Heat Treatment and Surface Hardening (Part–1)
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Lecture Number 20
Phase Diagram and G vs X plot

Let us begin twentieth lecture.

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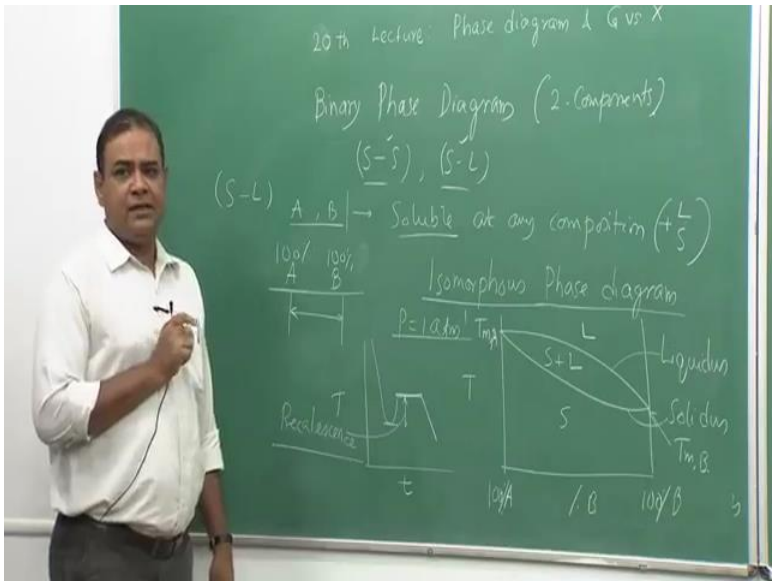

We will continue phase diagram and free energy composition diagram the discussion on this two particular topics.

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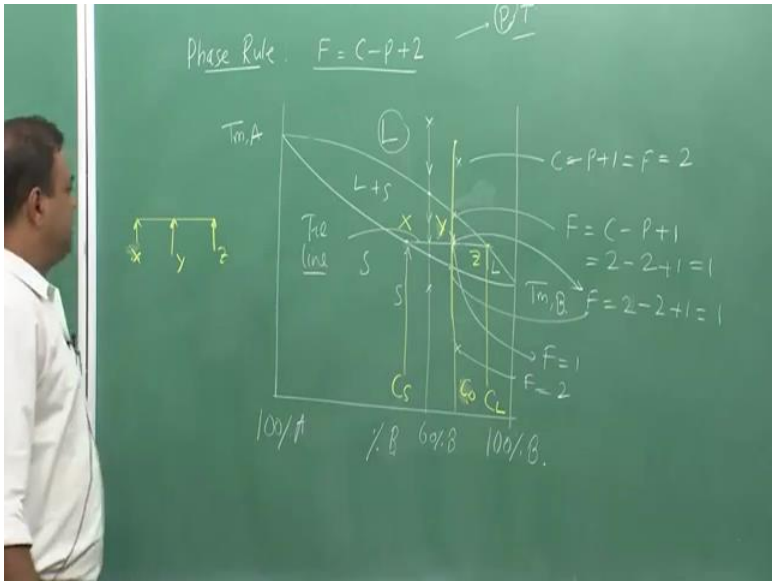

And let us come back to (ser) the diagram where we started discussing our isomorphous system and we saw that here the degrees of freedom is one, here the degrees of freedom is two in the single phase region it is two, but at this particular region we are seeing that the degrees of freedom becomes one, because once we take the liquid here this will dissociate into solid and liquid and the liquid would have this composition, solid would have this composition.

So this is two phase region, so component is two, phase is two and this becomes one. So again at this point F equal to 1 and here along this tie line the liquid is dissociating into two parts and we can also get the fraction of this liquid and the fraction of this solid. And this depends on the mass balance you look into different textbooks and see that whether you can get to that particular formulae you can prove that particular formula but along according to the tie line, if I indicate those points let us say these I am indicating by x and this point which is the this is y and this is let us say z point this point.

So now I have a situation like this, so this is z, this is y, this is x, x point and now if I try to see the composition if I take the composition of this point is x let us say C0 this composition I can take it as Cs that means the composition of solid and this point I can take it as C liquid.

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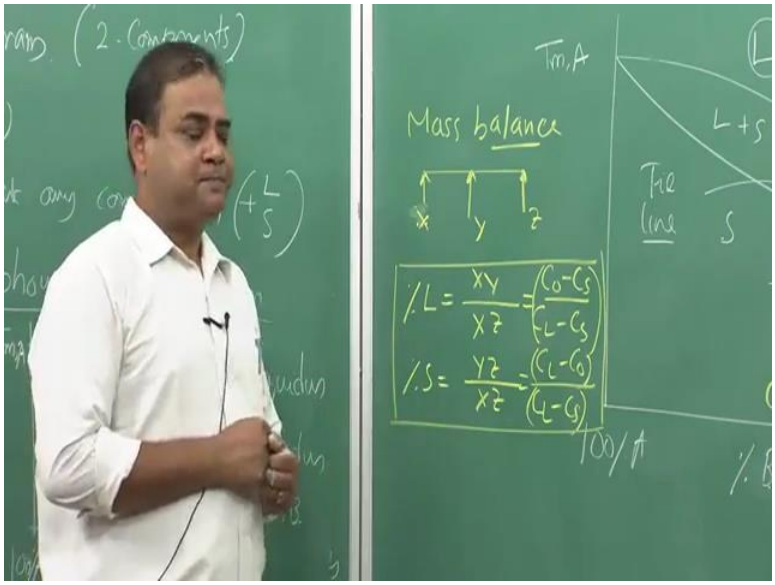

Then the percentage of liquid would be xy divided by xz equal to C0 – Cs divided by Cl – Cs. Similarly, I can also get percentage of solid that is a solid phase would be yz divided by xz equal to Cl – C0 divided by Cl – Cs, I can get this formula.

So this is coming from the mass balance I want you to look into different books and find out what is that mass balance also the T is will also interact with in order to let you know what is that mass balance. Now that means from this diagram what we have learnt? We have learned that it indicates a three different regions and these lines are the phase boundaries and this is the liquid in liquid plus solid and solid, both the components are completely soluble in liquid and solid. We have seen what what would be the degrees of freedom at different points in this phase diagram.

At the same time, we are also seeing that the what is the implication of this tie line? Now these diagrams are coming from derived from a free energy composition diagram. So we will talk about that free energy composition diagram, we will get back to this diagram again so we are not wiping it off. So we will get to other diagrams what we have discussed, what we have thought of discussing, okay. So that means it is the case where the both the phases are soluble, both the components are soluble.

Now let us get to system situation where the both the components will not have complete solubility over the entire entire composition range, okay. So there could be a phase separation we

call it phase separation, okay and there could be many other possibilities, so two possibilities which are important, okay so one is peritecitc the other one is eutectic. So we will talk about these two diagrams where we are dealing with liquid solid transformation, okay.

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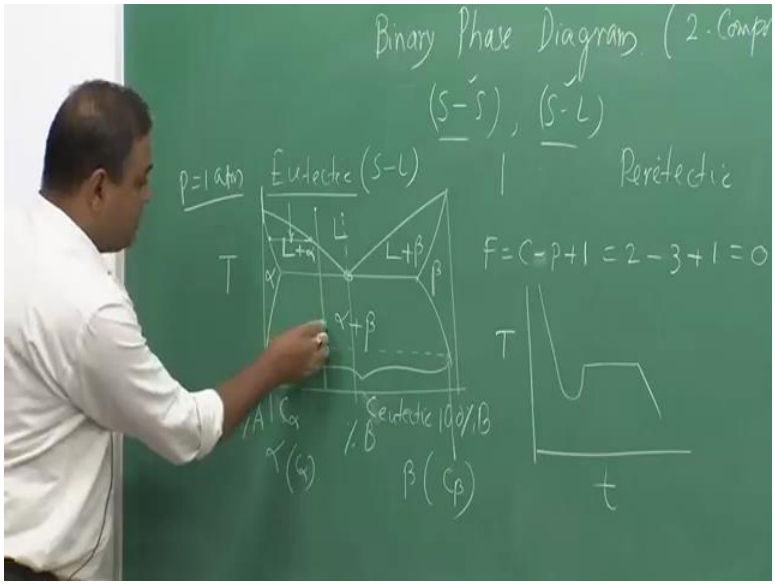

So let us get to that particular situation, so first let us see eutectic and then we will talk about peritectic and you will be amazed that these two reactions are possible in iron carbon system, okay. For example, cast iron as we have (se) we have we can see that many of those machine components are made of cast irons, okay. So that actually happens in the eutectic region, okay

and the peritectic region in case of iron carbon phase diagram it is there in that particular high temperature zone from fourteen ninety four degree Celsius to around (forty) around fourteen ninety degree Celsius and the composition range is of the order of 0.01 to 0.05 percentage of carbon, weight percent of carbon.

So now if I talk about eutectic, the eutectic says let us draw that phase diagram (eh) here also it is percentage of B and here we have 100 percent A 100 percent B, but they do not mix 100 percent over the entire composition range. There would be a A rich region and there would be (bay rich) B rich region and we get a diagram like this.

So here this is liquid and it is also talking about solid-liquid transformation and this is alpha this alpha means this is temperature axis and here also pressure is 1 atmosphere. This alpha is A rich phase and this particular region is beta which is B rich phase, okay and these different phase regions would be, this is L+alpha, this is L+beta and this is alpha + beta.

Now let us say if I talk about this particular point, this particular point does not remain at this composition, okay. It does not mean that the composition would be here. So rather they would be distributed into two segments, one is the composition this and this, so they will form alpha of composition let us this composition is Xc, let us say composition is C and C alpha, okay.

And this particular composition let us say C beta, so this is alpha of C alpha composition and beta of C beta composition they will be distributed between two different phases. And again we can use the tie line rule to in order to find out what would be the amount beta and what would be the amount of alpha. And here the amount of beta would be this divided by this and this is this divided by this is basically the amount of beta and the composition of beta would be this, okay. But if I try to find out what is the amount of alpha, say then this divided by the whole length that become the fraction of alpha and the composition of alpha would be this.

So that means at any point over this particular zone, it will distribute into two segments, okay as we have seen in case of isomorphous system. Similarly if I try to see in this zone, if I try to take the liquid at this point, so then the liquid will be distributed between two different portions, one would be this particular liquid of this composition and alpha of this composition, okay. And again I can use the tie line rule in order to find out what would be the fraction of liquid of this composition and fraction of solid of this composition, okay as per the same rule.

Now if I try to find out what would be the degrees of freedom at different points, okay so now degrees of freedom at this point if I try to find out F equal to C + P C – P + 1 because pressure we have kept 1 atmosphere. So the component again 2 minus there is liquid phase alpha beta these are the two phases, so the there would be three phases and one plus zero. So this becomes invariant point, so we have to fix both temperature and composition the composition is this which we call it as C eutectic, the composition of the eutectic.

And interestingly, at this point it would have a fix composition and it would have a fix melting point. Now interestingly let us see if I try to draw a, if I try to draw cooling curve temperature time, if I take the liquid of eutectic composition and then if I try to draw a the cooling curve, the cooling curve would look like this. But if I try to draw the cooling curve at any other point, for example if I take the liquid here and then start cooling reaching this point we will get, we get a cooling curve like this, okay. Now you can see the this is indicating it is sort of pure metal solidify, okay. So that happens at eutectic composition and that too at eutectic temperature, this is T eutectic.

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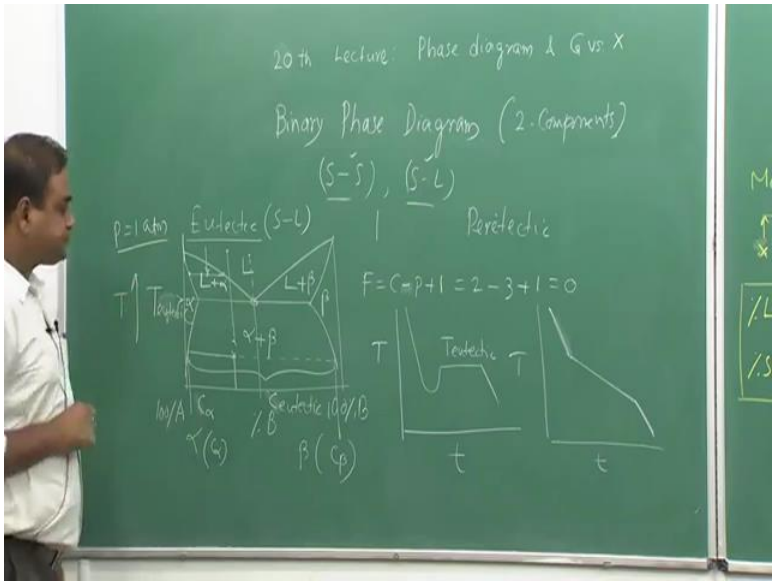

Now this point is basically this particular temperature T eutectic, eutectic this Ts.

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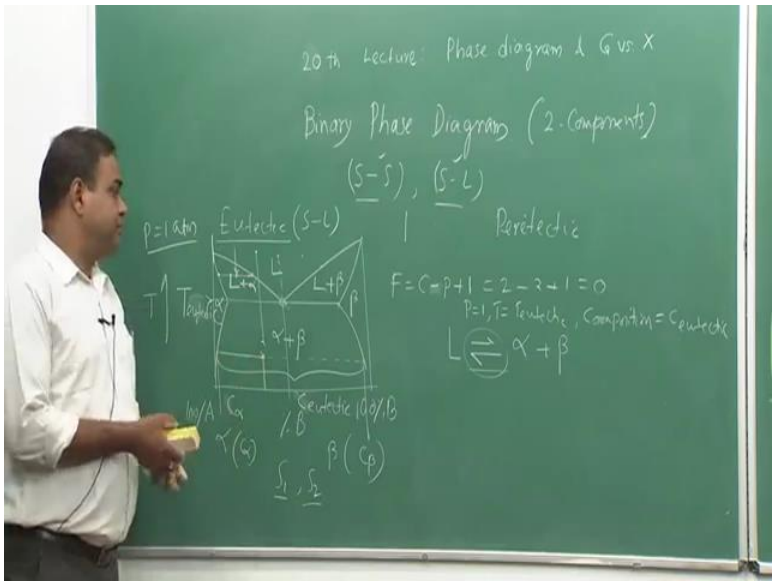

Now if we try to see what happens at this eutectic point, at eutectic point if I try to see the reaction the eutectic reaction says liquid converts to alpha plus beta. Liquid converts to two different solids of different composition and they can have same structure but they would have different composition and they can be of also of different structures, say here when I am talking alpha and beta, if these notations are given in phase diagram you can immediately assume that alpha and beta both have different structures, that means crystal structures.

And if instead of alpha and beta, if it is written as S1 and S2 solid one and solid two, people people assume that they have a different structures different they have similar structure. So that means alpha beta means they have different structures and of different composition of course at this point you will see the composition of alpha would be this and composition of beta would be this. So they would have different structures as well as different composition, it can be possible that they would same structure but of course they would have different composition.

So this equilibrium, that means reversible sign I have put because if I remain at this point, there could be a dynamic equilibrium between liquid and both the solids, this is eutectic and this happens at pressure equal to one and temperature equal to T eutectic and composition could be C eutectic. You can also find out at different regions what would be the degrees of freedom as per that rule, so we will have assignments where you will be asked to find out a degrees of freedom at different points of an eutectic phase diagram.

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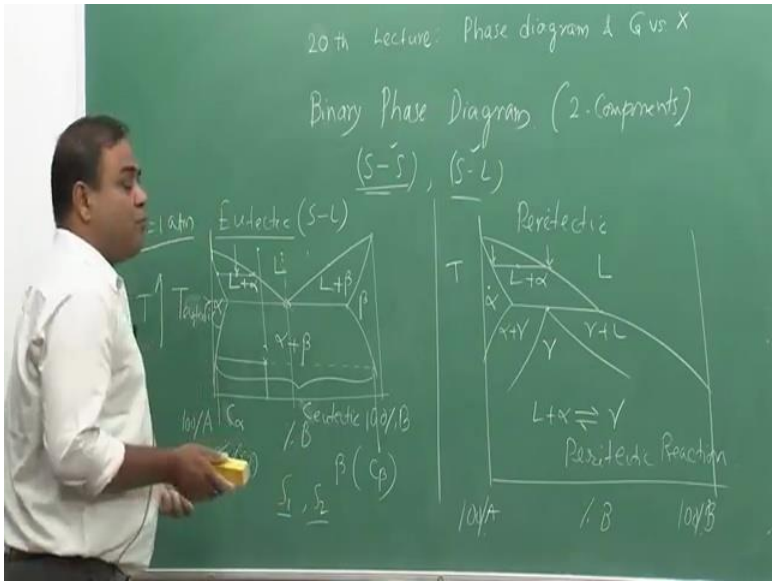

Now, on the other hand, if I try to see peritectic phase diagram, so the peritectic phase diagram looks like this, looks like this and where this is temperature axis and this is percentage of B and this is A and this is B 100 percent this is 100 percent. Now here it says that this is liquid and if we consider this is to be alpha, so then this is liquid plus alpha. And now at this point, liquid plus alpha converts to another solid which is gamma let us say, which is a new solid of different (composi) different structure, okay.

So this liquid plus alpha which is this particular zone, they react each other and form another solid or a new solid of different structure, okay and that time it is called peritectic reaction. So now if I try to see the different zones, this would be alpha plus gamma and this would be gamma plus liquid. And this reaction we can see in iron carbon phase diagram, and similar we can find out what would be the degrees of freedom at different points, we can also find out what would be the fraction of phases that would be there in two phase region.

Single phase region of course it will be all the time that particular phase, for example if I try to see what will be the fraction of different phases we cannot say that there could be any other phases that is possible, the only alpha phase is possible. But if I try to see what would be the different phases here, we can immediately say that there will be two phases, one phase would be this of this composition, the another phase would be of this composition and this is alpha phase composition, this is liquid phase composition.

So like that we can find out what would be the fraction of phases from tie line, what would be the composition of different phases in a two phase region like that we can get lot of informations and interestingly during heat treatment, these diagrams will be required in order to find that what microstructure would generate. And interestingly this microstructure will be consisting of the phases what we see in these diagrams, okay. So that part will be taken care of professor Sangal.

But now let us come to since we are telling that a this is (liq) eutectic as well as peritectic both the things are present in iron carbon diagram, there is one more diagram, one more reaction that is very important in case of iron carbon system and interestingly because of that particular reaction, we can get thousands of microstructures if we just vary the temperature time information or temperature time and then we can get a different levels of microstructures and different morphologies and we can get different properties and we can desire the specific microstructure in order to get a specific properties to serve a sum specific performance.

Now, let us get into that particular phase diagram and that particular phase diagram is related to solid-solid situation. So that means all the phases would be solid and here we see that one phase is liquid and here two phases are solid here one phase is liquid and the two phases are solid. And in case of isomorphous one phase was liquid and another phase was solid. Now let us get to that particular situation where both the phases would be solid.

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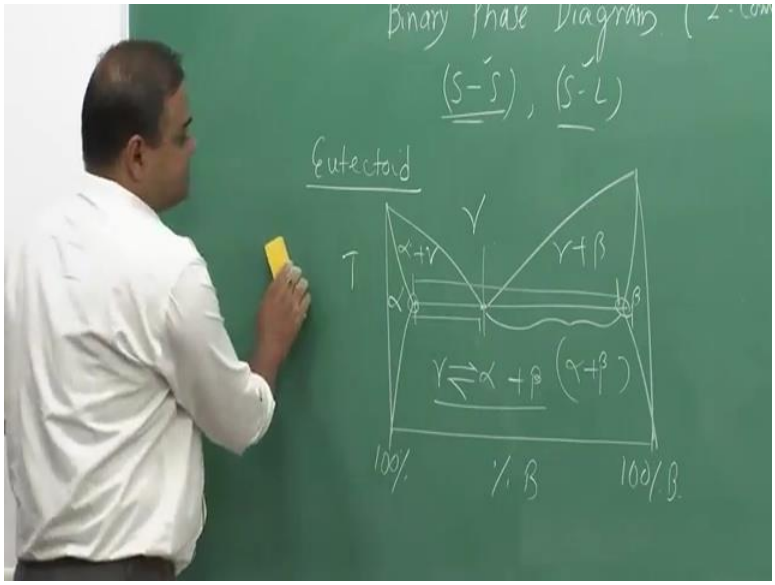

And in fact the phase diagram we call it as eutectoid. And in case of eutectoid we have a phase diagram like this, this is let us say gamma, this is alpha, this is beta, temperature percentage of B and at this point the reaction is gamma which is a solid converts to alpha and beta, these are also solids. But interestingly the composition of this would be different from the composition of the product phase. And similarly, the structure of this would be different then the product phases as well as this product phases would have different structures. So they could have similar structures also similar structures means both the things can have a either a FCC or BCC, but the structure of gamma would be different than the product phase, that is sure.

And they can have also a different structures too, but they would have a different composition, for example, if I try to see what happens if I take this composition we call it eutectoid composition and this is called eutectoid reaction and at this particular point, the product phase would be alpha and beta and alpha would have this composition and beta would have this composition. And we can also find out what would be the fraction of alpha and fraction of beta and from the same tie line concept the fraction of alpha would be this divided by the total length and beta would be this length divided by the total length, that is the fraction of beta and the beat composition would be this and alpha composition would be this.

Since we have given it the term the name we have given is alpha and beta, they are having a different structures. In case of steel of course they will have different structures, okay. So we let us see what happens in case of steel, of course in this case also we can find out and what are the different phases at different regions, this is alpha plus gamma, this is gamma plus beta, and in this zone we have alpha plus beta. And you can also calculate the degrees of freedom at different points and you will see at this point it becomes invariant because F becomes zero.

So there are three phases, two component and the one external variable so the F becomes zero. So le us get to a condition where, let us get to the iron carbon phase diagram.

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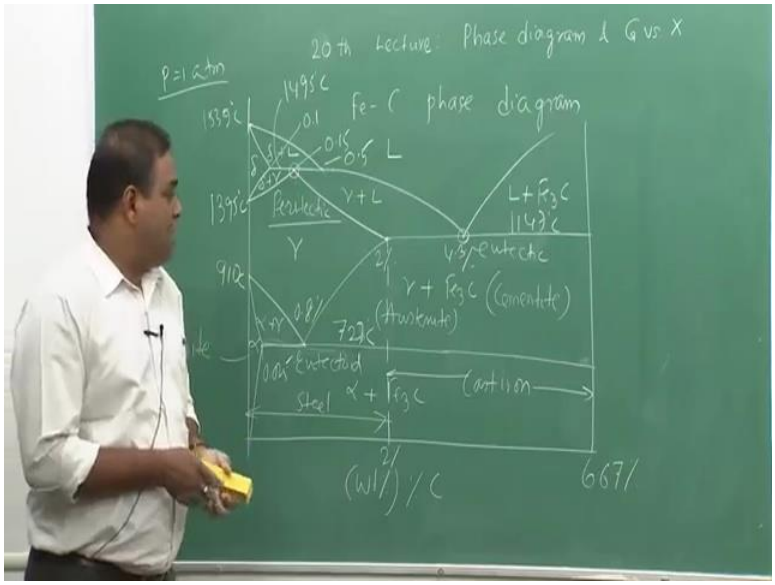

Now this iron carbon phase diagram would be very critical mostly the solid this steel part you we have two parts, one is steel part one is cast iron part. The steel part would be very critical because we will be looking at heat treatment of steel in the steel part only, okay though of course you can have lot of other heat treatments available for the cast iron part. So we will be concentrating on the steel part.

So now if I try to draw the phase diagram of iron carbon system, in case of iron carbon system this is percentage of carbon and we take weight percent, so there could be two composition composition mode that can be possible in phase diagram and if you go to ASM phase diagram handbook you will see the bottom one is weight percent and the top one is atom percent, okay. So you can convert either of this two, so now if I try to draw that, the iron melts at 1539 degree Celsius and this is pressure equal to 1 atmosphere.

So the diagram looks like this, diagram looks like this where this is liquid, this is delta sorry I made a mistake here, so it would be here, okay so this is gamma, this is gamma plus liquid, this is liquid plus Fe3C there is gamma plus Fe3C this is a cementite we call it cementite, gamma is austenite, and this is alpha which is ferrite, this is alpha plus gamma and this is alpha plus Fe3C. And if I try to see the temperature of different lines, so these are all invariant lines and here we have eutectic transformation, this is eutectic, this is eutectoid, so in this solid gamma converting to alpha plus Fe3C this is peritectic.

And this composition is 0.1, this is 0.15, this is 0.5, this is 0.8, this is 0.025, this is 4.3 percent carbon, these are all percentage and this is around 2 percent. So if I draw a dotted line, this region we call it steel part and from 2 percent onward to 6.67 percent which is the composition of carbon in Fe3C. So this is cast iron and this is the steel part, okay and the temperature here is 1147 degree Celsius, this 1495 degree Celsius, this is 1395 degree Celsius and this is 727 degree Celsius and here it is 900 degree Celsius.

So we can see all the temperature and composition here and we will be looking at the eutectoid part, okay so we will carry this discussion in our next lectures and mostly likely that would be given by professor Sangal, but if given a chance I would also try to take one more lecture where we will be discussing about this, okay. So let us stop here thank you very much.