Fuels, Refractory and Furnaces

Prof. S. C. Koria
Department of Materials Science and Engineering
Indian Institute of Technology, Kanpur

Lecture No # 17
Heat Utilization in Furnaces, Energy Flow Diagrams

Today, I will talk on heat utilization in furnaces.

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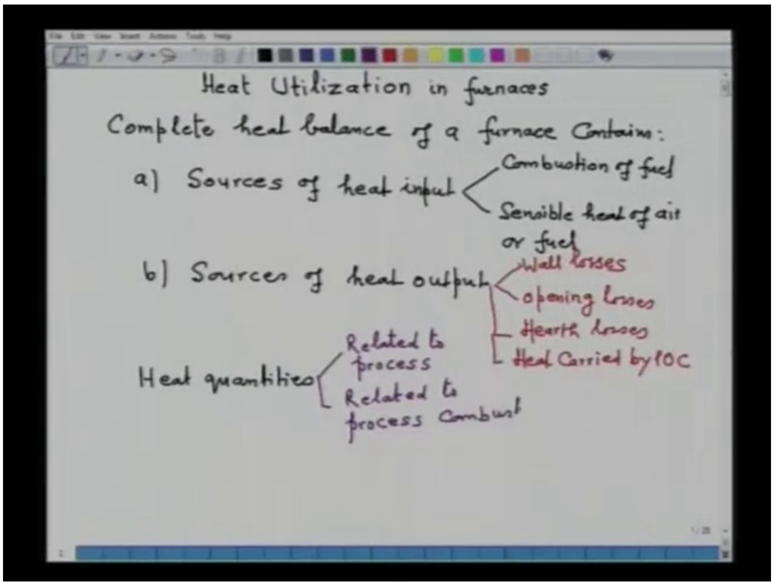

Heat Utilization in furnaces

Complete heat balance of a furnace Contains:

a) Sources of heat input
- Combustion of fuel
- Sensible heat of air or fuel

b) Sources of heat output
- Wall losses
- opening losses
- Hearth losses
- Heat Carried by POC

Heat quantities
- Related to process
- Related to process Combust

Complete heat balance of a furnace shows how the heat flows into the furnace; that means, the complete heat balance of a furnace contains a – sources of heat input. Now, these sources could be combustion of fuel and sensible heat of air or fuel. These are the heat input terms. And, sources of heat output – they comprise of for example, wall losses, then opening losses; in fact, all type of losses, which are possible on operation of the furnace. It could also be losses from the earth – earth losses and then heat carried by POC.

Now, in controlling combustion or in analyzing means to improve economy of fuel utilization, it is required that we consider heat quantities separately. There are heat quantities, which relate to fuel consumption and there are heat quantities, which relate to the process; that means, we have to distinguish the heat quantities related to process. I mean to say suppose we are carrying out heating of a billet, bloom or slab or we are carrying out melting or we are carrying out refining or we are carrying out roasting, smelting; that means, whatever metallurgical function we are carrying out; or, for example, in the cement industry, you are carrying out calcinations. So, the certain quantities, which directly relate to the process or to carry out a thermally derived function – which could be calcinations, which could be roasting, could be smelting, could be refining, could be heating only.

Then, there are heat quantities, which are related to process combustion; that means, these quantities relate to combustion and they tell us the consumption of fuel. So, we have to distinguish from the heat balance the two types of quantities. And, accordingly, that will help us to analyze the heat utilization in furnace; that means, we must be very clear in our mind that there is certain quantity of heat, which will utilize for the process; certain quantity of heat, which will be utilized for combustion purposes. So, now, in analyzing utilization of heat from fuel combustion, it is not only amount of heat important, but it is also the temperature at which that particular amount of heat is available, is also important; that means, when you want to analyze utilization of heat from the combustion of fuel, then it is the temperature as well as the amount of heat; both are important issue.

For example, we want to carry out a process say 1200 degrees Celsius. Then, whatever type of fuel or whatever combustion process we select – excess air, oxygen enrichment, preheating – whatever process we select, it must be able to generate the temperature, such that we can operate the process at a desired temperature. So, while considering the utilization of heat from fuel combustion, it is the temperature and amount of heat – both are important.

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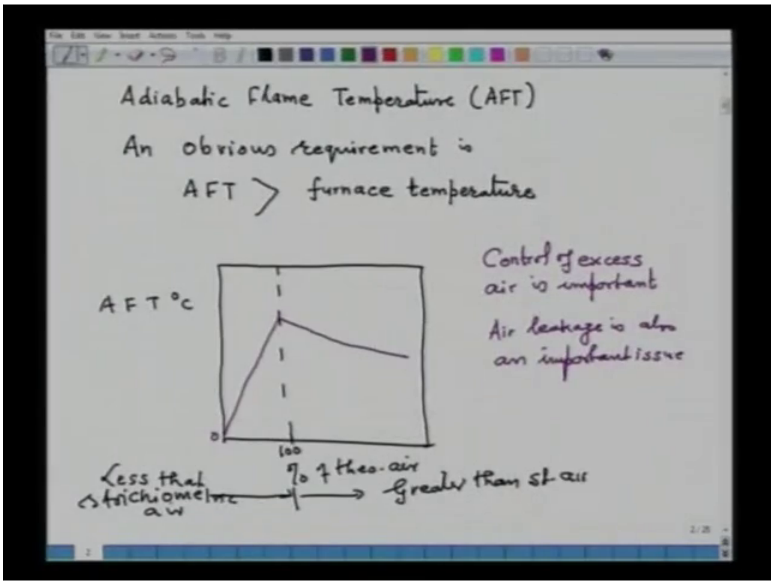

Adiabatic Flame Temperature (AFT)

An obvious requirement is

AFT > furnace temperature

Control of excess air is important

Air leakage is also an important issue

Now, in this connection, the adiabatic flame temperature – in short, I will be writing AFT, is a very important tool both are from indirect and indirect point of view as a criterion for fuel utilization; that means, the calculation of adiabatic flame temperature can give us a clue whether a selected fuel and the condition of combustion will give us the required temperature or not. So, an obvious requirement is that the calculated value of adiabatic flame temperature should be greater than furnace temperature. Now, why is it so? If adiabatic flame temperature is equal to furnace temperature, then no heat transfer will occur and the charge will not be raised to the desired temperature. Therefore, it is quite obvious.

Then, we proceed to select a fuel and combustion process. The adiabatic flame temperature so-calculated must have a higher value than the furnace temperature, because all of you know from the lecture 1, where I said sources of energy that the mechanism of heat available from combustion of fossil fuel is in terms of the heat of products of combustion; that means, it is the products of combustion that gives its heat to the charge; that is, here heat transfer rate is an important issue. For that matter, adiabatic flame temperature must be greater than the furnace temperature.

However, higher flame temperature though desired from the higher heat transfer rate point of view, but higher adiabatic flame temperature can also cause local overheating and can destroy the refractory. So, these things are to be kept in mind. And, these aspects

I have discussed in lecture 12. In lecture 12, I have also said how to calculate the adiabatic flame temperature; and in one or two problems, I have illustrated the calculation of adiabatic flame temperature. So, in connection of fuel utilization, adiabatic flame temperature is very important.

We have also seen earlier that adiabatic flame temperature decreases with excess air than a stoichiometric amount. In fact, if you… I will just… Once again, I will draw a semantic. Here I will take AFT; you can take in degree Celsius or in degree Kelvin, does not matter. And, here I take percentage of theoretical air (Refer Slide Time: 10:12). So, somewhere here I will connect 100 percent. So, this side is less than a stoichiometric air and this side is greater than a stoichiometric air; or, you can also call that beyond 100 percent, this is the excess air. So, we I also calculated in lecture 12, how the amount of air above a stoichiometric decreases the flame temperature by taking one example.

Now, here say if I want to show restart from 0 and as we increase the amount of air, then the adiabatic flame temperature attains maximum value at theoretical amount of air. And then, it again begins to decrease as you increase the percentage excess air. So, this one can calculate and one can show… So, from the utilization of fuel point of view, what is important? The control of excess air is important.

Now, as I have pointed out in my lectures 9 to 12, which are on combustion and material balance, I have said over there that in reality, the complete combustion does not occur with exact stoichiometric amount of air, because of certain practical difficulties, which I have mentioned earlier. If we have the gaseous fuel, around 4 to 5 percent excess air is required; if we have liquid fuel, the excess air may go around 15 to 20 percent; whereas, a solid fuel – excess air may be as high as 40 to 50 percent. So, what is important? The control of excess air is a very important issue in order to utilize the fuel or in order to increase the coefficient of utilization of fuel.

In this connection, also, it is important – air leakage; air leakage is also an important issue from fuel heat utilization point of view. What is said over here that though the combustion requires excess amount of air, but through the proper design of the combustion system, proper maintaining the mixing and so on in the combustion chamber, the excess air should be kept to the minimum possible. Even the operation carried out with the minimum amount of excess air, air should also be exercised, so that no air leakage can occur. That is why the furnace is slightly above atmospheric pressure to avoid the air leakage. So, that is an important thing.

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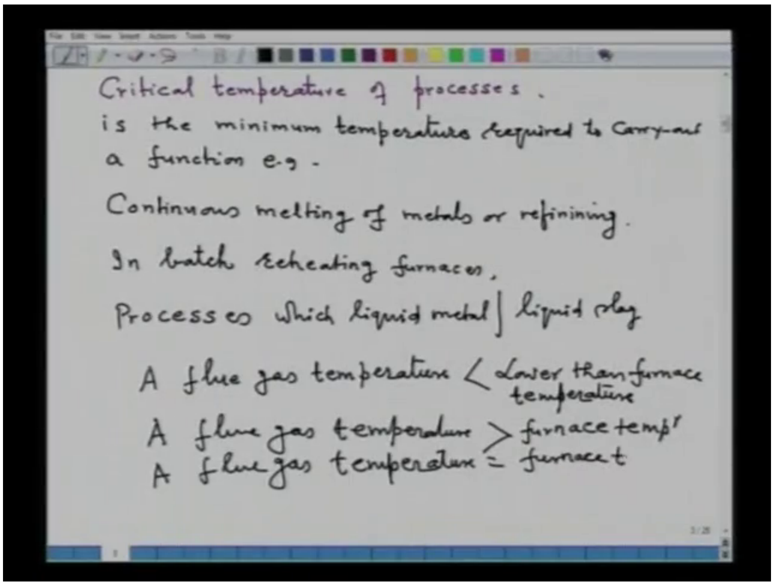

Critical temperature of processes.

is the minimum temperature required to carry-out a function e.g -

Continuous melting of metals or refinining.

In batch reheating furnaces.

Processes which liquid metal | liquid slag

A flue gas temperature < lower than furnace temperature

A flue gas temperature > furnace temp'

A flue gas temperature = furnace t

Now, another important thing is the critical temperature of processes. Critical temperature is the minimum temperature, which is required to carry out a process. So, I will write again – critical temperature is the minimum temperature required to carry out a function. For example, if we are having say continuous melting of metals or refining, we have to make sure that the entire process chamber is maintained at least at a temperature to the melting point of the metal; slightly above will be good. But, the minimum temperature that the furnace should have is the melting point of the compound. For example, if we are melting copper, then the minimum temperature that the furnace should have is of the order of 1083. But, slightly excess is required in order to have a uniform temperature.

Now, for example, if we are saying batch reheating, say in batch reheating furnaces, the temperature should be at least equal to the temperature at which we want to heat for example, slab, bloom or billet. For example, if we want to heat the billet for thermomechanical processing or heat treatment purposes to a temperature of 1200 degree Celsius, then the critical temperature of the reheating furnace is 1200 degree Celsius. So, that is what. The critical temperature is the minimum temperature at which the function is to be carried out.

A similar can be given. Say if we use say processes, which use liquid metal or liquid slag, then the critical temperature in this case would be the pouring temperature of liquid metal. If it is slightly lower, then you may not be able to pour the metal. The critical temperature for liquid slag is that free running of slag; otherwise, you will not be able to take all the slag. So, that is what the concept of critical process temperature is. In calculation of the heat utilization, it is important for us to know what is the temperature at which the process is operating. In cases or in the problem, where this is not known, then the concept of critical temperature has to be invoked and can safely be made assumption that at least the temperature of the furnace is that of critical temperature. For example, it is melting of metal; then, the melting point or liquid metal; it is the pouring temperature and so on, so forth. So, what it is said is that the critical temperature has significance in relation to utilization of heat from burning of fuel; that means, that critical temperature is the lowest temperature at which the flue gases will exit the furnace.

Now, as all of you know, from the mechanism of heat available from fossil fuel combustion is through the products of combustion; a flue gas temperature, which is lower than furnace temperature; or, a flue gas temperature greater than furnace temperature; or, a flue gas temperature equal to furnace temperature. Now, what I mean from here that in fossil fuel fired combustion furnaces, three conditions can arise. A flue gas temperature can be lower than the furnace temperature. What does it mean? That means certain parts of the furnace are under heated; that is not required. Another condition can occur – a flue gas temperature can be greater than the furnace temperature. When it is possible, can you think of a flue gas temperature, which is greater than the furnace temperature; that means, the furnace is not at uniform temperature. Certain parts of the furnaces are over heated and the flue gases are leaving at temperature higher than the process critical temperature; the both conditions are not desirable. What is ideally desirable? A flue gas temperature equal to furnace temperature; that means, the entire process or entire furnace is heated at a uniform temperature. You may consider it as an ideal condition.

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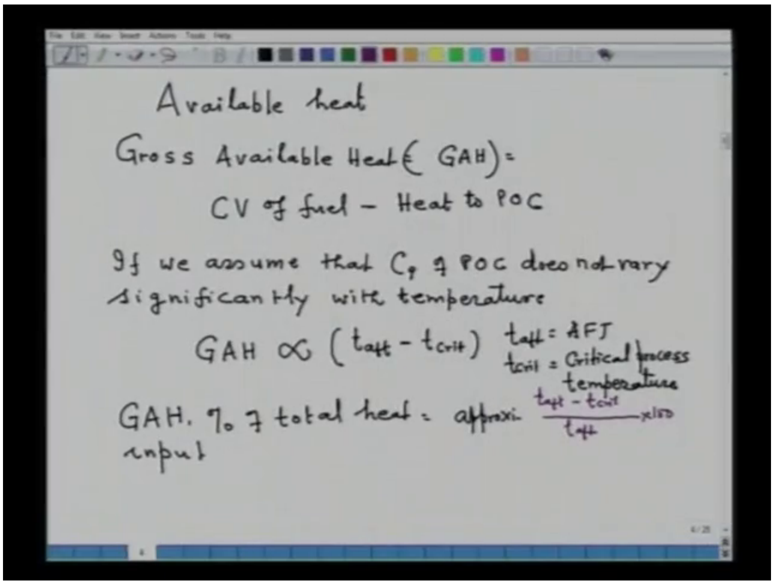

Available heat

Gross Available Heat (GAH) =

CV of fuel – Heat to POC

If we assume that C_p of POC does not vary significantly with temperature

$GAH \propto (t_{aft} - t_{crit})$

t_{aft} = AFT

t_{crit} = Critical process temperature

GAH. % of total heat input = approxi. $\frac{t_{aft} - t_{crit}}{t_{aft}} \times 100$

Now, from here we can we can invoke a concept of available heat. Let us state what an available heat is. It is known as I have said repeatedly that the heat carried away by the POC at the process critical temperature is not available to the furnace operator. This heat should not be considered as loss. It is not like wall losses or opening losses. But, it is the inherent feature of the thermal energy derived from fossil fuel combustion. So, considering that, we can define the so-called gross available heat; or, in short, GAH; that is equal to calorific value of fuel – CV of fuel minus heat to POC.

You may also consider gross available heat is the heat given by POC in cooling from flame temperature to the critical temperature of the furnace; that means, on combustion, the products of combustion will be raised to a flame temperature and the products of combustion cool to the process critical temperature. And, the heat, which is given in this cooling is in fact the gross available heat; that is, one can calculate both ways; one can also calculate the calorific value and subtract it, the heat carried by the POC; or, you can also calculate the heat released in cooling products of combustion from flame temperature to the process critical temperature.

Now, for example, if we assume that C P of POC does not vary significantly with temperature in the range we are talking about, then one can write gross available heat would be directly proportional to t aft minus t critical; where, t aft is the adiabatic flame temperature and t crit is the critical process temperature. Now, we can further define say gross available heat in percent of total heat input, will be equal to approximately… Now, this approximately is coming… because we have taken C P to be slightly independent of temperature in the range of cooling from flame to the critical process temperature. So, that will be equal to t aft minus t critic divide by t aft into 100. So, this is the gross available heat in terms of percentage total heat input.

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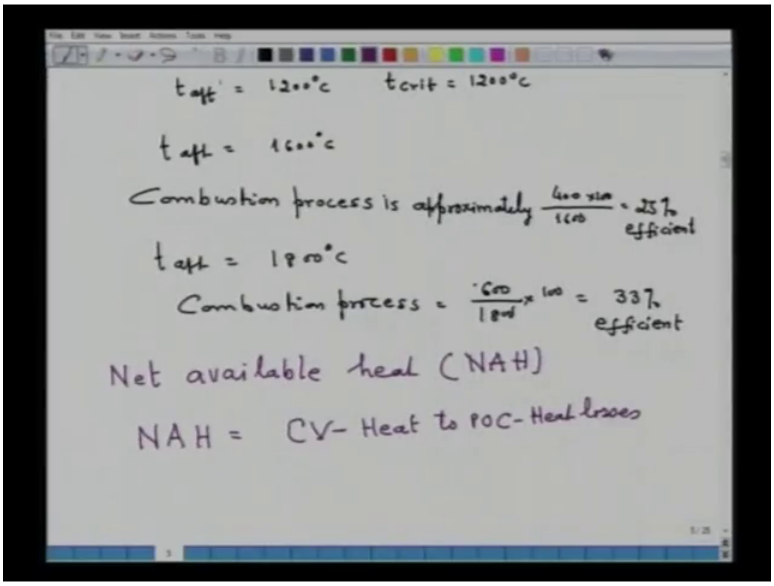

$t_{aft}' = 1200°c$ $t_{crit} = 1200°c$

$t_{aft} = 1600°c$

Combustion process is approximately $\frac{400 \times 100}{1600} = 25\%$ efficient

$t_{aft} = 1800°c$

Combustion process = $\frac{600}{1800} \times 100 = 33\%$ efficient

Net available heat (NAH)

NAH = CV − Heat to POC − Heat losses

Now, for example, let us take t aft is equal to 1200 degrees Celsius and the t critic is also 1200 degrees Celsius; that means, if we require a furnace temperature of 1200 degree Celsius and if the combustion process generates 1200 degree Celsius as the adiabatic flame temperature, this combustion process is useless from the heating point of view, because there will be no heat transfer and nothing will happen. This particular combustion process cannot be used for a metallurgical function. A t aft that is equal to 1600 degree Celsius; then, the combustion process is approximately 400 upon 1600 into 100; that is equal to 25 percent efficient.

Now, can we get a feel the importance of adiabatic flame temperature calculation? That I have illustrated also in my lecture number 12. Now, you can see from here how far the calculation of adiabatic flame temperature can help in selecting the fuel and in selecting the combustion process. In this particular example, if you are given a certain choices of fuel and choices to make of the combustion system and if you have assumed a certain value of the heat transfer rate, then you can select the type of fuel. In this particular example, an adiabatic flame temperature of 1600 degrees Celsius, in that case, the combustion process is 25 percent efficient.

Now, another example if you take, if t aft is equal to 1800 degree Celsius, then combustion process would be 600 upon 1800 into 100; that will be 33 percent efficient. Say if you take now t critical as say 1000 degree, then the same AFT will give little higher efficiency. So, what this calculation suggests? That adiabatic flame temperature is a very important parameter for fuel utilization purposes. From the calculation of adiabatic flame temperature, one can select the type of fuel, because that type of fuel is useful, which can give you… For example, if you want 25 percent efficiency or 30 percent efficiency or 40 percent efficiency, accordingly, one can select or one can make a choice of selection of fuel.

Also, one can make a choice of selection of the combustion process. With this, I mean that the adiabatic flame temperature besides calorific value of the fuel is also influenced by the where whether air is more than stoichiometric or oxygen (( )) has been used or preheating has been done. So, in a sense, the adiabatic flame temperature can be used safely as the criteria of selection of the fuel. This criterion can be further also explored in switch of the fuel. With switch, I mean suppose furnace is operating for example, with natural gas and we want to replace by producer gas – a natural gas is a high quality fuel, because it generates a very high adiabatic flame temperature and a producer gas is a low quality fuel, because it generate less adiabatic flame temperature. And, if you want to replace, that is, if you want to conserve the natural gas resources and you want to replace that producer gas, then by calculating the adiabatic flame temperature, one can find out what would be required if we want to switch over from high quality fuel to low quality fuel in order to conserve the natural resources.

The importance of adiabatic flame temperature – now, one should also remember that the gross available heat represents the heat available at critical process temperature. It does not represent heat available to the metallurgical process, because what we are doing in calculating the gross available heat, we are simply considering the heat released by the products of combustion from flame temperature to the critical process temperature. So, it only says that much amount of heat is available to you at critical process temperature; whereas, the furnace requirement or the metallurgical function requirement could be different. For example, melting – if we just supply a gross available heat, which is calculated on the basis of critical process temperature, then the metal may not melt, because you will not consider the losses which are occurring, because the amount of heat which is being lost through the wall or through the opening has to be compensated by extra amount of fuel. Therefore another quantity is important, which is called net available heat (Refer Slide Time: 33:00) or in short, one can say NAH – net available heat.

Now, the net available heat can be calculated from calorific value minus heat to POC minus heat losses. All types of losses one has to consider. Now, the amount of heat, which will be available – that will represent the heat, which is available for metallurgical function; or, in that way, for any function, which you want to carry out. So, the concept of gross available heat and net available heat is a very important from fuel utilization point of view. Depending on the objective, one can calculate either gross available heat or net available heat.

Now, say consider a situation where the daily requirement for the process is known; you know that on per day basis, I will be requiring that much amount of fuel; or, per hour, per day requirement or per month requirement of heat is fixed. Then, one can also calculate the consumption of the fuel.

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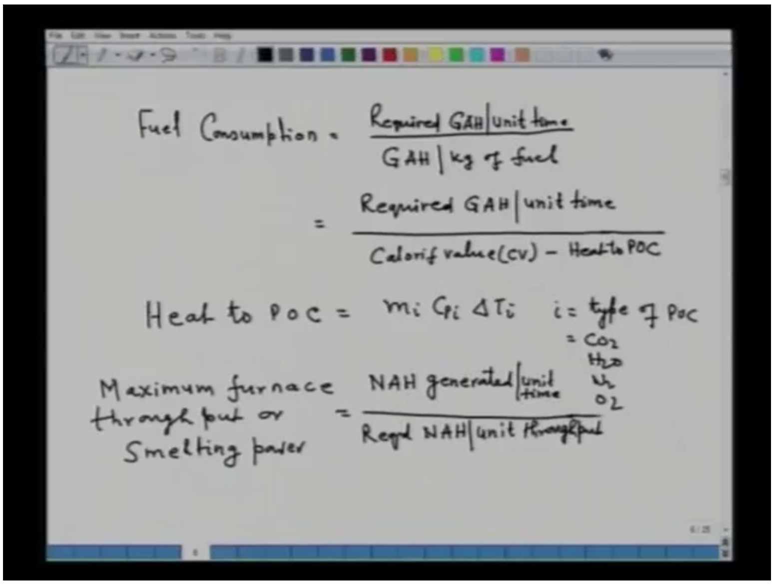

$$\text{Fuel Consumption} = \frac{\text{Required GAH}|\text{unit time}}{\text{GAH}|\text{kg of fuel}}$$

$$= \frac{\text{Required GAH}|\text{unit time}}{\text{Calorif value(CV)} - \text{Heat to POC}}$$

$$\text{Heat to POC} = m_i\, C_{pi}\, \Delta T_i \qquad i = \text{type of POC}$$

$$= CO_2,\ H_2O,\ N_2,\ O_2$$

$$\begin{array}{c}\text{Maximum furnace}\\ \text{through put or}\\ \text{Smelting power}\end{array} = \frac{\text{NAH generated}|\text{unit time}}{\text{Reqd NAH}|\text{unit throughput}}$$

Now, let us see how we can calculate say fuel consumption. Fuel consumption will be equal to a required gross available heat per unit time upon gross available heat per kg of fuel. That will give us the fuel consumption. This is further equal to say required gross available heat per unit time upon – gross available heat per kg of fuel can be calculated from calorific value of fuel – calorific value in bracket CV minus heat to POC. Heat to POC can be calculated; say heat to POC – that will be equal to m i C p i into delta T i. So, that is how; where, i is the type of POC, that is, i is equal to CO 2 or H 2 O or N 2 or O 2. In the lectures 9 to 12, I have illustrated how to calculate the heat to POC. So, that is how one can calculate the fuel consumption.

Now, in many cases, it is also important to know what the furnace throughput is; that is, the objective of the fossil fuel combustion is to carry out a metallurgical function. So, there it is also important what the maximum furnace throughput is. And, the maximum throughput of the furnace will not depend on gross available heat, because gross available heat will simply tell you, that much amount of heat is available to you at the process critical temperature. It will not tell you the throughput.

Throughput means suppose you are heating at 1200 degree Celsius a slab or bloom, then throughput of the furnace will be the slab or the amount of the flame, which are coming out at 1200 degree Celsius. So, there concept of gross available heat is not sufficient, because you are not considering in fuel consumption losses which are occurring. So, the maximum throughput… or, for that matter, you are carrying out smelting as a function. So, then we can define the term maximum furnace throughput or a smelting power – that will be equal to NAH (net available heat) generated per unit time upon required net available heat per unit throughput. So, one has to distinguish the fuel consumption and maximum throughput. So, this is about… Now, here in the fuel combustion, we have taken only calorific value of the fuel. In fact, one should also take… Suppose if the fuel is preheated, then the heat input will be calorific value of the fuel plus sensible heat of the air or fuel whatever the case may be.

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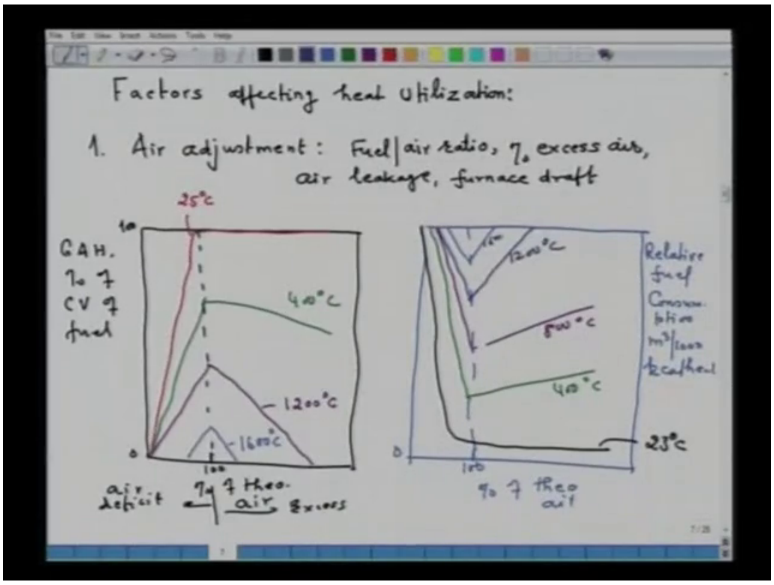

Factors affecting heat utilization:

1. Air adjustment: Fuel|air ratio, % excess air, air leakage, furnace draft

Now, let us consider the factors affecting heat utilization. Say first one – air adjustment – this constitute for example, fuel air ratio. One has to control fuel air ratio percent excess air, air leakage, furnace draft; that is, the air adjustment is very important; one has to control the excess air, fuel air ratio and so on. So, for example, if I want to semantically represent how the variation will affect, then this will look something like this. In the semantic, here I put percentage of theoretical air. So, somewhere here it is 100, which is the theoretical air. So, this side is excess air and this side is air deficit; that is, less than stoichiometric air and more than stoichiometric air. 100 – this point is 100, is the stoichiometric amount of air.

Now, on the y-axis, this is the (Refer Slide Time: 41:44) gross available heat (GAH) in percent of calorific value of fuel – say at maximum of 0 to 100. So, what we are plotting now, we are seeing the effect of air adjustment on gross available heat, which is expressed in terms of percentage of calorific value of the fuel. Now, if you recall, the gross available heat, which is calculated – calorific value minus heat to POC; and, heat to POC depends also on the critical process temperature. So, this plot, which is gross available heat in terms of percentage of calorific value of the fuel – if I plot against percentage of theoretical air, then naturally, it will be a function of process critical temperature.

For example, if I take 25 degrees Celsius, then the maximum amount of heat will be available for example, if I take 25 degree Celsius as the process critical temperature; there is no heat loss. All the heat will be available to you in the process; now, less than stoichiometric and more than stoichiometric. So, more than stoichiometric – this value (Refer Slide Time: 43:09) will be constant; nothing will be happen. Why it increases? Because as you increase the amount of air, more and more fuel will be burnt and less and less fuel will be formed; at the 100 percent, which is a stoichiometric amount, the fuel is completely burnt. Therefore, you will be getting the maximum amount of gross available heat.

Now, for example, if we take a process critical temperature of 1200 degrees Celsius, this one (Refer Slide Time: 43:40) and again the gross available heat will drop rapidly. So, this is for the process critical temperature 1200 degrees Celsius. Now, if I take a process critical temperature 400 degrees Celsius, then it will go something like this. And, if I take a process critical temperature say 1600 degrees Celsius, then it drops very rapidly. Now, the temperatures, which I have written, it is just to illustrate what happens to the gross available heat if the process critical temperature increases. Say for a given type of fuel, this plot can be generated. If you know the type of fuel, if you know the calorific value, then all that you require is to combust heat and calculate gross available heat. So, what this particular gross says, that the gross available heat depends on process critical temperature for a given amount of air.

Now, suppose if we select a stoichiometric amount of air, then as the process critical temperature increases, the gross available heat decreases naturally, because then, the heat taken out by POC will increase, because the process critical temperature increases. And therefore, gross available heat will decrease as the process critical temperature increases. Now, the whole idea or the reason for decrease in the gross available heat with the excess amount of theoretical air, that is, if you go on the right-hand side of 100 percent, then this is essentially due to the excess amount of nitrogen and oxygen, which will be available in the products of combustion as you increase the amount of air greater than the stoichiometric amount of air.

Now, if the same plot can be used also to calculate the fuel consumption; that means now, say (Refer Slide Time: 46:00) if I plot now, this is again 100; this is the percentage of theoretical air; this is 0. And, here I will plot relative fuel consumption say for example, meter cube per 1000 kilocalorie heat. So, if I now, try to generate a plot of the fuel consumption with the theoretical air, then same way if I have a process critical temperature 25 degrees Celsius, then the fuel consumption will be minimum; this is for 25 degrees Celsius. Now, if I have a process critical temperature as 1600 degrees Celsius, then the fuel consumption will be very high. Naturally, higher is the process critical temperature, more amount of heat will be carried away by the POC and hence higher amount of fuel will be required in order to carry out the process.

Now, if I have for example, 400 degrees Celsius, then this is for the 400 degree Celsius (Refer Slide Time: 47:51). And, if I have for example, 800 degrees Celsius, then… And, what is important to know, say if I take say 1200 degrees Celsius, then the fuel consumption decreases up to the stoichiometric amount; then, it drastically increases – this is for 1600 degree Celsius (Refer Slide Time: 48:22) – then, it drastically increases if the process critical temperature is 1200 degrees Celsius. A 400 or 800 degree process critical temperature – the fuel consumption increases gradually. But, at higher temperatures say 1200 or 1600, the fuel consumption increases rapidly mainly because of the C P value of nitrogen and oxygen. So, this is how the effect of air adjustment on gross available heat and fuel consumption can be illustrated. However, these all things can be calculated; I will try to calculate in one or two problems in the subsequent lecture, so that you can understand how to calculate the fuel consumption, how to correlate gross available heat with the fuel consumption and so on, so forth. We will take few problems, so that you can understand.

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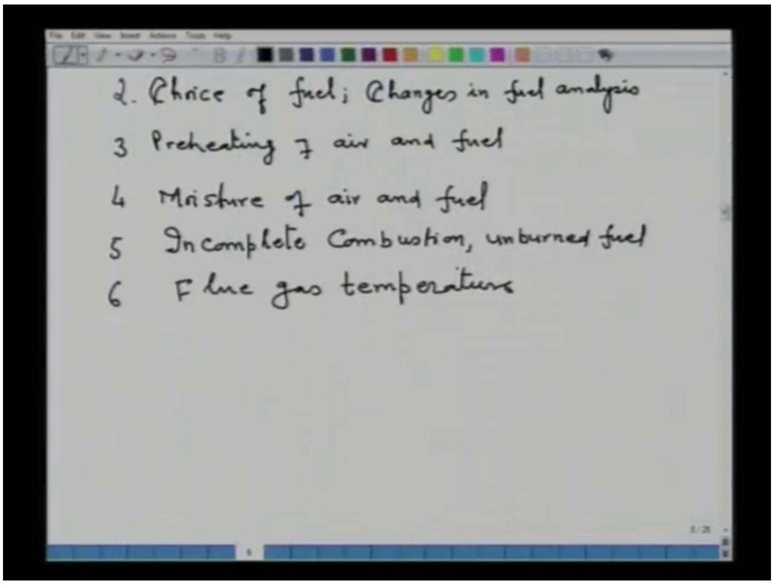

2. Choice of fuel; Changes in fuel analysis
3 Preheating of air and fuel
4 Moisture of air and fuel
5 Incomplete Combustion, unburned fuel
6 Flue gas temperature

Now, another sector, which is important, is choice of fuel; changes in fuel analysis – naturally, if you change the fuel analysis, then the caloric value of the fuel will change. And, accordingly, the gross available heat will be affected; and hence, the fuel consumption is also affected. So, the third sector is preheating of air and fuel. Now, needless to say that preheating of air and fuel brings sensible heat or it is a heat input. So, naturally, gross available heat will be more as well as fuel consumption will be less, because gross available heat and fuel consumption are related to each other.

Fourth sector is moisture of air and fuel. Now, moisture of the air or fuel will increase the fuel consumption, because whatever amount of moisture will be there, it will take away the heat to the process critical temperature. So, that means, increase in the moisture content of air or fuel will increase the fuel consumption; or, other way, it will decrease the gross available heat into the furnace. Fifth point is that incomplete combustion, unburned fuel – they will also affect the heat utilization in furnace, because if there is incomplete combustion, CO will be produced and the CO will be also raised to the process critical temperature. So, those type of contribution of heat will not be available to the furnace. And, if there is incomplete combustion, then the entire calorific value of the fuel is not available; and accordingly, the fuel consumption will be higher and gross available heat will be lower. Similarly, if they have unburned fuel, then corresponding to the amount of unburned fuel, that much amount of energy is not available. So, naturally, for incomplete combustion and unburned fuel, the gross available heat will decrease and fuel consumption will increase.

Sixth – flue gas temperature – now, just I will summarize this flue gas temperature, because I have said at many point say higher is the flue gas temperature, more heat will be carried away by the POC, because the heat carried away by the POC is not available to you. Now, the heat carried away by POC is calculated from m C P into t POC minus t reference. So, t POC is higher; more amount of heat will be taken by the POC; and hence, the flue gas temperature also plays an important role. Of course, one cannot do much because of the requirement that a flue gas temperature has to be equal to that of process critical temperature. If higher is the temperature, flue gas temperature will also be high. But, what one can do is that flue gas temperature should not be higher than the process critical temperature. Now, this condition can occur only when the furnace temperature is not uniform. If some part of the furnace is over heated, then naturally, flue gas temperature will be higher than the process critical temperature. So, that point is to be considered.

Seventh important point is the oxygen enrichment. Now, this oxygen enrichment is a very important thing. Why? Because when you enrich air with oxygen, you will be decreasing the amount of nitrogen. And, as it is known that nitrogen of air is inert, it does not take part in the combustion process. Whatever amount of nitrogen is present in the air, it will take the heat of the fuel and it will go as waste heat. So, if one can reduce the amount of nitrogen by substituting oxygen, then naturally, the heat carried by the POC will be less, because oxygen is utilized in the combustion process; whereas, nitrogen is inert. Therefore, it is obvious; it does not require any discussion; that if you enrich air by oxygen – that means, if you decrease 79 percent of nitrogen to for example, 70 percent or 60 percent, then the nitrogen of the flue gas will be less and less heat will be carried away. Therefore, oxygen enrichment of air is bound to decrease the fuel consumption and it will increase the gross available heat to the furnace. It does not require any discussion. Now, this aspect I will take in the next lecture.