know how to control, those your blast temperature keeping the flame temperature constant; because that is more important and then this.

But this is also important, but sometimes you do not want to go really up to 700, you want to go probably a 1000. Then, and you should know how much moisture or humidified air, you have to make this blast or put the water.

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As pulverised coal injection reduces the Raceway Adiabatic Flame Temperature (RAFT) or flame temperature, usually oxygen enriched blast is used. To calculate the RAFT, a following empirical correlation has been proposed (all parameters are in SI unit).

RAFT = 1489 + 0.82xBT – 5.705xBM + 52.778x(OE) – 18.1x(Coal/WC)x100 – 43.01x(Oil/WC)x100 – 27.9x(Tar/WC)x100 – 50.66x(NG/WC)x100

BT: Blast Temperature in °C
BM: Blast Moisture in g/m^3 STP dry blast
OE: Oxygen enrichment (% O_2 – 21)
Oil: Dry oil injection rate in kg/tHM
Tar: Dry tar injection rate in kg/tHM
Coal: Dry coal injection rate in kg/tHM
NG: Natural gas injection rate in kg/tHM
WC: Wind consumption in m^3/tHM

So, these things had been done with many experiments and have been put forward the in that figure. As similarly, as we said when we say about the flame temperatures many times this is known as the Raceway Adiabatic Flame Temperature.

So, the pulverized coal injection reduces Raceway Adiabatic Flame Temperature or flame temperature that we were referring before. So, usually oxygen enriched blast is used. To calculate the RAFT, which is nothing the short form of Raceway Adiabatic Flame Temperature, a following formula empirical correlation has been proposed and all these units actually are in SI. So because this is an empirical correlation.

So, there is no theory behind it with the many experiment that people have proposed this relation. So, BT is a Blast Temperature. BM is the Blast Moisture content in gram per meter cube. OE is Oxygen enrichment. So, of whatever like 25 percent when we said essentially you are putting a 4 percent oxygen and enrichment because 21 is already present in the air.

Similarly, this is WC the Wind concept Consumptions of coal per wind consumption in meter cube per ton hot metal. Similarly, the oil dry oil injection rate divided with the consumption. Similarly, the tar, dry tar injection rate, natural gas injection rate in kg per ton of hot metal so, based on this, one can roughly calculate what would be the flame temperature?

If one is not using natural oil or something; then, certainly this term will become 0. So, one should not consider this one. How to use this one? One example is given here.

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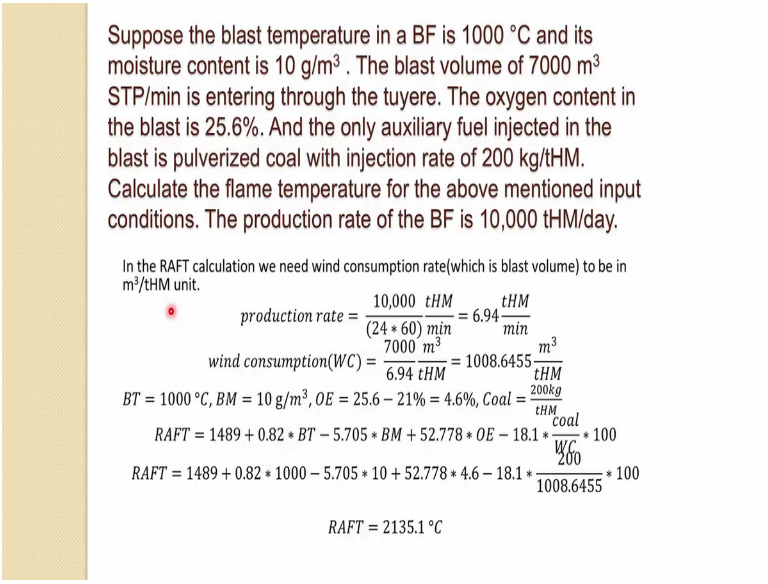

So, suppose the blast temperature in a Blast Furnace is 1000 degree Celsius and its moisture content is 10 gram per meter cube. The blast volume of 7000 meter cube. STP per minute is entering through the tuyere. The oxygen contained in the blast is 25.6 percent, which means it is a enriched oxygen blast which is about 4.6 percent enrichment.

And the only auxiliary fuel injected in the blast is part of a pulverized coal with the injection rate of 200 kg per ton of hot metal. So, one had to find the flame temperature in the above condition. The production rate of the blast furnace is 10000 ton hot metal per day. So, really we need a bin. So, if you look at the formula this. So, we have to use this one, because we are using pulverized coal. Blast Moisture, Blast Temperature, Oxygen enrichment.

But other things are not coming into the picture, but we need also the Wind consumption. So, in meter cube per ton of hot metal and directly it is not given as such blast volume is given. So, we have to calculate that one from the products and rate in combining blast volume. So, products and rate a 1000 ton hot metal per day which will give you 6.94 ton hot metal per minute.

So, 24 into 60's was going to convert your day in to minutes. So, wind consumption would be when to divide this turn hot metal per minute, will give you the in the meter cube per ton of hot metal. So, 7000 meter cube per minute you are having. So, that. So, that is a meter cube per minute actually, that is going to give you the ton of hot metal. So, what you got once you go WC, other values are given the Blast Temperature, Blast Moisture, Oxygen enrichment, 4.6 and the coal rate is also given you can directly put into the formula.

And this formula, of 0.82 into BT is 1000. So, BM is 10. It is 4.6 and then, your coke relative divided by when consumption. These 2 flame temperature comes, 2135 and that seems quite reasonable as we have seen under the previous table of this one. So, that seems very reasonable flame temperature in that condition.