Fuel, Refractory and Furnaces

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Lecture No. # 13
Flame Temperature Calculations

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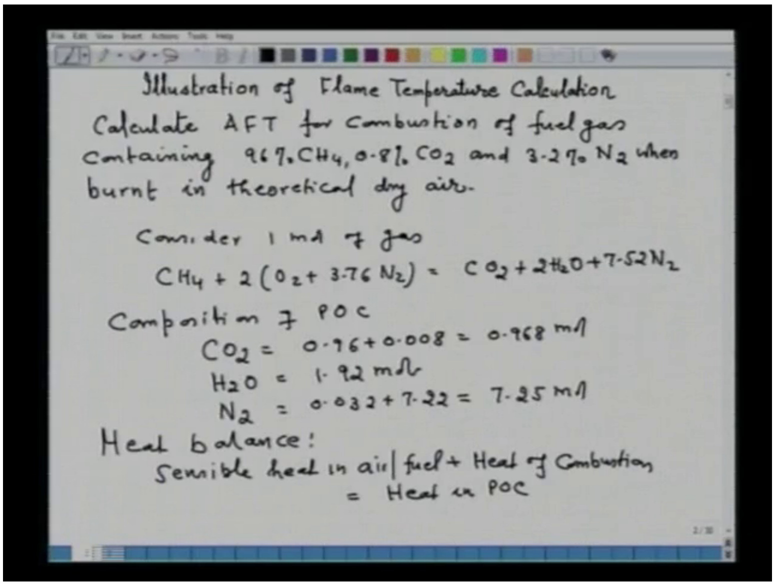

Illustration of Flame Temperature Calculation

Calculate AFT for combustion of fuel gas containing 96% CH_4, 0.8% CO_2 and 3.2% N_2 when burnt in theoretical dry air.

Consider 1 mol of gas

$CH_4 + 2(O_2 + 3.76 N_2) = CO_2 + 2H_2O + 7.52 N_2$

Composition of POC

$CO_2 = 0.96 + 0.008 = 0.968$ mol

$H_2O = 1.92$ mol

$N_2 = 0.032 + 7.22 = 7.25$ mol

Heal balance:

Sensible heat in air| fuel + Heat of Combustion = Heat in POC

So, let me illustrate today, the calculation of flame temperature. So, let us calculate, let us calculate A F T, as I said earlier, it is adiabatic flame temperature for combustion of fuel gas, for combustion of fuel gas containing 96 percent methane, 0.8 percent carbon dioxide and 3.2 percent nitrogen, when burnt in theoretical air, theoretical dry air. We are calculating now, adiabatic flame temperature, also called theoretical adiabatic flame temperature, because they are not considering dissociation of the product of combustion in our calculation. A detail exercise, that can be done, if anyone is interested, by considering the dissociation, (( )) constant, because it is a very rigorous exercise. So, I will be illustrating theoretical adiabatic flame temperature, where the dissociation of product of combustion is not being taken into account.

So, now, for this, as I have said, calculation of A F T or adiabatic flame temperature, is essentially a heat balance exercise. In order to, to do heat balance, material balance is a prerequisite; you cannot do any heat balance without doing the material balance. So, first of all, we have do material balance and find out the amounts of product of combustion, when a fuel gas is burnt with theoretical amount of dry air. As you also know, the dry air contains 79 percent nitrogen and 21 percent oxygen, of course, by volume, and the composition of fuel gas is also given on volume percent. As I have said earlier, unless otherwise specified, the composition of gaseous fuel is always given as volume percent, whether it is mentioned or not. So, let us do, first of all material balance. So, consider 1 mole of gas; consider 1 mole of gas.

So, now, in order to material balance, we write down the combustion reaction, which is C H 4, C H 4 plus 2 O 2 plus 3.7 6 N 2, as this is the composition of air, that is equal to C O 2 plus 2 H 2 O plus 7.52 nitrogen. This is the basic chemical reaction or combustion reaction, which will be occurring, when this fuel is burnt with theoretical amount of air. Now, we have to calculate the moles of products of combustion. This exercise I will ask you to do yourself. I will straight away writing down the composition of P O C, the composition of P O C, because you have 0.96 mole percent of C H 4; so, accordingly, C O 2, that will be equal to 0.96; do not forget to add 0.008 percent of carbon dioxide. So, that makes, 0.968 moles of carbon dioxide; then, H 2 O, 1.92 moles and nitrogen also, do not forget to add the nitrogen which is present in the fuel. So, this becomes 0.032 plus 7.22 and that is equal to 7.25 moles. So, now, we have before us, the products of combustion with their amount, C O 2 0.968 mole, H 2 O 1.92 mole and nitrogen 7.25 moles. Now, in order to do heat balance, sensible heat…So, I write down again, the heat balance is, say, sensible heat in air or fuel, plus heat of combustion, plus heat of combustion, that is equal to heat in P O C.

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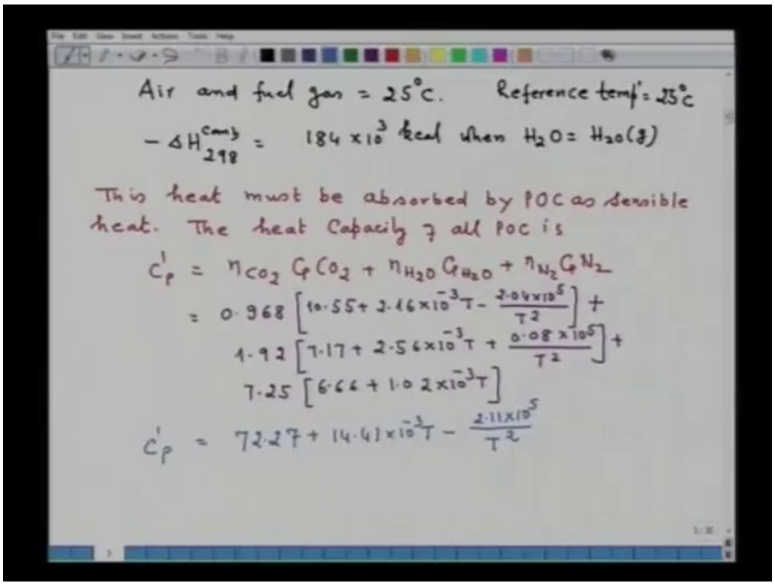

Air and fuel gas = 25°C. Reference temp = 25°C

$$-\Delta H_{298}^{comb} = 184 \times 10^3 \text{ kcal when } H_2O = H_2O(g)$$

This heat must be absorbed by POC as sensible heat. The heat Capacity of all POC is

$$C_p' = n_{CO_2} C_{P CO_2} + n_{H_2O} C_{P H_2O} + n_{N_2} C_{P N_2}$$

$$= 0.968\left[10.55 + 2.16\times10^{-3}T - \frac{2.04\times10^5}{T^2}\right] + 1.92\left[7.17 + 2.56\times10^{-3}T + \frac{0.08\times10^5}{T^2}\right] + 7.25\left[6.66 + 1.02\times10^{-3}T\right]$$

$$C_p' = 72.27 + 14.41\times10^{-3}T - \frac{2.11\times10^5}{T^2}$$

Now, we have to do this heat balance. Now, we have to note the air and fuel gas are supplied at 25 degree Celsius. Air and fuel gas, they are at 25 degree Celsius and mind you, the reference temperature for our calculation, reference temperature for our calculation is 25 degree Celsius. Therefore, the sensible heat supplied by air and fuel, it is zero in the present problem. Now, we have to calculate the heat of combustion, and as we know how to calculate, I have illustrated earlier; so, straight away I am calculating. It is a exothermic reaction, so delta H f combustion 298, that is the heat of formation of products minus heat of formation of reactants; heat of formation of reactant, for example, oxygen is 0; heat of formation of C H 4, you have to take into account; C O 2 and H 2 O, you have to take into account and the reaction which we are considering, is H 2 O is in gaseous state. So, minus delta H 298 heat of combustion, if you calculate, it will come out to be 184 into 10 to the power 3 kilocalorie. Now, when H 2 O, that is equal to H 2 O in gaseous state. So, now, this heat which we have calculated, it must be absorbed; it must be absorbed by products of combustion as sensible heat.

So, now, we can find out the heat capacity; the heat capacity of all products of combustion is given by C dash P, that is equal to n number of moles of C O 2 into C P C O 2 plus n H 2 O, C P H 2 O, plus n N 2, C P N 2. So, this is the heat capacity of the mixture of the product of combustion. So, what I have to do now, I have to substitute the value of n C O 2 and C P C O 2; these values I have given already, but I can give once again over here. So, that will be equal to 0.968, C P C O 2, 10.55 plus 2.16 into 10 to the power minus 3 T minus 2.04 into 10 to the power 5 upon T square; this is about n C O 2, C P C O 2; plus 1.92 moles of H 2 O, 7.17 plus 2.56 into 10 to the power minus 3 T plus 0.08 into 10 to the power 5, T square, plus 2 n N 2 is 7.25, plus 7.25, 6.66 plus 1.02 into 10 to the power minus 3 T. So, this has become the C P of the mixture of products of combustion which contain 0.96 moles of C O 2, 1.92 moles of H 2 O and 7.25 moles of nitrogen. So, if I solve it, then, C dash P, that is equal to 72.27 plus 14.41 into 10 to the power minus 3 T minus 2.11 into 10 to the power 5 upon T square.

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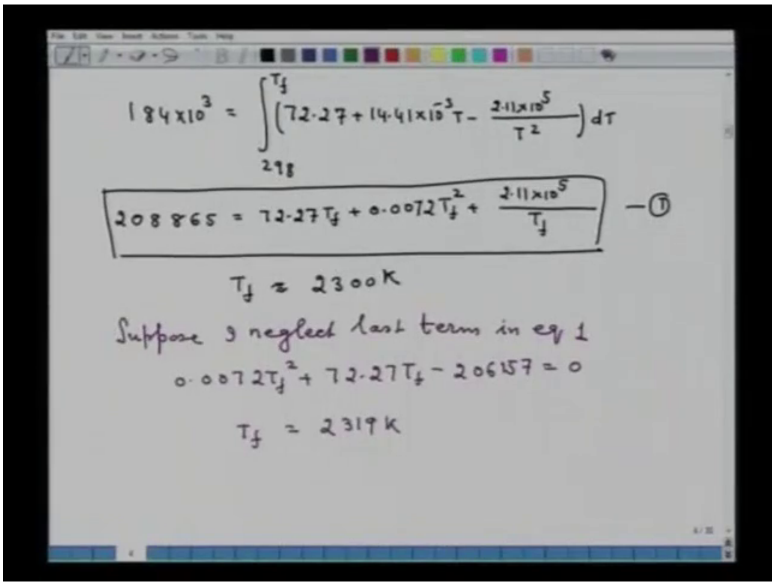

$$184\times10^{3} = \int_{298}^{T_f}\left(72.27 + 14.41\times10^{-3}T - \frac{2.11\times10^{5}}{T^{2}}\right)dT$$

$$\boxed{208865 = 72.27T_f + 0.0072T_f^{2} + \frac{2.11\times10^{5}}{T_f}} \quad -①$$

$$T_f \approx 2300\,K$$

Suppose I neglect last term in eq 1

$$0.0072T_f^{2} + 72.27T_f - 206157 = 0$$

$$T_f = 2319\,K$$

Now, we have to do the heat balance. It is heat input, that is equal to heat output. So, if we do that, then, we will be getting, we have calculated, 184 into 10 to the power 3 was the heat input and that should be equal to heat output; 298 Kelvin is our reference temperature, raise to the flame temperature T f, integration of 72.27 plus 14.41 into 10 to the power minus 3 T minus 2.11 into 10 to the power 5, T square, it should be integrated over temperature d T. So, if we do this integration, this, I left an exercise to be done by you; the straight away I will write down the calculated result, that is, 208865, that is equal to 72.27 T f plus 0.0072 T f square plus 2.11 into 10 to the power 5 T f; this is our equation, which should be solved for the T f. Now, you have two ways to solve this equation. One way is by iteration; or you develop a simple program, where you substitute a gas value of T f and see that, right hand side is equal to the left hand side. Another way is that, you plot graphically, the total amount of T against T f; that means, you take some value of T f and plot the value of the left hand side of the equation; and, wherever you find that, the left hand side is the ordinate value, that is the value of the T f; that is a graphical method. Now, I left, I leave you this exercise; you do either of the method and solve for T f. So, I have solved it. So, T f is coming approximately equal to 2300 Kelvin.

Now, what I have done, suppose, if I neglect, suppose, I neglect last term in equation 1; that is, I am neglecting now, 2.11 into 10 to the power 5 upon T f in my T f calculation. What is the error that I get? So, in that particular case, the equation straight away becomes quadratic equation and that will be equal to 0.0072 T f square plus 72.27 T f minus 206157, that is equal to 0. So, we have to resolve this equation 1, in order to get this equation. Straight away the quadratic formula, T f will be equal to minus b plus minus b square plus 4 a C under root divided by 2 a. So, if I solve it, then, the value of T f, it comes out to be equal to 2319 Kelvin. So, you note, the difference between when you consider C P is equal to a plus b T plus C by T square in your T f calculation, and if we neglect C by T square, then, there is a difference of 19 Kelvin that comes equal to, I mean, that is the difference between the two values. Now, you can also calculate by taking the average value. And, if you, if you calculate by taking the average value, then, the value of flame temperature is bound to be higher, because we are using the average C P value, and I leave you the exercise; you can also try to calculate by taking the average value. But as I said, the exact value for calculation of flame temperature is, when you take C P is equal to a plus b T plus C by T square; however, in order to avoid some complication, if you take C P is equal to a plus 2 b T only, then, the error is there, but less; it is less than, if you take the average value.

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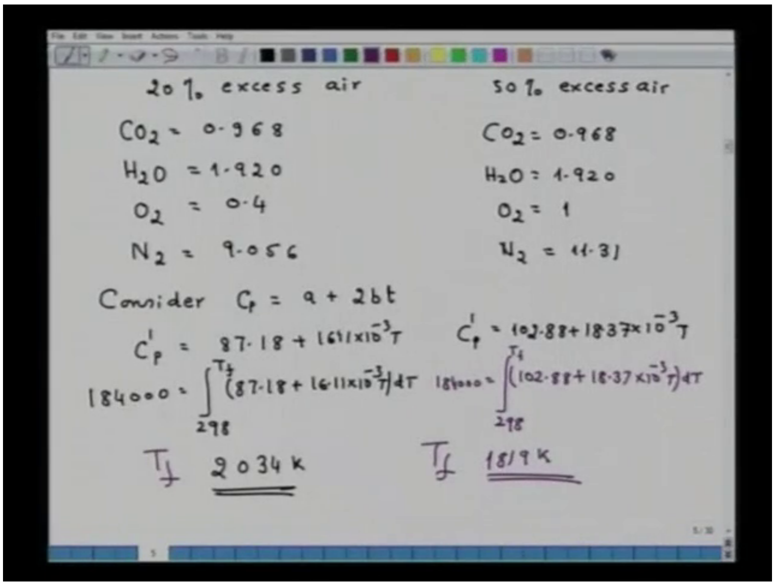

20 % excess air

$CO_2 = 0.968$

$H_2O = 1.920$

$O_2 = 0.4$

$N_2 = 9.056$

50 % excess air

$CO_2 = 0.968$

$H_2O = 1.920$

$O_2 = 1$

$N_2 = 11.31$

Consider $C_p = a + 2bt$

$C'_p = 87.18 + 1611 \times 10^{-3} T$

$C'_p = 102.88 + 1837 \times 10^{-3} T$

$$184000 = \int_{298}^{T_f} (87.18 + 16.11 \times 10^{-3} T) dT$$

$$184000 = \int_{298}^{T_f} (102.88 + 18.37 \times 10^{-3} T) dT$$

T_f $\underline{\underline{2034 \text{ K}}}$

T_f $\underline{\underline{1819 \text{ K}}}$

Now, just to illustrate what is the effect of excess air, what I have done, if you take now, for example, 20 percent excess air, if you take 20 percent excess air and if you take 50 percent excess air; that means, what is the effect of excess air, than stoichiometric on the A F T. So, again, I have to do the material balance for both the cases. So, C O 2, that is equal to 0.968, because it will not change; 50 percent excess air, C O 2 is again, equal to 0.968; H 2 O will also not change, 1.920; H 2 O 1.920; what it will change? Now, since I have 20 percent excess air, the products of combustion will have oxygen, and oxygen it will be here, 0.4; here oxygen will be…Then, nitrogen it will be 9.056 and here, nitrogen will be 11.31. So, oxygen is 1 mole of O 2. Now, again, I have to calculate the heat of combustion. Heat of combustion is not going to change; it will remain as it was in the previous case.

Now, suppose, if I consider, say, if I consider C P, that is equal to a plus 2 b T and calculate the adiabatic flame temperature, say, for example, first for 20 percent excess air; and if I do that, again I have to calculate the, the heat capacity of the mixture of the products of combustion. So, in this case, if I calculate the C dash P, that is equal to 87.18 plus 16.11 into 10 to the power minus 3 T; and the for 50 percent excess air, I will be getting C dash P, that is equal to 102.88 plus 18.37 into 10 to the power minus 3 T. So, that is what the values. Now, again, I have to do the heat balance. Here, heat balance will be 184000, that will be equal to 298, T f, 87.18 plus 16.11 into 10 to the power minus 3 T d T. Here, it will be 184000, 298, T f, 102.88 plus 18.37 into 10 to the power minus 3 T d T. Now, I solve. So, here, I will be getting the T f, 2314 Kelvin, when excess air is 20 percent. Now, when excess air is 50 percent, then I will be calculating flame temperature as 1819 Kelvin. Now, remember, these two calculations which I have done, I have considered C P is equal to a plus b T; however, you can take C P is equal to a plus 2 b T plus C by T square and recalculate the value of the flame temperature. And, the flame temperature values will be somewhat lower, than what you have calculated. So, what I wanted to illustrate that, increase in excess air, it decreases the flame temperature.

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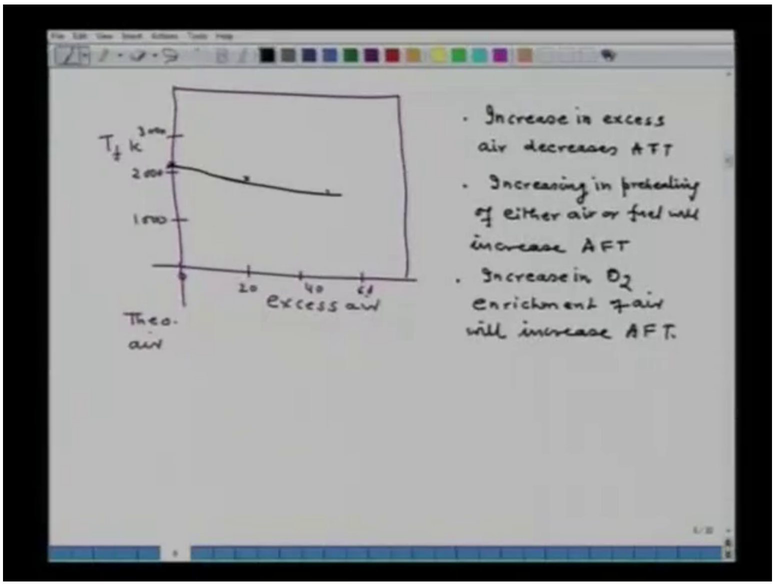

- Increase in excess air decreases AFT
- Increasing in preheating of either air or fuel will increase AFT
- Increase in O_2 enrichment of air will increase AFT.

So, for example, if we now plot, say, here, if we take excess air and here, if we take flame temperature in Kelvin…So, well, we have to see what type of plot you will get; plot 20 percent, 40 percent, 60 percent; here, say, 1000 Kelvin, 2000 and 3000. So, 0 percent means, no excess air; that means 0, that is, here the theoretical air. So, for 0, we have measured around, let us say, 2319; for 20 percent, say, 2034 and for 50 percent, we are measuring around somewhere this (( )); so, this plot could be a slightly straight line or little bit. So, what it illustrates is that, if we increase the excess air, the flame temperature decreases. This is valid for all types of fuel. Now, similarly, if we preheat the air or fuel, then, you are aiding sensible heat; so, the flame temperature will increase, with the increase in the addition of the sensible heat.

So, what I have illustrated through this problem, there are few things. First, increase in excess air, decreases flame temperature. So, I will write down, I illustrated first, increase in excess air, increase in excess air, decreases A F T. The exercise which we can also do is that, increase in preheating, or increasing in preheating of either air or fuel, will increase A F T. We can also think of, that if you enrich air by oxygen…Conceptually what you are doing, you are removing nitrogen, and enriching with oxygen, oxygen. So, as a consequence, less heat will be taken now by the product of combustion to nitrogen and the adiabatic flame temperature has to increase with the increase in oxygen enrichment of air. So, third thing which I can write now, increase in oxygen enrichment of air, increase in oxygen enrichment of air will increase A F T; this is what the observation that we can make, from the calculation; however, about the preheating, what you can do, you can just take some 10000 calorie to the heat of combustion, 20000 calorie to the heat of combustion and then, you can calculate, what will be the effect of preheating of air and you can arrive at this conclusion. Second point that I have illustrated that, the calculation of adiabatic flame temperature is accurate, if you consider C P, that is equal to a plus 2 b T plus C upon T square; that is no doubt; but for faster calculation, we can use C P is equal to a plus 2 b into T. The error will be there, but the error will be lower than if we use the average value of C P. So, that is what the conclusion of the particular calculation.

Now, I can also illustrate another problem where preheating is done. Now, if we recall that, I have given this particular problem, in the last lecture, which I am reading; a blast furnace gas of composition 24 percent C O, 12 percent C O 2, 4 percent hydrogen and 60 percent nitrogen is burnt with theoretical amount of air. The blast furnace gas is preheated to 500 degree Celsius oblique 527 degree Celsius. Air is preheated to 250 or oblique 227 degree Celsius. With the oblique, what I mean, you can calculate, when the air is preheated to 250 and 227 degree Celsius and blast furnace gas is heated or preheated to 500 and 527 degree Celsius, and then, calculate the adiabatic flame temperature. So, I will be illustrating now, this particular problem, by taking the preheat temperature of blast furnace gas of 527 degree Celsius and preheat temperature of air as 227 degree Celsius.

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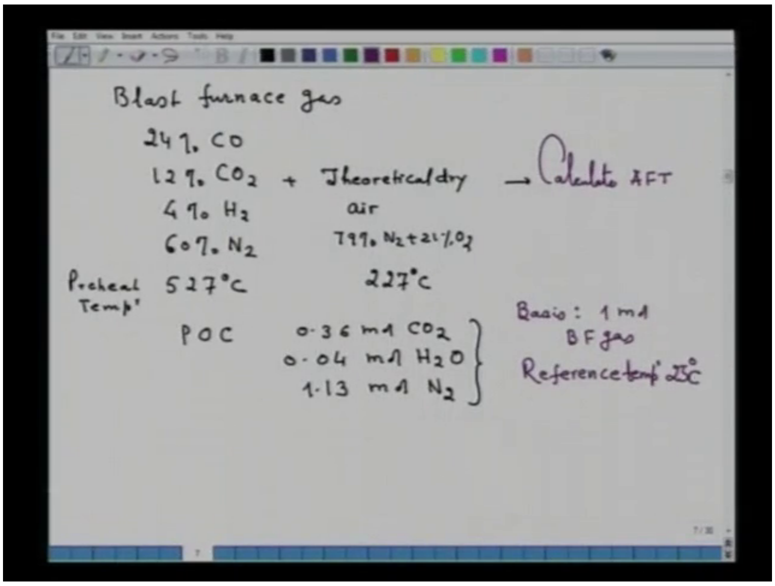

Blast furnace gas

24 % CO

12 % CO_2 + Theoretical dry air → Calculate AFT

4 % H_2

60 % N_2 79 % N_2 + 21 % O_2

Preheat Temp' 527°C 227°C

POC 0.36 mol CO_2, 0.04 mol H_2O, 1.13 mol N_2

Basis : 1 mol BF gas

Reference temp' 25°C

So, let me illustrate this problem now. So, I will just put it here, say, I am taking a blast furnace gas whose composition is 24 percent carbon monoxide, 12 percent C O 2, 4 percent hydrogen and 60 percent nitrogen. This is burnt with theoretical amount of air, theoretical, let me put dry air, which is 79 percent nitrogen plus 21 percent oxygen and it is preheated to 227 degree Celsius and this blast furnace gas is preheated to 527 degree Celsius. This is the preheat temperature; this is the preheat temperature; one is 527 and 227. So, what I have to do now, I have to calculate the adiabatic flame temperature. So, calculate A F T. Now, here again, first of all, I have to do, the so called material balance and straight away I can write down the material balance, that is, the product of combustion which will result on combustion of blast furnace gas on theoretical amount of air; that will be equal to 0.36 moles C O 2, 0.04 moles H 2 O and 1.13 mole nitrogen. Now, I have taken the basis, 1 mole blast furnace gas and reference temperature 25 degree Celsius. So, now, I have specified everything. So, first of all, I have to calculate the sensible heat in blast furnace gas. Now, before that, I will just write the heat balance.

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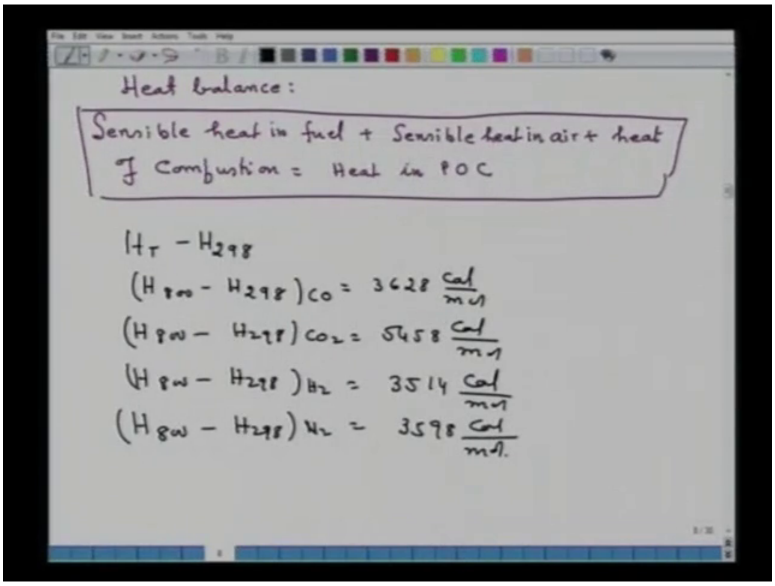

Heat balance:

Sensible heat in fuel + Sensible heat in air + heat of combustion = Heat in POC

$H_T - H_{298}$

$(H_{800} - H_{298})_{CO} = 3628 \frac{cal}{mol}$

$(H_{800} - H_{298})_{CO_2} = 5458 \frac{cal}{mol}$

$(H_{800} - H_{298})_{H_2} = 3514 \frac{cal}{mol}$

$(H_{800} - H_{298})_{N_2} = 3598 \frac{cal}{mol}$.

Now, the heat balance, that is equal to sensible heat in fuel plus sensible heat in air plus heat of combustion, heat of combustion, that will be equal to heat in products of combustion; that is what my heat balance is; because now, some amount of sensible heat is also added along with the air and blast furnace gas, since both are preheated to a temperature. Now, I have to calculate, first of all, the sensible heat of air and blast furnace gas. Now here, there are two ways. You can again calculate sensible heat in air, that is equal to C P, C P of every component of air into d T, that will be equal to a plus 2 b T into C by T square into d T and you have to write down these value for oxygen and nitrogen when air is preheated, integrate it and get that values and that will be the sensible heat of air. Or, other way around, you can also take help of the heat content table, because the H T, the H T minus H 298, this heating values are listed at several temperatures for different types of gases. Both ways can be done; you can either integrate C P d T, or you can take H T minus H 298 value.

So, what I am doing, I have listed some of the H T minus H 298 relevant for this problem. So, here, since blast furnace gas is heated to 527, so, I will be writing H 800 minus H 298; this is for C O, that is, 3628 calorie per mole; then H 800 minus H 298 C O 2, 5458 calorie per mole; H 800 minus H 298 hydrogen, that is equal to 3514 calorie per mole; H 800 minus H 298 nitrogen, that is equal 3598 calorie per mole. You can see these values in any thermodynamics book.

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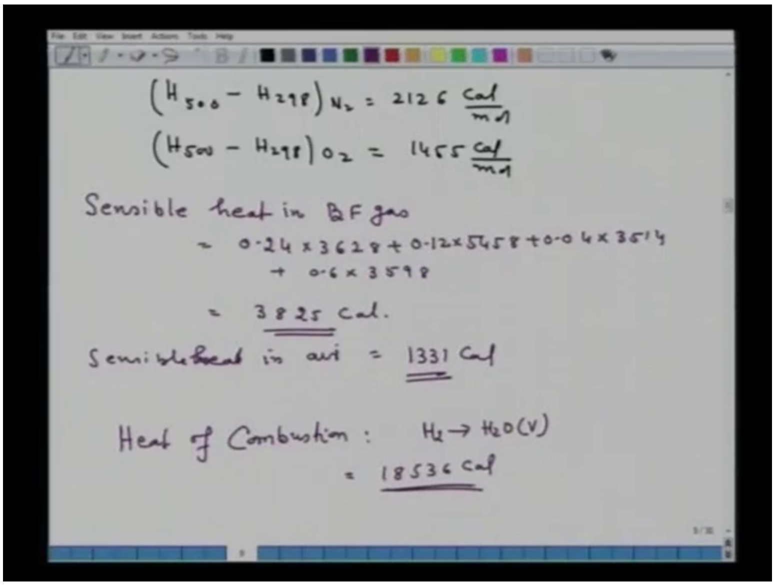

$(H_{500} - H_{298})_{N_2} = 2126 \frac{cal}{mol}$

$(H_{500} - H_{298})_{O_2} = 1455 \frac{cal}{mol}$

Sensible heat in BF gas

$= 0.24 \times 3628 + 0.12 \times 5458 + 0.04 \times 3514 + 0.6 \times 3598$

$= \underline{\underline{3825}}$ cal.

Sensible heat in air $= \underline{\underline{1331}}$ Cal

Heat of Combustion : $H_2 \rightarrow H_2O(v)$

$= \underline{18536}$ Cal

Similarly, air is preheated to 227 degree Celsius. So, I will be writing H 500 minus H 298 for nitrogen, 2126 calorie per mole and H 500 minus H 298 for oxygen, that will be equal to 1455 calorie per mole. Now, what I have to do, I have to find out the sensible heat. So, sensible heat in blast furnace gas, sensible heat in blast furnace gas, just I have to multiply by the moles 0.24 into 3628 plus 0.12 into 5458 plus 0.04 into 3514 plus 0.6 into 3598. So, that will be equal to 3825 calorie. Similarly, sensible heat in air, that I can again find out; you can multiply and get it 1331 calorie; this is a sensible heat in air and that will be applied along the reactant. Now, I have to calculate the heat of combustion. Now, I have to calculate heat of combustion. Now, in this particular blast furnace gas, the combustible component are C O and H 2, and I am considering now H 2, it will go to H 2 O and it will form vapor state. So, accordingly, I will select the heat of formation of H 2 O, heat of formation for C O to C O 2 and if I calculate the heat of combustion, the heat of combustion, that will be equal to 18536 calorie; this you can calculate.

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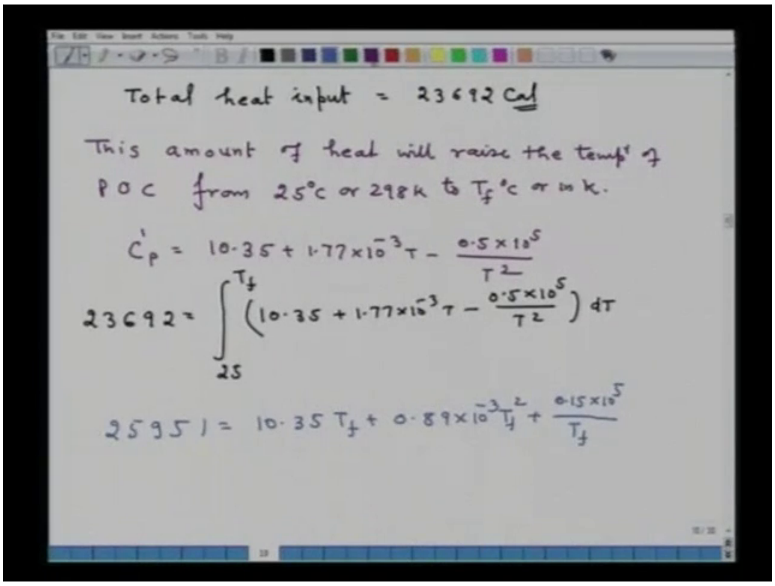

Total heat input = 23692 Cal

This amount of heat will raise the temp' of P O C from 25°C or 298K to T_f °C or in K.

$$C'_p = 10.35 + 1.77\times10^{-3}T - \frac{0.5\times10^5}{T^2}$$

$$23692 = \int_{25}^{T_f}\left(10.35 + 1.77\times10^{-3}T - \frac{0.5\times10^5}{T^2}\right)dT$$

$$25951 = 10.35\,T_f + 0.89\times10^{-3}T_f^2 + \frac{0.15\times10^5}{T_f}$$

So, now, the total heat input, total heat input, I have to add all the three; so, I will be getting 23692 calorie, that will be the amount of heat, that will be added in. Now, this amount of heat, this amount of heat will raise the temperature of P O C from 25 degree Celsius or 298 Kelvin, to T f , either in degree C or in Kelvin. So, now, we have to find out the heat capacity of the mixture of the product of combustion, and as I have illustrated in the last case, I am straight away writing down C dash P, that will be equal to 10.35 plus 1.77 into 10 to the power minus 3 T minus 0.5 into 10 to the power 5 upon T square. Now, I will do the heat balance; and, in the heat balance, as all of you know, the heat balance will go how is it; that will be 23692, that will be equal to 25 degree to T f, naturally, I will get here, T f in degree Celsius, 10.35 plus 1.77 into 10 to the power minus 3 T minus 0.5 into 10 to the power 5 upon T square into d T. Well, I have to integrate it and solve. So, the equation which I will be getting, 2595, that will be equal to 10.35 T f plus 0.89 into 10 to the power minus 3 T f square plus 0.15 into 10 to the power 5 upon T f. Now, again, solve by iteration. So, to illustrate what I have done, I have neglected the last term.

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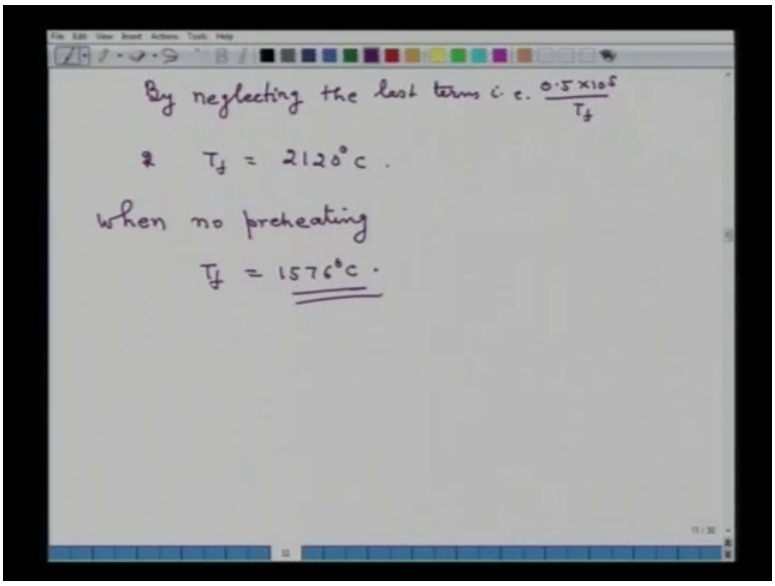

By neglecting the last terms i.e. $\frac{0.5 \times 10^5}{T_f}$

$T_f = 2120^\circ C$.

when no preheating

$T_f = \underline{\underline{1576^\circ C}}$.

Then, I can straight away solve by neglecting, by neglecting the last term, the last term, that is, 0.5 into 10 to the power 5 upon T f; then, I can straight away calculate; that will be equal to. that will equal to, and I can straight away calculate T f by quadratic equation, that will come up to 2120 degree Celsius. However, you can calculate by considering this term also; temperature may come up to be equal to 2105 or something of that order of magnitude. Now, when no preheating is done, when no preheating, it (( )) illustrate, though I have illustrated earlier, T f, that is equal to 1576 degree Celsius; that is the effect of no preheating or preheating. Now, you can calculate adiabatic flame temperature by considering, say, for example, 500 degree C is the preheat temperature of blast furnace gas and 200 degree C is the preheat temperature of the air. All that you have to do, you have to collect the value of C P, integrate it from 25 to 500 and get the sensible heat in air and sensible heat in blast furnace gas; add it into the heat of combustion, and then, you can find out the value of the flame temperature.

Now, I had given one more problem, that was a producer gas of composition 22.4 percent C O, 12 percent C O 2 and 65 percent nitrogen is burnt with stoichiometric amount of air. The gases enter the furnace at 250 degree Celsius. We have to calculate the flame temperature. Now, I will go very quickly; just I will give you some method and you can solve yourself.

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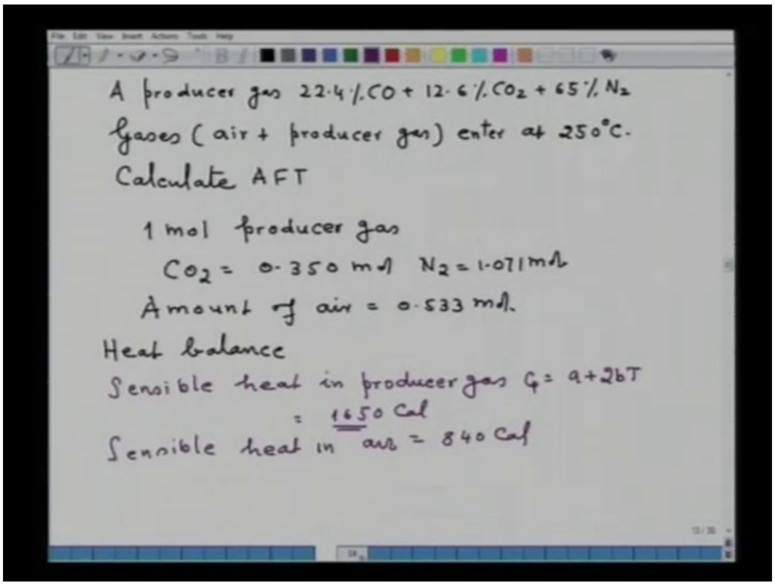

A producer gas 22.4 % CO + 12.6 % CO_2 + 65 % N_2

Gases (air + producer gas) enter at 250°C.

Calculate AFT

1 mol producer gas

CO_2 = 0.350 mol N_2 = 1.071 mol

Amount of air = 0.533 mol.

Heat balance

Sensible heat in producer gas $C_p = a + 2bT$

$= \underline{\underline{16}}50$ Cal

Sensible heat in air = 840 Cal

So, I am illustrating now, another problem, a producer gas composition 22.4 percent C O plus 12.6 percent C O 2 plus 65 percent nitrogen is burnt with theoretical amount of air. The gases, that is air plus producer gas enter at 250 degree Celsius; that is here, both air and producer gas are heated and they bring sensible heat into the reaction. So, we have to calculate adiabatic flame temperature, calculate A F T. Same, first of all, we have to perform material balance; so, consider 1 mole producer gas and corresponding to 1 mole producer gas, C O 2, that will be equal to 0.350 moles and nitrogen, that will be equal to 1.071 mole. Amount of air, that is equal to 0.533 moles, of which, 79 percent is nitrogen and 21 percent is oxygen. Now, you have to do the heat balance. So, first, you have to calculate. Now, we have to do heat balance.

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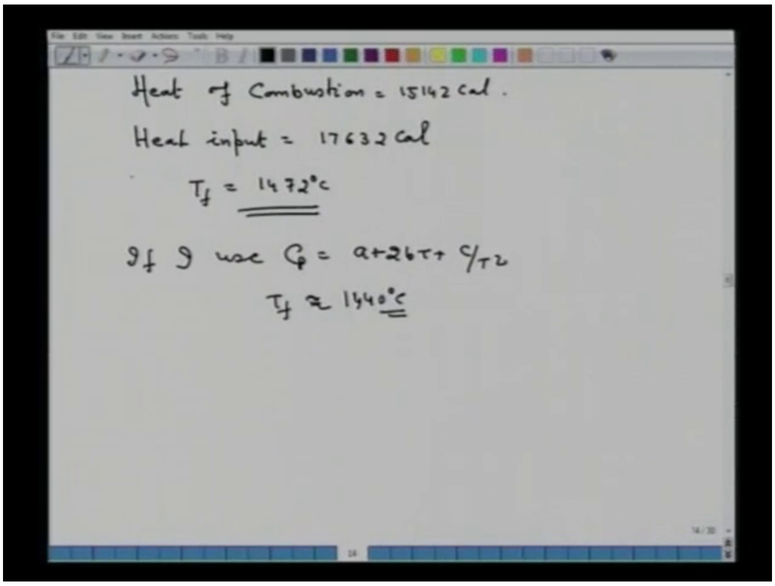

Heat of Combustion = 15142 cal.

Heat input = 17632 cal

$$T_f = \underline{\underline{1472^\circ C}}$$

If I use $C_p = a + 2bT + c/T^2$

$$T_f \approx \underline{\underline{1440^\circ C}}$$

We know, heat balance, sensible heat in air plus sensible heat in producer gas plus heat of combustion, that is equal to heat output in product of combustion. So, first of all, I have to calculate the sensible heat in producer gas; sensible heat in producer gas; then, I have to use the C P values and I have to perform the integration. Now, in this calculation which I am going to illustrate to you, I have used C P, that is equal to a plus 2 b T; for more accurate and precise calculation, you can take a plus 2 b T plus C by T square. So, if I calculate sensible heat in producer gas, that will be equal to 1650 calorie. Similarly, sensible heat in air, that will be equal to 840 calorie. Now, heat of combustion, heat of combustion, in this case, that will be equal to 15142 calorie. So, heat input, that will be equal to 17632 calorie. So, this will be raised, in raising the product of combustion from 25 to T f; I put this C P values; if I use C P is equal to a plus 2 b T, then, the T f, that is equal to 1472 degree Celsius.

Now, mind you, here I have used C P is equal to a plus 2 b T. Now, if I use C P is equal to a plus 2 b T plus C by T square all, then, T f will be approximately around 1440 degree Celsius. So, this, you can calculate yourself and see that, you can calculate the adiabatic flame temperature for any other case.

Thank you.