Phase Diagrams in Material Science Engineering
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Lecture - 54
Ternary Four Phase Equilibria-I

Students, today, we are going to talk on a new topic that is on ternary four phase equilibrium. So far, we have discussed two phase and three phase equilibrium. Now, we are going to talk about four phase equilibria. And, after I complete this, I am going to discuss specific cases like stainless steel, super alloys, high speed steel or even some are ceramic systems.

So, the next 4-5 lectures we are going to discuss about these four phase equilibrium. As you know, in a ternary system, maximum four phases can coexist. Why it is so? Because we know that, according Gibbs phase rule, there are f, which is degrees of freedom, which is equal to c minus p plus 1; for a system, our pressure is constant. So, if you calculate number of components to be 3 in a ternary system; so, for f is equal to 0, it will be 4. The number of phases will be 4. Maximum number of phases, which can coexist at a particular – in a ternary system, is 4; correct? So, that means what? Either one of the phases will transform into three phases or three phases will react to form one phase or two phases will react to form two phases; that means, it is basically the transformation of some phases or interaction of the some phases, where total number of phases will be equal to 4. So, that is what we are going to discuss.

Now; obviously, there are three specific cases, which deserves the attention. The first specific case is what is known as I discussed in the last class let me just write down. The first specific case is the type 1.

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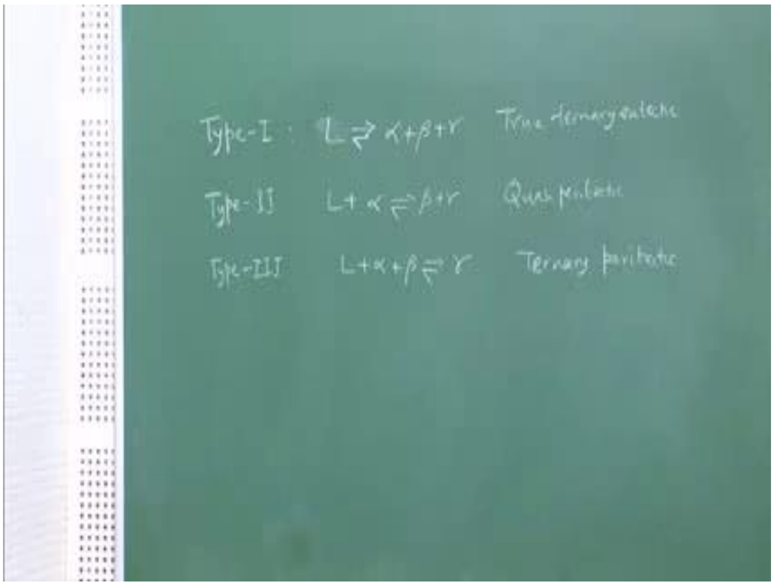

Type 1 four phase equilibria is true ternary or let me write down the reaction first – liquid going to alpha plus beta plus gamma; where, alpha, beta, gamma – solid phases. This is the true ternary eutectic. Why it is true ternary eutectic? Very simple we have seen in the three phase equilibria; you can also have a ternary eutectic involving three phase like liquid going to alpha plus beta; correct? So, we have seen different cases. Even in last class also, I have discussed a case in which two binaries of the three component system or out of three, two binaries will have isomorphous and one of the binaries will have eutectic system. This will also lead to eutectic phase. In the ternary triangle itself, composition corresponds to ternary. So, that is not a true ternary eutectic; those are binary eutectic extended to ternary. But, here this one is a true ternary eutectic.

Type 2 is – type 2 is written like this liquid plus alpha going to beta plus gamma. This is known as quasi peritectic. Why it is known as quasi peritectic? This is can be a eutectic – liquid plus liquid going to beta plus gamma; or, it can be peritectic liquid plus alpha going to beta. This is sometime known as you know reaction, which is neither peritetic nor eutectic. That is why you call as a quasi peritectic. The third type is basically perfectly peritectic. It is a ternary peritectic or rather we can write down – ternary peritectic.

So, basically, there are three different types of four phase equilibria possible in a ternary system; one – true ternary eutectic; type 2 – quasi peritectic; type 3 – ternary peritectic.

For the sake of this course, I am going to discuss mostly on this ternary eutectic, because that is observed and that is found many many systems. But, I will not discussed in detail of these two (Refer Time: 04:46) that I will inform in one of the lectures, how the phase diagram will change; correct.

So, now, let me just tell you that four phase equilibria in a ternary system involves basically it is an invariant equilibria; right? Why it is invariant equilibria? It is mainly because it involves four phases; the f is equal to 0; right. So, invariant equilibria means temperature and the compositions of the all the phases; compositions of all the phases means compositions of solid, compositions of liquid phases all are fixed. So, that means what? In a particular temperature, you will have a picture (Refer Time: 05:38) All the four phases will exist on a horizontal plane; correct. I will draw it and show it you later on. All the phases will exist on a horizontal plane; whether it is a ternary eutectic or quasi peritectic or peritectic; does not matter. In all these cases, because it is an invariant system, all the four phases will exist on a horizontal plane at that temperature. This composition and all four phase compositions will be given or fixed at each of the points on these four phases plane; correct.

So, let us now discuss about these first case, which I told you I will discuss in detail. First one is ternary eutectic systems. Now, I will discuss; I will show you some pictures or slides, where try to make sure that, you concentrate properly and understand the three dimensional shapes of different regions. You know as we have been doing for the last few lectures, a ternary four phase equilibria in case of type 1 involves all the binaries will have eutectics.

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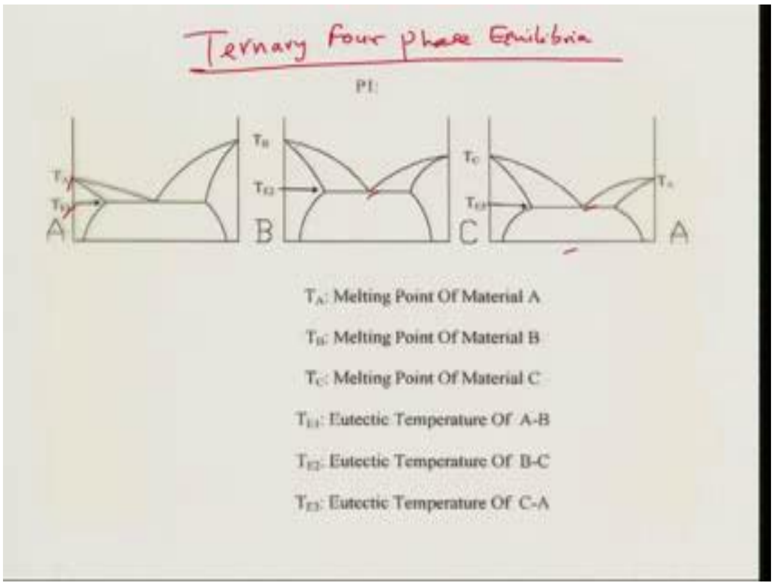

Like A B binary is a eutectic – T E 1; B C binary is a eutectic – T E 2; C A binary is a eutectic – T E 3. And, here you see A has lower melting temperature than B or B has a higher melting temperature.

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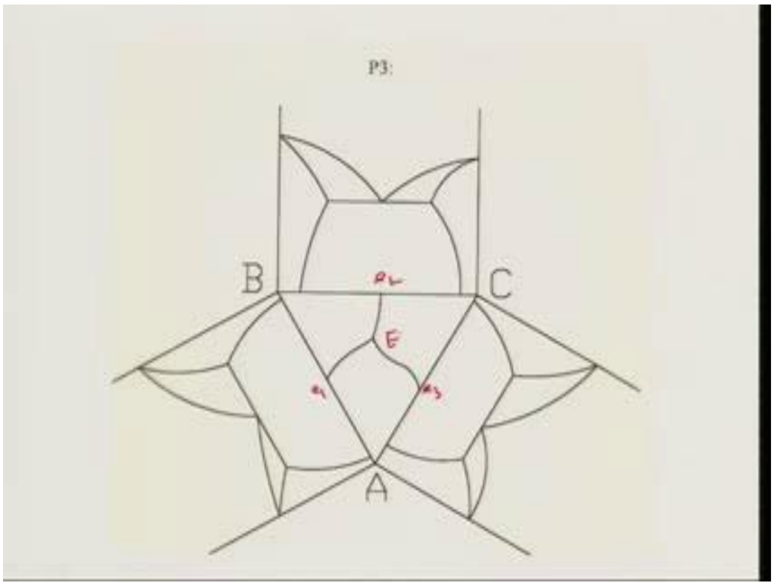

This is what is the system. So, you have a eutectic between AB, BC and CA; right? You can see here. So, what will happen if these three things are mixed together? What will happen to the ternary phase diagram? That is what is the purpose of discussion in the class. Correct? Basically, obviously, few things which come to your mind is that, you will understand that. Because there are three eutectics exist in the three binaries, there must be a ternary eutectics existing; correct? See if I represent this is as a e 1, e 2, e 3 – these points; they will be ternary eutectic e, whose melting temperature will be even lower than the individual binary eutectics.

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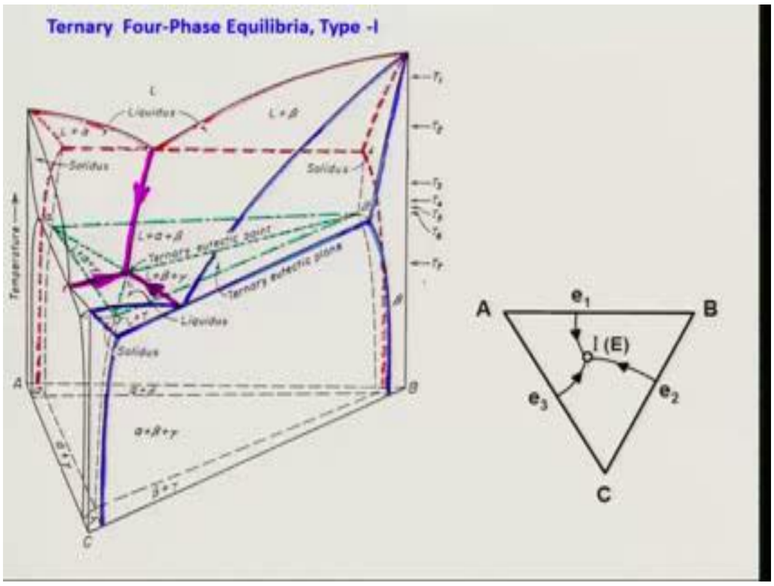

Let us see that; correct? Well, you see here very clearly; I am going to draw it also. You see here that, AB has a eutectic here; AB has a eutectic given by this point. And, this is this eutectic having terminal solutions alpha and beta on the both sides. AC has a eutectic between alpha and gamma; terminal solutions being alpha and gamma. So, this is the eutectic. And, CB or BC has a eutectic between gamma and beta; because of that, you have a ternary eutectic point coming down. This actually surface has coming down and meeting at ternary eutectic point E; that is what is represented here.

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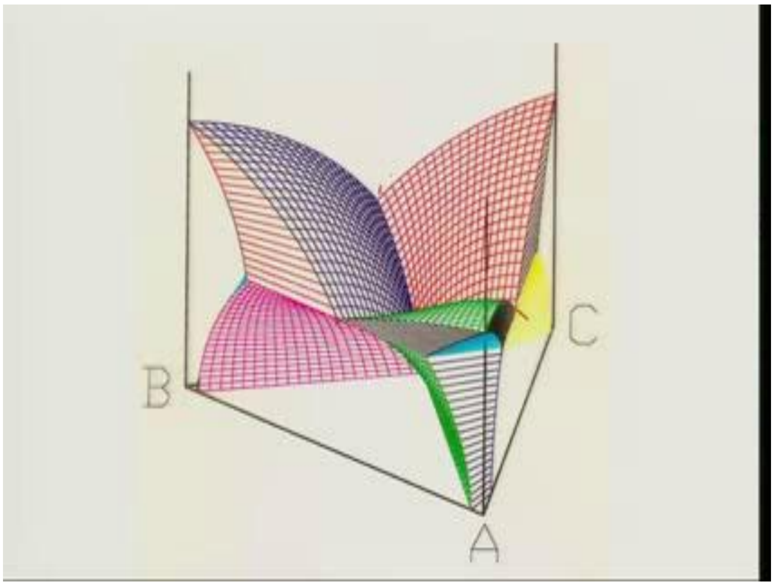

Things will be clear much here. This is a very good picture. So, you can see here this is the binary eutectic between BA, binary eutectic between AC, binary eutectic between CA. A ternary one is basically curving down. They are curving down here; correct. So, if I draw a horizontal plane at the ternary eutectic temperature, the three points will be the ternary – you know is the four phase equilibrium plane; correct. So, be sure about it. These are the liquidus surfaces – one, two, three; correct. They are going down; correct. This is the way it is going; it is going; it is going like that and going down. So, if I take a projection of those surfaces, it will look like this; correct? You see here this is the surface. This is a surface projected. And, there is a ternary eutectic point. It must be like this. Obviously, other than that, there will be other things coming into picture, which is not shown here.

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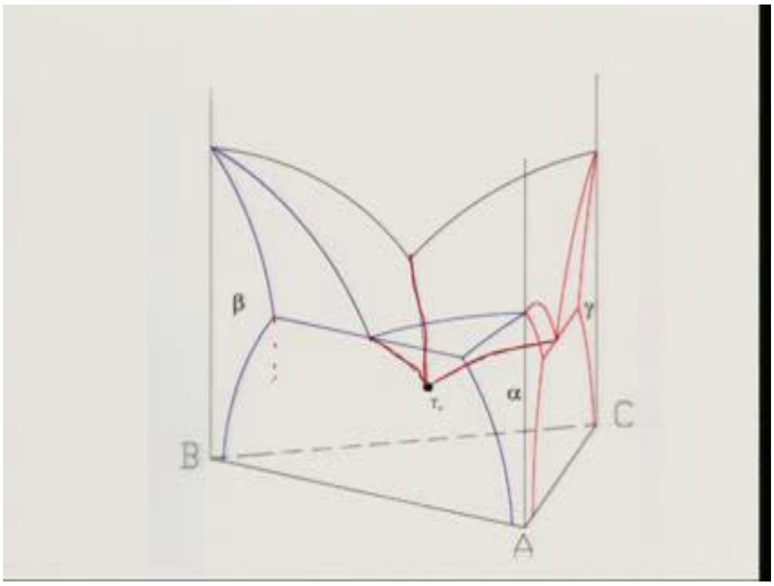

So, if i remove all the shades, this is how it will look like. These things will be looking like this if I remove. This is a eutectic here, eutectic there, eutectic there in the binary. And, together ternary we connect these three points like this – one, two and three. So, that means what? Three values are actually coming down and meeting at point T E. So, now, if I drop, I will show you how I can draw this triangle on the ternary equilibrium.

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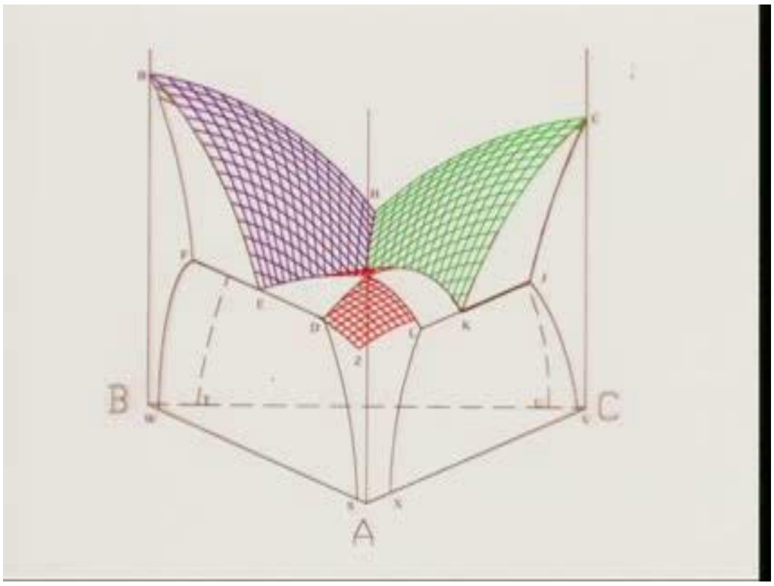

Now, first, look at the liquidus surface. This is a liquidus surface coming into down. This is the one; this is the one; correct.

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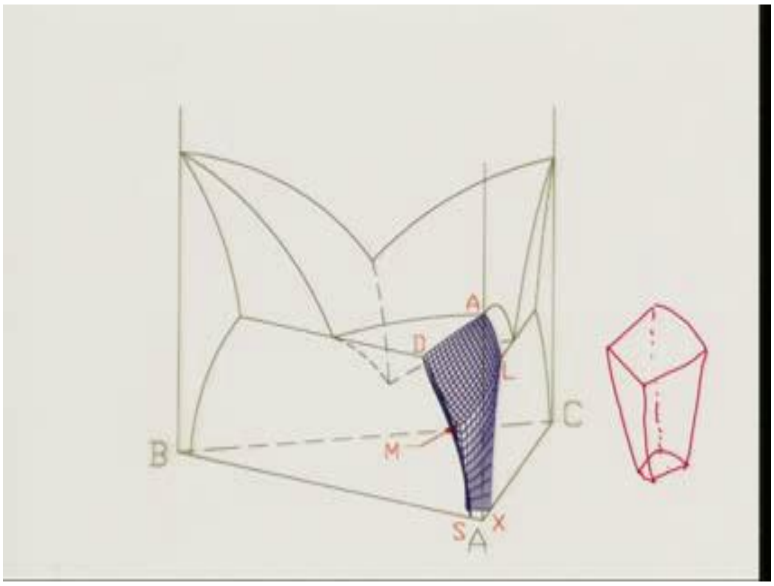

Now, second thing is this one of the primary phase fields. I think this is alpha between AB. So, this looks like this if I draw it correctly. This is how it will look like. This is alpha. So, all these other surfaces also look like same.

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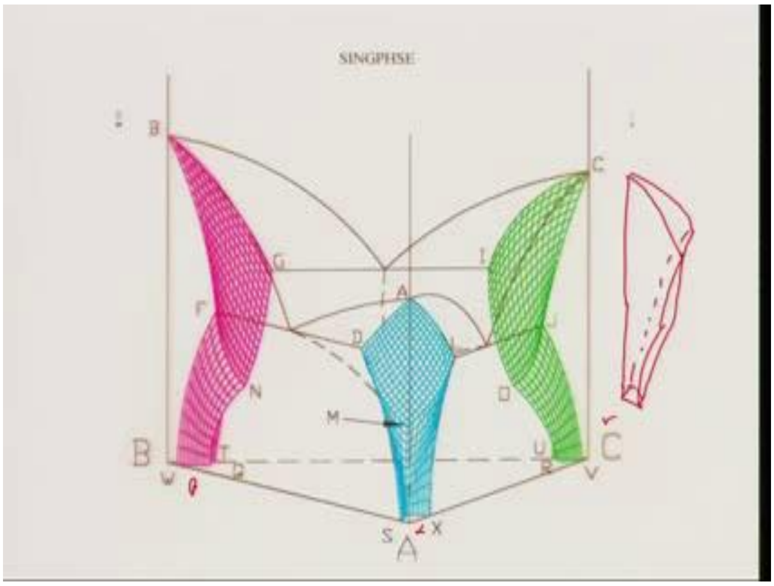

You can see here – alpha, beta and gamma. This is alpha, beta, gamma; gamma is little bit different. (Refer Time: 11:09) it is not different, it will slightly distorted. So, if I draw it correctly, this is like this. So, gamma will be exactly like that and beta will also be similar. So, these are the three dimensional steps.

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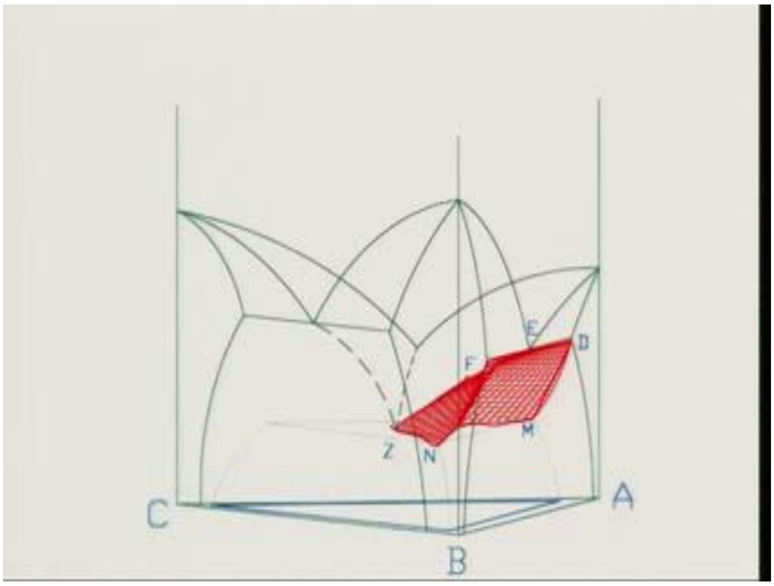

Now, if you want to look at the plane containing alpha and beta phases, that is how it will look. This is like a asbestos sheet coming down in a house; you can clearly see that. This is exactly the same.

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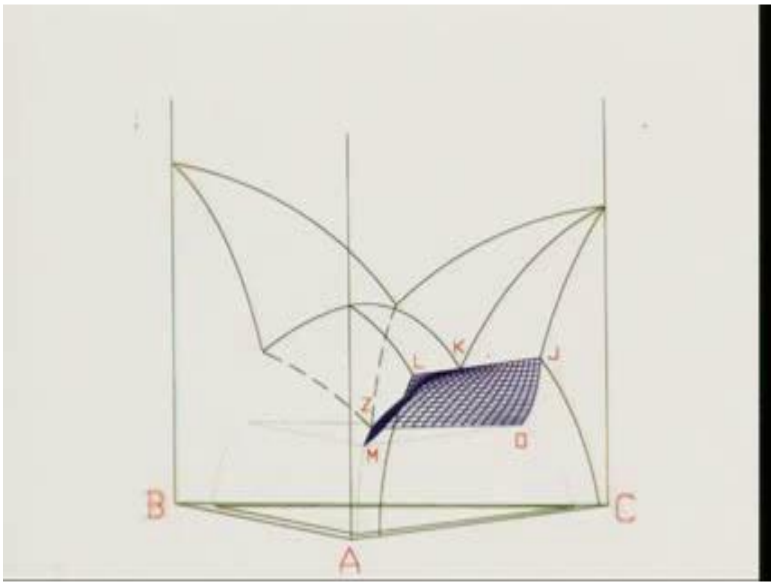

Similarly, this is between AC, AB, AC.

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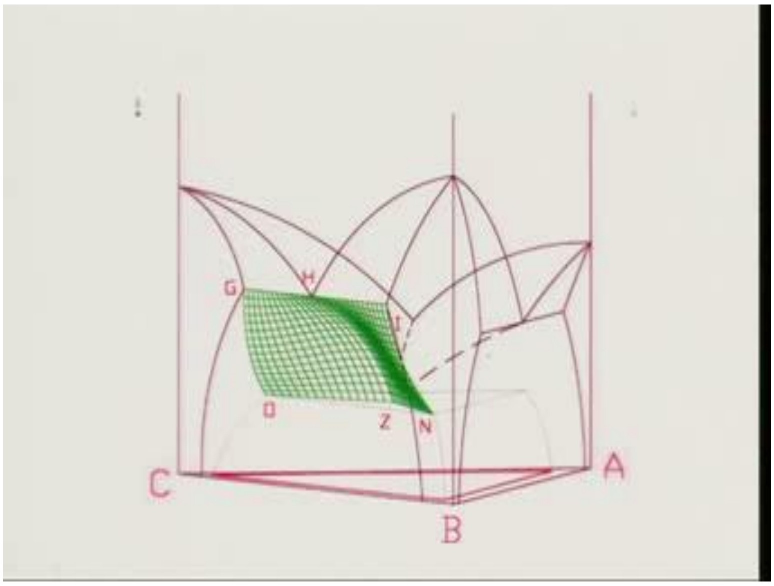

CA – CA is much more clearer. This has the distortion on the surface also. This is not exactly a flat on the top surface; correct.

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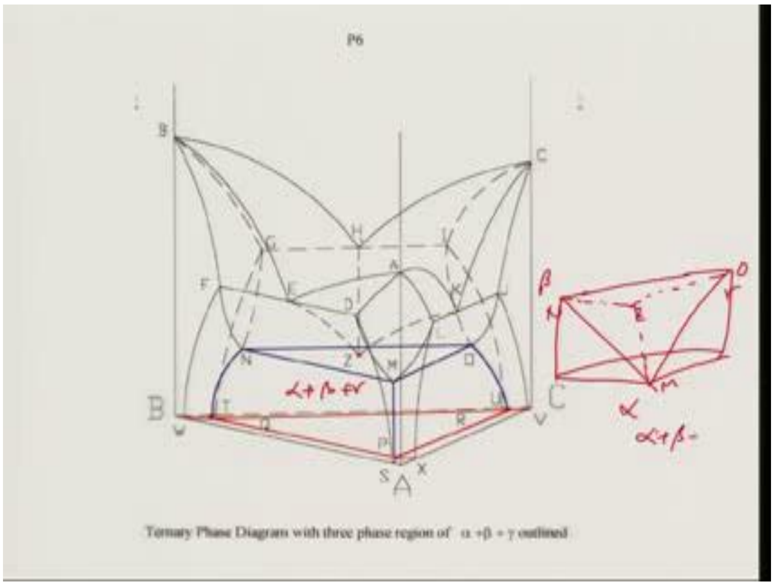

Now, if I remove everything, how does it look like? It will look like this. There are three points E, H and K corresponding to three eutectics. And, this is what the N, M and O with the Z at centre; not at the centre, in the eutectic ternary point. That is what is I am saying – the ternary four phase plane. So, if I draw it properly, N, M, O and Z; correct; that is what you have seen. So, each of these points, this will tell you the composition of beta, alpha and gamma; and, this is a eutectic. So, one can actually join this. This will form a tetrahedral. Many times this picture you will see in the books. Say it looks like that liquid is dissociating into three phases; compositions are given by N, M and N; M, N and O; correct. That is how it looks like. How do I get the N, M and N? N point is obtained from these two ends; this is the one binary; this is another binary; ternary (Refer Time: 13:29) solution. If you connect it here, m is also similar; this also similar; correct.

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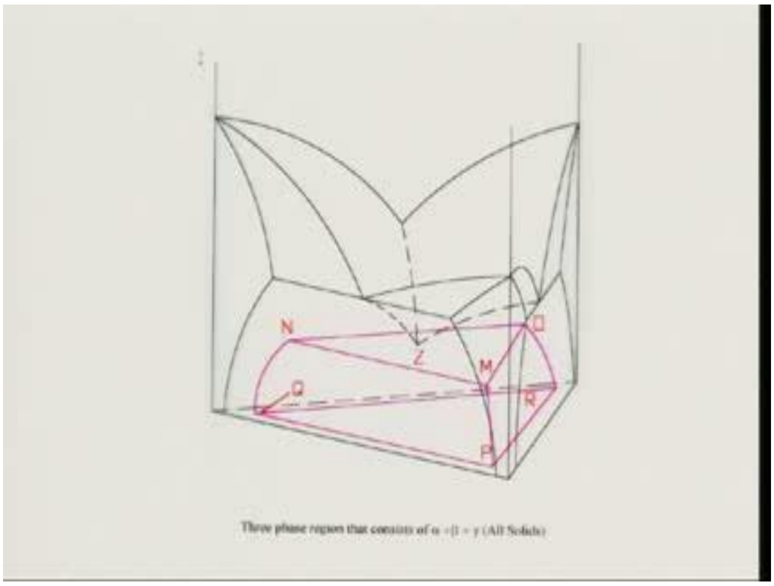

Now, below that, below this surface, below This, in fact, it is already drawn. This is what is alpha, beta, gamma surfaces – alpha plus beta plus gamma; correct – three phase surface. So, it looks like this, this and this. This is how it will look like. So, this is the alpha plus beta plus gamma surface.

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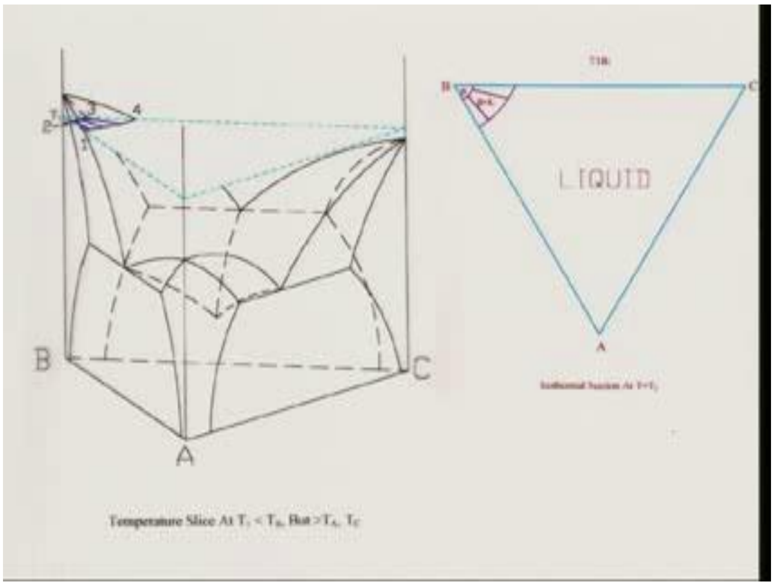

I think I should go back to the board and to draw it and show you now; otherwise, it will not be clear to you. And, while doing that, I am going to use some colour chalks.

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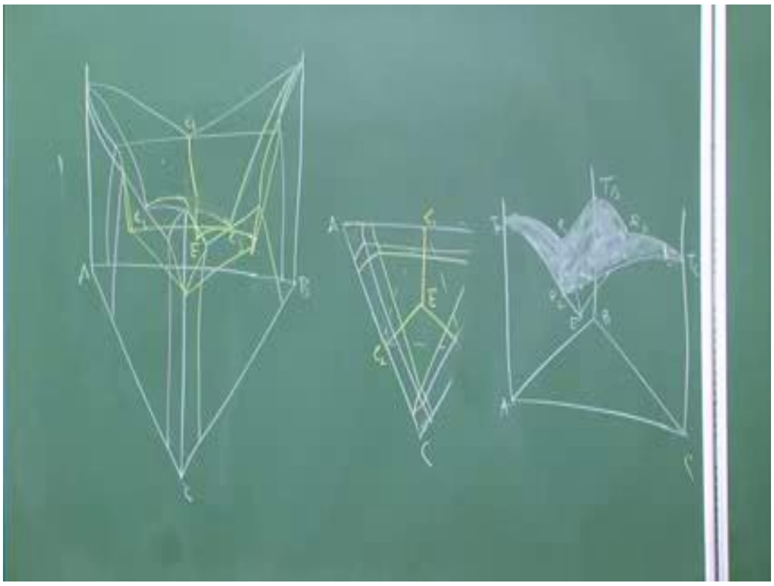

So, first thing I draw is this triangle. This is getting distorted. Better to draw in this way. So, first eutectic is between A and B; fine. Second eutectic is between B and C – A and C. Again this is going to come down like this. And, third one between B and C will be little different. Let us see how I can draw it; correct. So, that is how it will look like. Now, you can join these three points by yellow colour chalk. This is e 1, e 2, e 3, E. In fact, it should quit it down further; then, it will look nice. That is how it will look like. And now, to get these A, B, C points, which is sitting on this, I can join these two. Similarly, I can join these and these. And, I can join these and these. So, these triangles is – actually speaking, this E should fall on that; E should sit on that; that means E will be first further down. So, this is what is the ternary phase model.

So, now, if I take a projection on that, it will be little distorted. These are the three single phase zones; these are the three – so, alpha, beta and gamma. This will be alpha plus gamma beta plus gamma. Let us now write it to be complex. This will look like clumsy. All is shown by points or the lines. And now, we can draw these projections. And finally, I can draw three eutectic meeting at a point e 1, e 2, e 3, E. See if I project everything, it will look like this. These are the two phase region; this is a liquid region; this is basically beta plus gamma; this is beta plus gamma plus liquid; alpha plus beta plus – alpha plus gamma plus liquid. And, this is the three phase region. So, one can actually draw this triangle to show the three points are also eutectic very clearly. This is exactly I just wanted to show you, so that you can draw yourself; you should try it and draw yourself.

Now, what we are discussing now in this further – what we will do is as follows. We are going to take the isothermal sections and the vertical sections and show you how things will change. This is really important because if you understand it, you draw it; you would not able to appreciate how things happen. So, before that, let me just tell you that, you know let me just draw this liquidus surface; yes, that is very important, which I have not drawn it. So, I will draw it at the top and show you. So, let us suppose here actually – I have to remove little bit this. So, you can shade this. This is what is that liquidus surface looks like; this is the eutectic point; this is the binary eutectic point – e 1, e 2, e 3; right. So, I think you should try and drawing yourself, so that you will understand much better way.

In the next lecture, I am going to talk about these projections and also little bit about solidification, how it is happening.