Phase Diagrams in Material Science Engineering
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Lecture – 55
Ternary Four-Phase Equilibria-II

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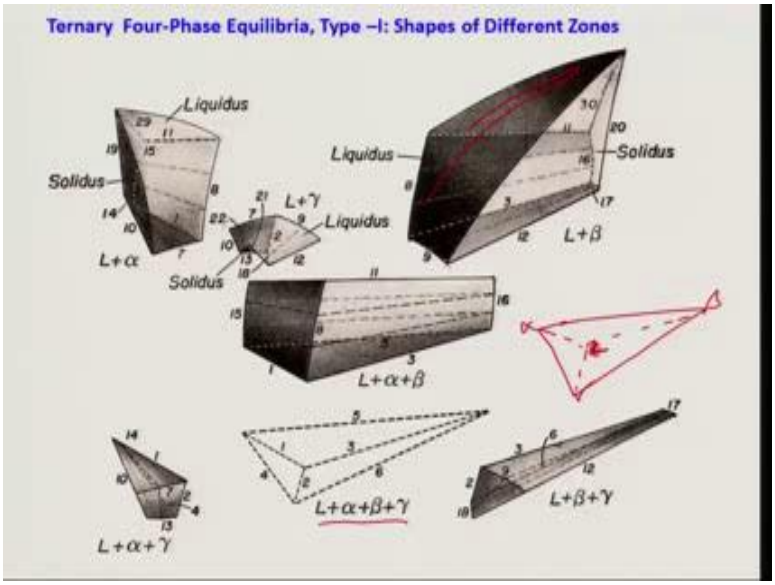

Let us now discuss about further on this ternary four-phase equilibria type one. I have already drawn and shown you shapes here you see all the shapes together. What you see here the shapes of the mixture of the phases like liquid plus alpha these as a prism like shapes; liquid plus beta this is the liquideous surface you can see this is the liquidous surface. And then you have three phase regions like liquid plus alpha gamma, liquid plus beta plus gamma, liquid plus alpha plus gamma, they look like a long cylindrical long actually pyramid. You can see here this is the base and that is the pyramid, similarly here also.

Sometime, it is not there is no apex at the top, but shapes are like that. Most importantly the four phase equilibria has shapes like a triangle, it is like a tetrahedral, but not a regular tetrahedral, it is going to be like this one can draw I am only draw that for you. So, this is corresponding to the eutectic and this is corresponding to the other three phases or the liquid sorry liquid and alpha, beta, gamma correct.

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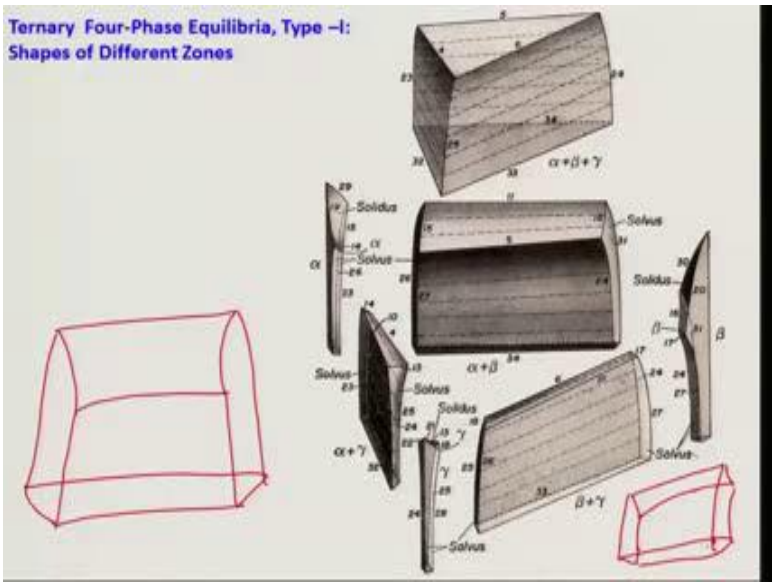

So, now not only that one can also look at solid phases the as I have only drawn you for alpha and beta and gamma also. You see here the solid phase between alpha plus gamma, alpha plus beta, alpha plus beta is very simple one can you can draw yourself it is like this. And beta plus gamma is almost similar not must different, you can clearly you can draw it is same and alpha plus beta is also very easy. So, therefore, these two solid phases two phase solid mixtures are very easy not difficult. The only problem comes about the three phase regions which are little bit complex, but you can practise it and see that basically you can take out these shapes from the 3D space model correct.

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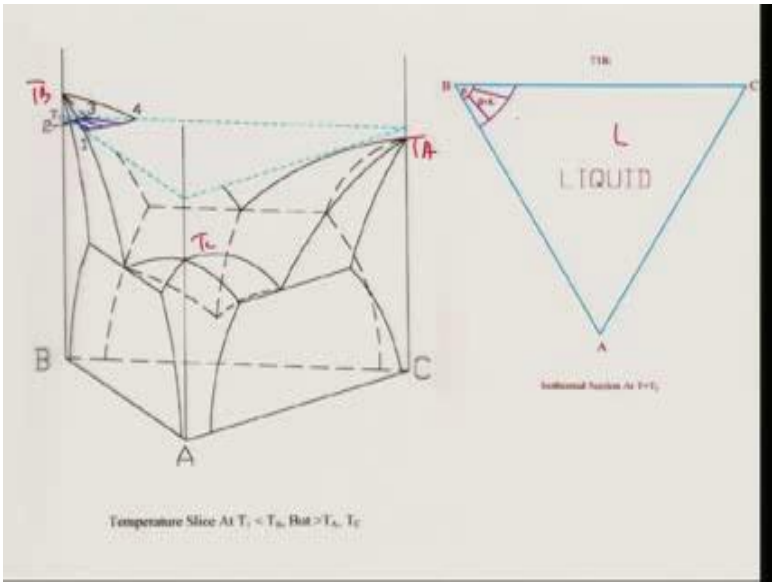

Now, I am going to discuss with you about the thing let me go back this is better I believe I think one can see it you can see it very clearly. So, I will just show you how the three phase how this isothermal sections will looks like. As you know isothermal section is nothing, but a section taken at a fixed temperature. So, how do you do, I just take a triangle at fixed temperature and cut this three-dimensional space model here. This is done at temperature is T1; T1 is little bit lower than the middle temperature of T B, but higher than T A and higher than T C correct. What do you do you cut it what you see here you have a beta and beta plus liquid zone; this is liquid L correct. And one can draw tie lines in two phase zone of beta plus liquid thus state for and not difficult to understand.

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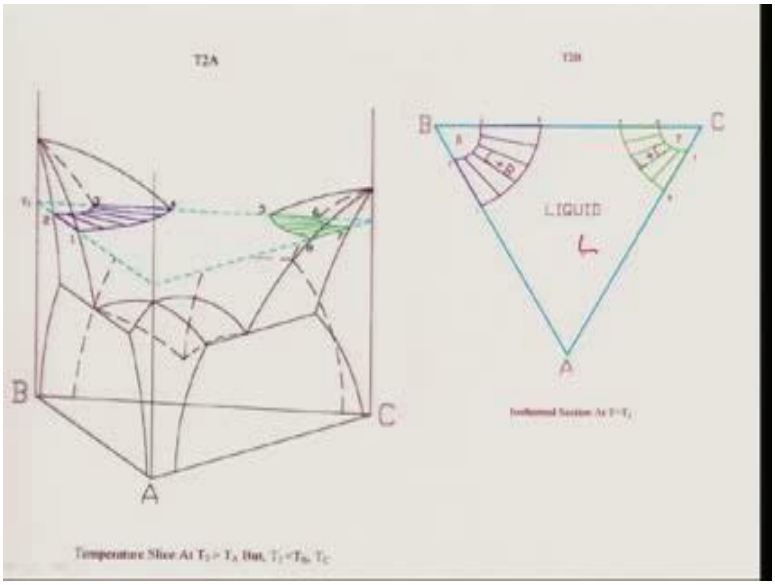

Now, what will happen if you take a temperature T2 which is little lower than the T A melting temperature, but it is above the eutectic temperature between A B that is a e 1 is the eutectic between sorry between BC actually here. So, what actually happens is that it cuts even on the gamma end c end; I am going to show it for when A will be higher than the melting temperature also in the board, but let us try to understand the basic things about it. So, you have a gamma and liquid plus gamma on the c end cut it as not eutectic between temperature between E and C and a liquid correct that is also very not very difficult to understand.

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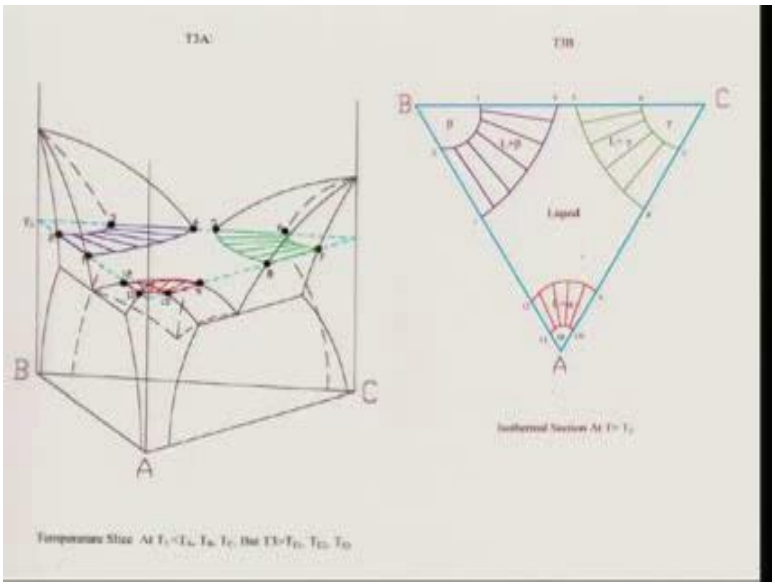

Now, if you go to a temperature little lower than that but in a steel you have not reached the eutectic temperature between B and C, but temperature is still higher than the any of the binary eutectics. What will happen you will have alpha, alpha plus beta plus gamma three single-phase zones and then liquid plus beta, liquid plus gamma, liquid plus alpha and in between a centre level liquid correct?

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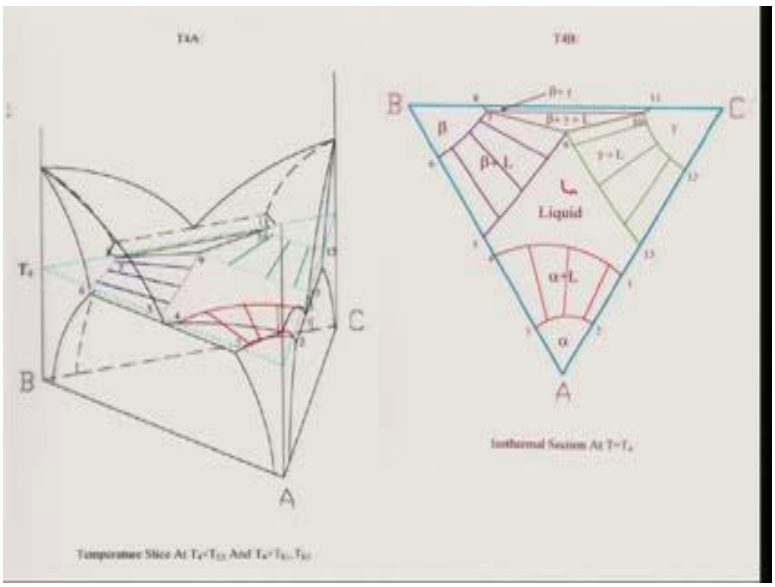

Now, different things will come once you take a section which is little lower than these eutectic between B and C, but hard than the eutectic between A and B, and B and C, A

and C, in this particular case. So, you see here because you have already gone to temperature lower than the eutectic temperature between b and c you have a triangular region beta plus gamma plus L this are three phase equilibrium region. And also you have a region between beta plus gamma between gamma plus beta that is why things are remaining same liquid remains at the centre correct.

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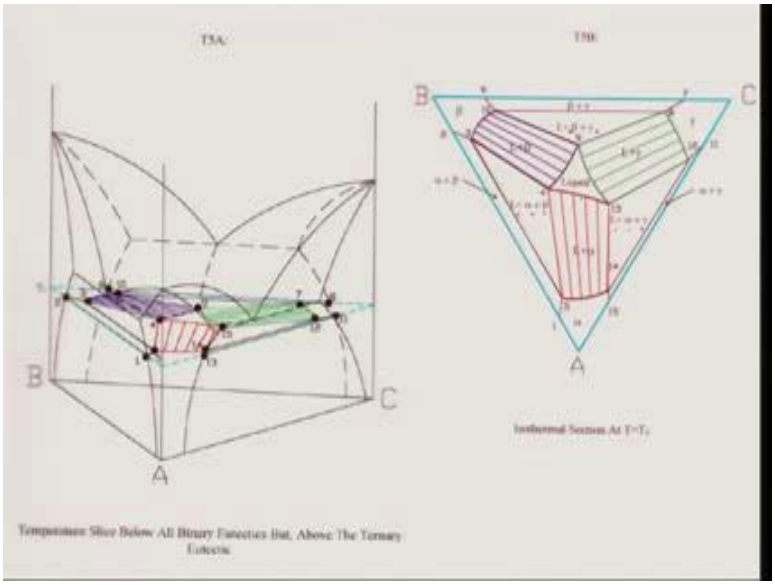

So, if I still go down the temperatures below the you know all the binary eutectics that is easy. So, what will happen you have a triangle between alpha plus gamma what is have been a liquid alpha plus beta liquid plus beta plus alpha, then between B and C liquid plus alpha plus gamma between B and C which is beta plus liquid plus gamma. Three triangles (Refer Time: 05:57) in the three phase regions, and two phase regions extending from this liquid plus beta, liquid plus gamma, liquid plus alpha as a centre you have a eutectic liquid, so that is what it happen. This is just is about the ternary eutectic obviously, but temperature is below the binary eutectic temperatures.

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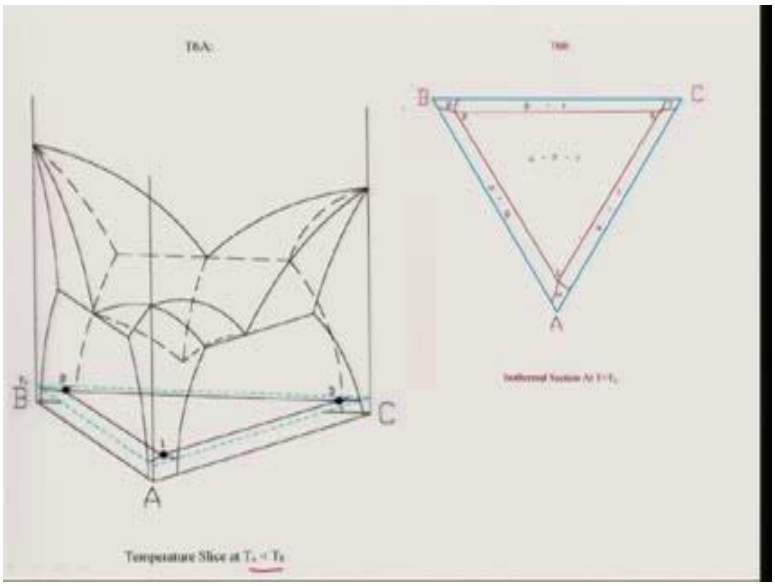

What will happen if I go down below the ternary eutectic temperature that is what is shown here? You see you have a beta, gamma and alpha at the corners and central you have alpha plus beta plus gamma obviously because this is what is the eutectic has going to form and your binaries alpha plus beta plus gamma and gamma plus beta alpha eutectics correct, so that is how it will occur. Now, I am going to draw it for you for a system which is little bit different not that this one because unless and until I draw you will not be able to make it clear.

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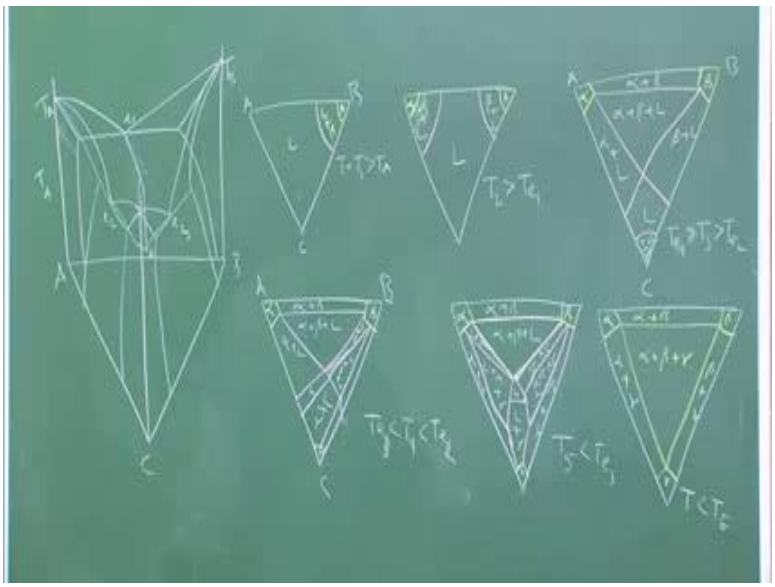

For a eutectic use in which b has highest mainly temperature than and then C. So, now, I can join this three points this is my ternary eutectic. So, A,B, C this is the temperature T A,T B,T C correct and this is e 1,e 2,e 3.So, let me just draw, I will draw a temperature suppose T equal to T1, but T1 is greater than T A, but it is less than T B correct. So, what will happen what do you get is this like this, this is how it will look like beta liquid plus beta liquid A, B, C. Because B has the highest mainly temperature beta will start following first unlike the case I have shown you in the slides where A has lower temperature (Refer Time: 09:04) than c, but b has the highest melting temperature also, but here Chas the lower than temperature A.

So, now, if I go temperature which is T2 where T2 is greater than T e 1T 1 is this melting temperature what will happen it will be same I shown you already. So, we have beta here alpha here, alpha will be smaller (Refer Time: 09:38) and these are the regions of what liquid, alpha plus liquid, beta plus liquid. Remember you have not even touched the eutectic temperature. What will happen if you will touch the eutectic temperature a little bit below a eutectic temperature that is let us draw. First eutectic temperature, so T3 is or rather T e 1 is greater than T e 2.So, it will be little bit different; obviously quite different we have alpha beta and also little bit gamma. So, alpha, beta and gamma.

Then what you are going to have is a triangle, these triangle, which is a feature of three phase equilibria between alpha, beta and liquid and obviously, you will have other things like this one, this one and this one, which is as usual. So, you will have alpha plus beta, alpha plus beta plus liquid, alpha plus liquid, this is liquid beta plus liquid, gamma plus liquid. This is distinct it is that because temperature is lower than the first eutectic temperature. So, first eutectic reaction has happened that is why you have equilibrium between alpha plus beta.

So, now, I go to a temperature which is in between which is below even below the eutectic temperature of B and C correct or sorry A and C. So, A, B, C here now you have alpha beta gamma. So, you draw this triangle there will be two different types of triangle one is this and then you have a triangle here correct this is one triangle this may not be a triangle this will like this yes and then you have a this region this is liquid this is that this will extend. So, what are the regions this is alpha plus beta alpha plus beta plus liquid alpha plus liquid this is liquid, liquid plus beta, liquid plus beta plus gamma, because the third the eutectic here e 3 the temperature is lower than that. So, what the temperature

correct the temperature what then T2, what had that T 3, T 3, T3 now higher than T2, but lower than T3. So, and this is liquid plus gamma that is the one.

Now if you are below this T2, so suppose T5 is less than T 3 what will happen? You will have both the all the three triangles present alpha beta and gamma, sorry this is the first triangle ternary equilibria between alpha liquid alpha plus beta, and this is the second triangle second triangle will be and the third triangle will be here. This is the most complex one alpha plus beta, alpha plus beta plus liquid, this is alpha plus gamma, this is liquid plus alpha, liquid plus beta, liquid plus beta plus gamma.

This is liquid plus alpha plus gamma this is liquid plus gamma beta plus gamma that is how the phase regions because you have all the three this is temperature lower than all the three binary eutectic temperature that is why the three triangle will exits this, this, this. And obviously, whenever the three phase zone in between the two phase zone here, there is a two phase here there is a two phase here there is a two phase zones existing and between this two single phase there will be single phase between this two between this two also.

So, now, I am going to draw the last one which is the temperature is lower than ternary eutectic temperature. So, T is lower than T e that is very easy is one of the easiest one alpha beta gamma that is all. So, this is alpha plus beta plus gamma, this is alpha plus beta, alpha plus gamma beta plus gamma. So, you can clearly see how this you know how this isothermal sections are getting involved.

From here with very high temperature to two temperature little bit above the first eutectic temperature both the two phase regions liquid solid regions exist. Then it is between first eutectic, but higher than second eutectic the first triangle develops then it is fit in between the two you know lower than both the eutectics, but higher than the third eutectic. So, two triangles develop. So, if it is lower than the three all the three eutectics three triangle develop and with this lower than the ternary eutectic you have all the solid phases present with alpha plus beta plus gamma at the centre of (Refer Time: 16:51) that is what.

So, whatever I have shown in the slides is exactly similar, but only thing is that the temperatures the regions are rotated as compared to the earlier cases. So that is about the isothermal section this two will come back when you discuss about the solidification of

the alloys correct. So, now, let us seethe let me see vertical sections. So, vertical sections are also very important as you know vertical sections are taken normally like what there are two ways we can take.

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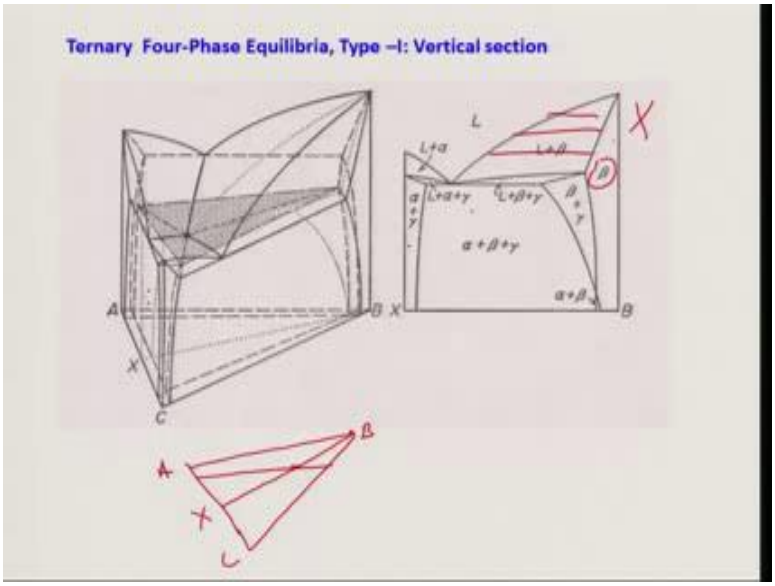

I told you earlier I am tell you again and again, so that you dont forget. So, this is B, this is A, this is C. One is taken like thism, this is x; other one you can take parallel to one of the sides like this. So, here you have been you have taken the vertical sections by X B or B X. So, if I take a plain cut across this will look like this is the alpha plus gamma regions were existing this is alpha plus gamma.

Then we have above we have liquid plus alpha plus gamma and above that we will have liquid plus alpha. Similarly on the right side, you have a beta plus gamma liquid plus beta plus gamma. In addition to that because you have taken we have taken a vertical section from one of the ends of the triangle like B. So, because that there is a single phase zone B correct any of that remember on the vertical sections I cannot draw tie lines like this, this is wrong not allowed, this is one such way.

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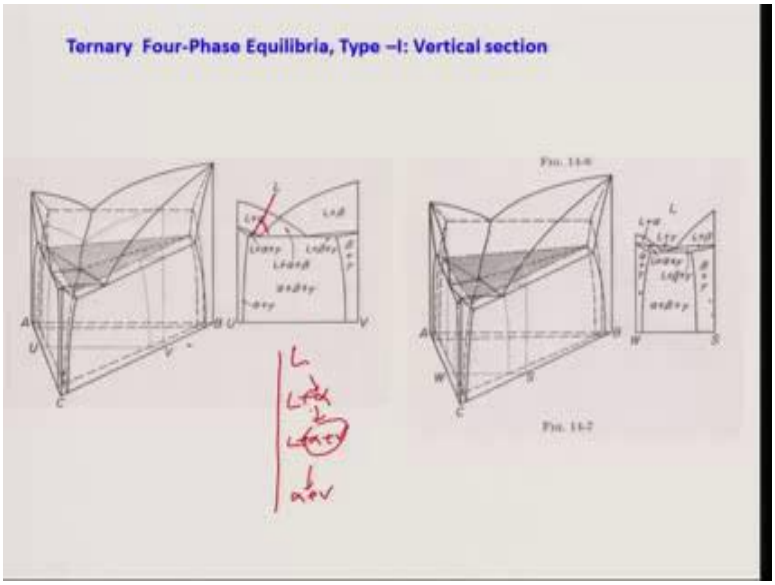

There is other way of taking it this is what is shown here W s here is parallel to two the two sum, W s side is parallel to one of the sides of this Gibbs triangle A B. And if you take it, it is exactly similar accept that because you have taken along the side not along the corner from corners of the triangle. So, you have beta plus gamma, alpha plus gamma on the both the sides the liquid plus alpha plus gamma liquid plus beta plus gamma above that, then you have liquid plus alpha and liquid plus beta. It is similar to the one this one, this region, this side is getting repeated on the right side. Similarly if i take along U V, U V is little bit longer (Refer Time: 19:14) closer to A B then W s. So, we have all the regions remaining same.

Vertical sections are basically important to know how this phase field will appear as the function of temperature, as the temperature is getting down how the phase field will appears. So, liquid to alpha to liquid plus liquid plus alpha plus gamma and alpha plus gamma that is how things happen.

So, when you discuss solidification this is how it will happen liquid, liquid plus alpha, liquid plus alpha plus gamma, alpha plus gamma what does it mean. From the liquid first alpha will precipitate then the binary eutectic reaction happen alpha plus gamma will form finally, will have alpha plus gamma mixture same thing on the right side also that is what it tells it does not tell anything else. So, in comparison to vertical section, the horizontal section sorry isothermal sections are more important that tells you much better

story. So, in the next class, I want to take up, so I have given you some basic idea in these two lectures about this four phase equilibria. I want to take up solidification of different alloys.

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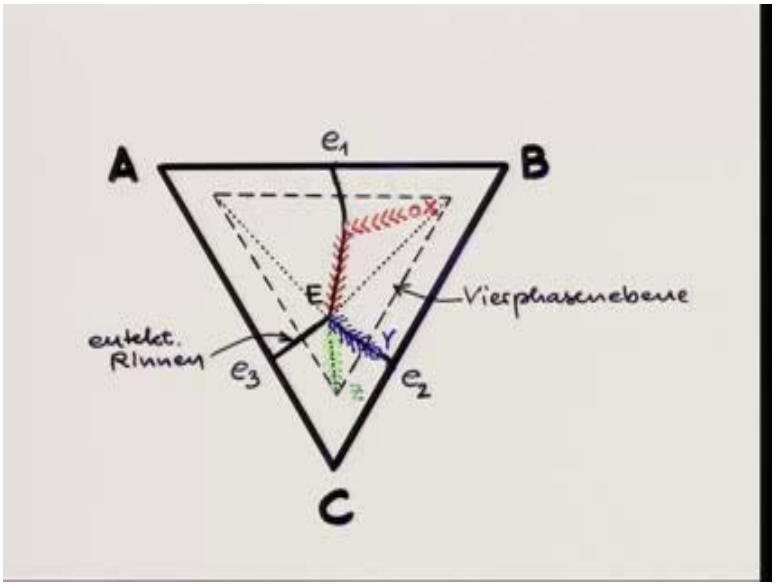

So, will take up solidification of alloy x solidification of alloy z, and solidification of alloy y. See, this is y, this is z, this is x. And we will discuss what will happen and then will tell you how thing this is not important how solidification will follow; obviously, we have to discuss this thing using both space model as well as the using the isothermal sections correct. Let us finish the lecture today and then in the next week, next time, we will discuss the lecture on the solidification.