Thermal Engineering: Basic and Applied

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Lecture - 25
Superheaters and their Arrangements, Steam Temperature Control

I welcome you all to this session of thermal engineering and the topic of our today's discussion is the superheaters. In the last class, we have discussed about the boiler attachments and we have seen that superheaters are attached to the boiler for its efficient operation. Though superheaters are not the mandatory components, yet these components are attached to the boiler essentially for the efficient operation of the boiler.

So these are accessories, what we have discussed in the last class. So since these accessories like superheaters, reheaters are the components which directly affect the performance of the boiler, and we need to look into the operation of superheaters and that is why in today's class we shall briefly discuss about this particular component.

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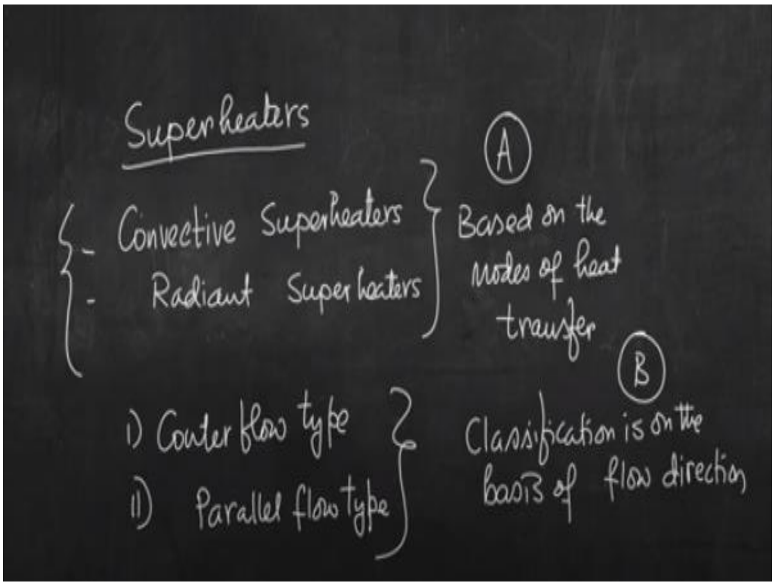

Superheaters

So we have seen that superheaters are basically high temperature heat transfer surfaces in the boiler. So superheaters take dry saturated steam as the input and provide superheated steam at the outlet. Superheaters are of two types, which are used in the boiler and those are convective superheater and radiant superheater.

From the name itself we can understand that convective superheaters utilizes the convective mode of heat transfer to take heat from the flue gas and that heat is used to increase the temperature of the steam which is circulated. On the other hand, radiant superheaters utilize the radiative mode of heat transfer to increase the temperature of steam essentially to provide superheated steam.

So superheaters are basically convective superheater and radiant superheaters. So this is the classification depending on the mode of heat transfer. But we all are mechanical engineering student, electrical engineering student, chemical engineering student. So we all have study about fluid mechanics. So when you talk about convective mode of heat transfer, the heat transfer is an important aspect there and in addition to that particular aspect, the fluid mechanics also will play an important role.

So when you talk about convective heat transfer, then it is kind of conduction plus advection. So you know that for advective transport fluid mechanics will play an important role. So why not to look at the classification which should be based on the flow configuration.

So when we are talking about convective superheaters or radiant superheaters, the modes of heat transfer is the basic criteria for which we have arrived at this sub classifications. But when there is flow of steam through the superheater and flue gas also will try to flow over the superheaters. Depending on the flow configuration, superheaters can be classified into again two categories. One is counter flow type and other is parallel flow type. So this classification is on the basis of flow direction. Whether the flue gas and the steam, these two streams are flowing in the same direction or opposite direction, depending on that particular flow direction, we can classify superheaters into two sub classes. One is counter flow type another is parallel flow type.

So the classification which is based on the modes of heat transfer is listed over here under A that is the fundamental one. And again the classification based on flow configuration is listed under B. So as long as the superheater type is radiant superheater this classic this particular sub classification is not that much important.

But while we are talking about convective superheaters the flow direction will play an important role and based on the flow direction we can classify superheaters into these two subclasses that is counter flow type and parallel flow type. So let us now look into what is counter flow type and parallel flow type.

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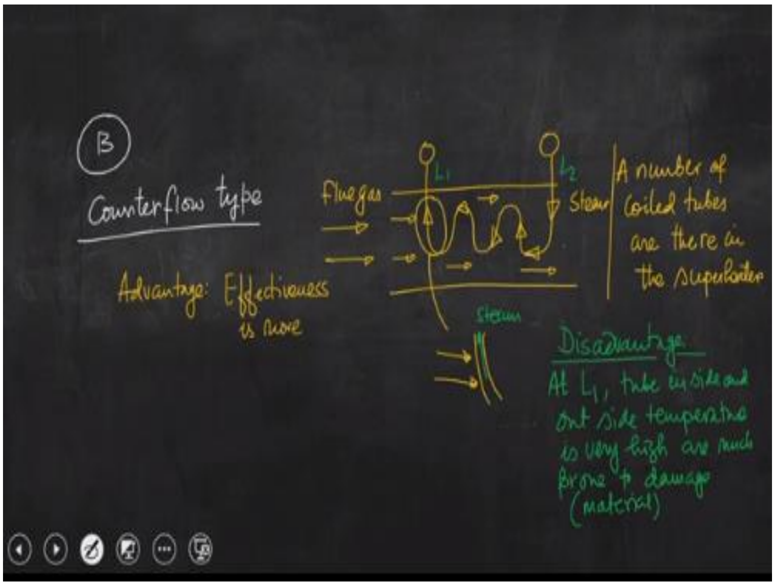

Counter flow type superheater

So you all have studied counter flow heat exchanger in your heat transfer course. The same principle is applicable here. Basically we have identified that the hot flue gas stream and steam will flow in the direction opposite to each other.

So let us draw the schematic for counter flow type superheater. Basically, whether it is a convective superheater or radiant superheater, a number of coiled tubes are there in the superheater. So you can see the steam direction and the flue gas direction in schematic drawn in slide. So in this superheater, the direction of steam is from right to left while the flue gas is flowing from left to right. So these two streams are flowing in the direction opposite to each other and that is why the name counter flow is there.

So you can see this superheater is hanging from the roof of the boiler. Basically you can see the inlet port and the outlet port and this superheater is hanging from the roof of the boiler. And the particular coil is placed inside the confined space and flue gas is allowed to pass through the confined space. So flue gas is flowing in the direction left to right. So if you try to look at over here, we can check flue gas direction and steam direction. So these two streams are flowing in the direction opposite to each other.

Now what is the advantage? When the flue gas is first approaching this superheater, here the steam temperature is very high. That means if we take this particular portion and draw over here, then this is basically a tube and here the flue gas is first approaching. So this portion is first to approach the incoming hot flue gas stream. So the outer temperature of the tube is very high. Also the steam is coming from extreme right to that particular location. And this steam has already acquired some temperature from the flowing flue gas.

But particularly when that steam is coming over here, inside temperature of steam is very high already, while the outside temperature of tube also will be very high because this is the part which is first approaching the flue gas which is having high temperature. So flue gas when flowing from extreme left to right it is exchanging heat and when the flue gas is reaching at the right side of this particular device, the temperature is reduced.

So let us give name to the locations L_1 & L_2 as shown in the slide. So the temperature of flue gas at L_1 is very high, while temperature of flue gas at L_2 is relatively less. But steam temperature at L_2 is also less relatively less but at L_1 is high. So that means, this particular portion L_1 of the superheater is prone to high temperature because tube inside and outside temperature at this particular location is very high and this may cause the damage of the tube. So this is the disadvantage. So before coming to the advantage, let us first write the disadvantage.

So disadvantage is that at L_1 tube inside and outside temperature is very high and this location is much prone to damage that is material damage of course and chances are there that leak may happen, means it is much prone to leak as well. So this is the disadvantage of this particular arrangement. What is the advantage? Definitely advantage is effectiveness is more. This is quite intuitive because we all have studied in the context of counter flow type heat exchanger that the effectiveness is more. So following the similar argument we can say even in this particular case, the counter flow type superheaters are more effective than the parallel flow type. So this is the advantage. But the disadvantage is what we have already discussed. So this particular aspect should

also be taken into consideration while designing the counter flow type superheater.
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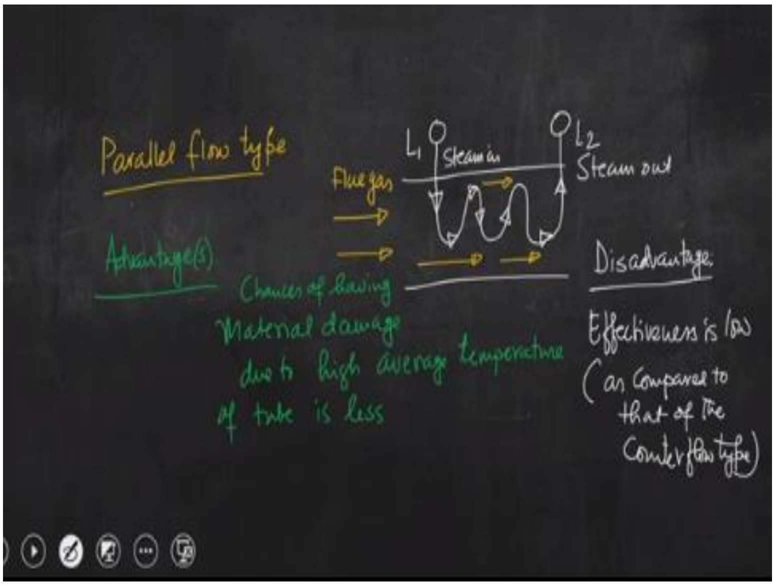

Parallel flow type superheater

So let us draw the schematic. You know there are a number of coil tubes and I have shown one coil in the schematic. So the steam direction and the hot flue gas direction is shown in the schematic. So this particular coil is hanging from the roof of the boiler. Now this coil is placed inside a confined domain and flue gas is allowed to flow through that particular domain. We can give name to the tube location as L_1& L_2.

So if we look at this particular portion, we can see that the two streams are flowing in a direction parallel to each other. So flue gas is flowing from left to right, also steam is flowing from left to right. So these two streams are flowing in a direction parallel to each other and that is why the name parallel flow is coming over here. Again let us look at the advantage and the disadvantage.

So first if we write the disadvantage, then following the same logic that we have studied in the course heat transfer, the effectiveness of parallel flow heat exchanger is low as compared to the counter flow. So I can straightaway write that effectiveness is low as compared to that of the counter flow type.

Then we need to look at the advantages. Now if we compare counter flow vis-à-vis parallel flow, what we can see? In the context of counter flow, we have seen that when steam is coming from extreme right to the left, we have seen that at this particular location L_1 the temperature of steam inside is very high. Outside temperature of tube is also very high. So because of this reason, the material may damage and chances are there to have leakage. But if we now consider this particular arrangement that is parallel flow, then the inner surface temperature of tube is not very high because steam temperature is not very high.

Though the flue gas is first approaching this particular portion, it is quite expected that here the outside temperature of tube will be very high, but the inner surface temperature is not that much high. So the problem which will arise because of the excessive temperature of the tube material will not be there. So I can write that the chances of having material damage due to high average temperature of tube is less. So this is the advantage.

Now, you know that our objective is to get superheated steam. So when these two streams are flowing in the same direction they will get time to have heat exchange. But when the steam is coming at section L_2 that time though steam has acquired temperature in the course of flow, from the flue gas stream but since flue gas has already lost temperature. So when flue gas is coming in sections close to L_2, that time flue gas temperature is very less.

So you know that the temperature of steam which you will be getting at section L_2 is not very high. On the other hand, if we go back to the counter flow type, we have seen that when steam is coming at section L_1 that is the outlet port, the steam temperature is very high. So effectiveness is very high in this counter flow type but that is not there in the parallel flow type.

But on the other hand in the parallel flow type, chances of having material damage due to high average temperature of tube surface is not very high. So considering these two, if we consider parallel flow type, we have to compromise the efficiency or effectiveness of the superheater. On the other hand if we consider counter flow type, although we may get high effectiveness, but still chance will be there that the material may damage.

So considering these two a special type which is neither purely parallel flow nor purely counter flow is considered to attain relatively higher effectiveness and at the same time we can eliminate the possibility of having material damage. So let us look into that particular configuration.

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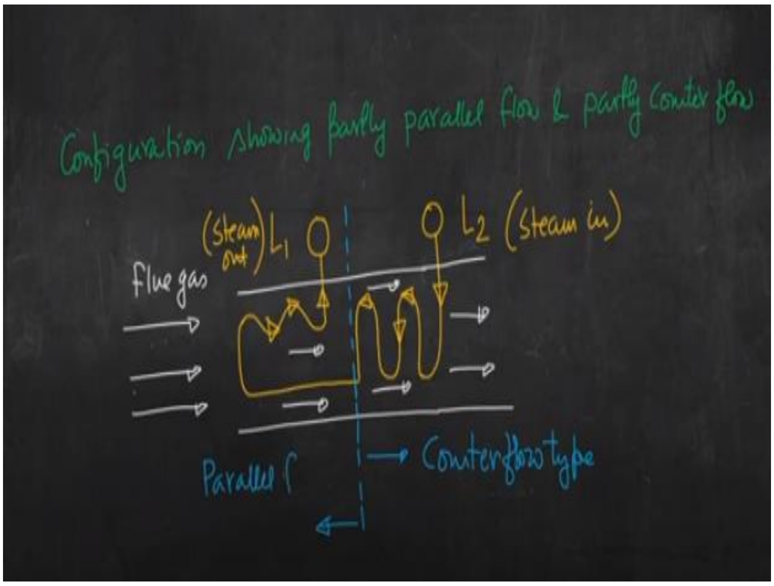

Configuration showing partly parallel flow and partly counter flow

So let us look into this particular configuration, through the schematic depiction. So there is a confined space in which that superheater coil will be placed. We can take the superheater coil and represent one end of the coil through the schematic as shown in the slide just to make you understand the configuration.

Now I have tried to mark arrow for steam flow direction and flue gas direction. So we can see that this particular coil is suspended from the roof of the boiler. So L_1 is inlet or steam in and L_2 is steam out. Now in this this particular schematics, if we give one demarcating line, such that the line demarcates two different flow configurations. What are those? If we look at the right side of this line, in this particular zone, we can see that the flue gas is flowing from left to right while steam is flowing from right to left. So this is counter flow type.

While if we look at the left side of the demarcating line, we can see that the steam is flowing in the upper part of the coil from left to right direction and flue gas is also flowing in the same direction. So these two streams are flowing in the same direction that is from left to right and this particular configuration show similarity with the parallel flow type.

So this is neither purely counter flow nor purely parallel flow, it is a combination of these two. And the main purpose of having this type of configuration is to get the advantage of high effectiveness and at the same time to reduce the possibility of having high average temperature of tube material, so that the chances of having material damage can be prevented. So this is the configuration.

So basically we have discussed about the classification based on the modes of heat transfer that is the fundamental classification. Then we have discussed about classification based on the flow direction and we have discussed three different cases; parallel flow, counter flow, and combination of these two.

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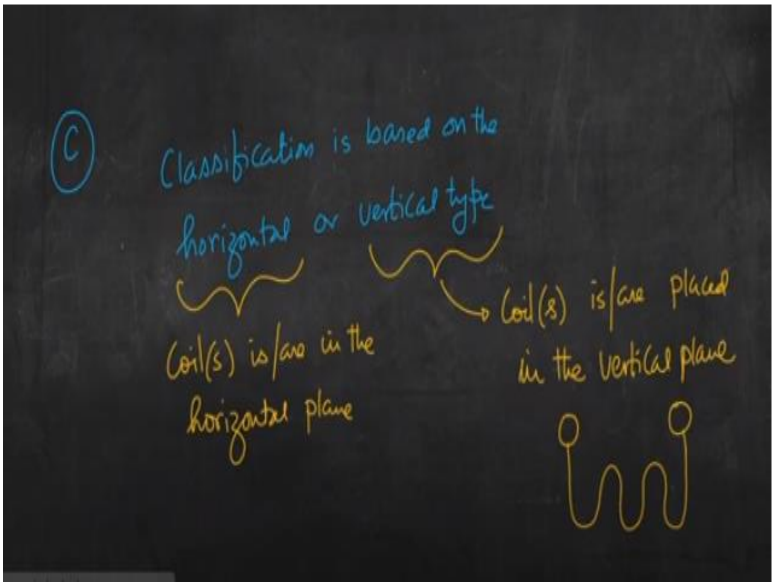

Next we will be discussing about third type of classification which is based on the horizontal or vertical type. So basically we can go back to the previous three examples to understand this aspect. In case of counter flow arrangement, the coil is suspended from the roof of the boiler and it is placed in the confined chamber through which hot flue gas is flowing. In the next case that is the parallel flow type, the coil is also suspended from the roof of the boiler and placed in the confined space through which flue gas is flowing. Then in case of the third one that is the combination of previous two it is also the same, but little different I mean we have discussed that it is having both counter flow and parallel flow type arrangements. So even in this case also the entire coil is placed inside the confined chamber and the coil is suspended from the roof of the boiler.

So in all these three cases, the coil is vertical type as it is suspended from the roof and placed in the confined domain or space wherein the flue gas will be flowing. So whether the coil is in horizontal plane or in the vertical plane, depending on this particular aspect the superheaters can be classified into two sub classes, one is horizontal type another is vertical type.

Let me tell you once again. Whether the coil is in the vertical plane or in the horizontal plane, depending on this particular aspect, we can classify superheaters into two subclasses, one is horizontal type that means coil(s) is/ are in the horizontal plane, and vertical type, in which coil(s) is/ are placed in the vertical plane. So this is the classification.

Till now we have discussed parallel flow type, counter flow type and combination of these two. All these are the examples of vertical type. So coil is placed in the vertical plane. So in vertical type, basically coils are in the vertical plane.

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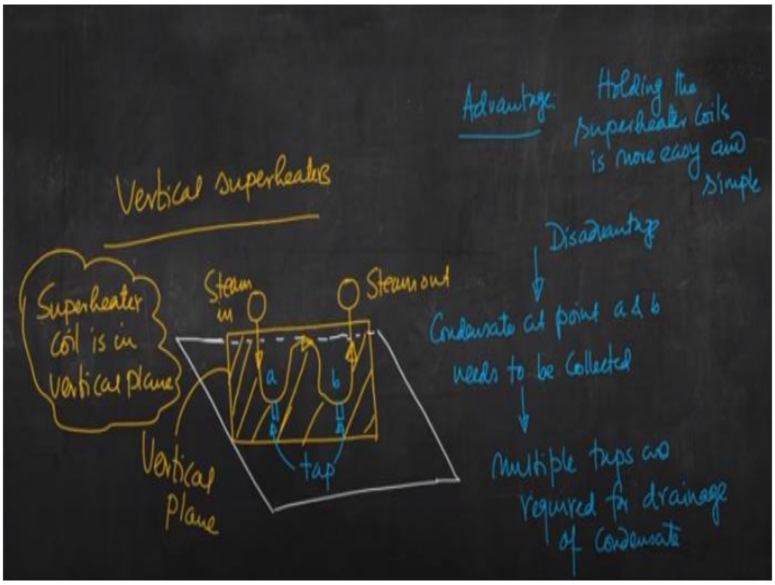

Vertical superheaters

Now we can draw the schematic of vertical superheater as shown in the slide. So there is the vertical plane shown. Now the steam inlet and steam outlet has been marked in the schematic. The direction of steam flow is also shown. The important thing is that any mechanical component or device after a long period will start malfunctioning because of several reasons. So when steam is coming in and going out from this particular coil, so chances are there that condensate will be collected in the coil because of this particular arrangement. The collected condensate will remain there in these particular parts named as a and b. So condensate at points a and b needs to be collected on a regular basis.

And because of this particular arrangement, it is very difficult to collect condensate or to drain out the condensate in a normal way. So what is needed? We should have this tap. So multiple taps are required for drainage of condensate. See this condensate should be collected on regular basis to have proper functioning of the superheater.

If we need to collect condensate on regular basis, then because of this particular arrangement, it is not so easy to take it out. Since we need to take it, we should have multiple taps. So this is the disadvantage of this particular type. So this is the disadvantage. Advantage of vertical superheater is that holding the superheater coil is more easy and simple because it is hanging from the roof of the boiler. So this is vertical superheater. So now let us briefly discuss about the horizontal superheater.

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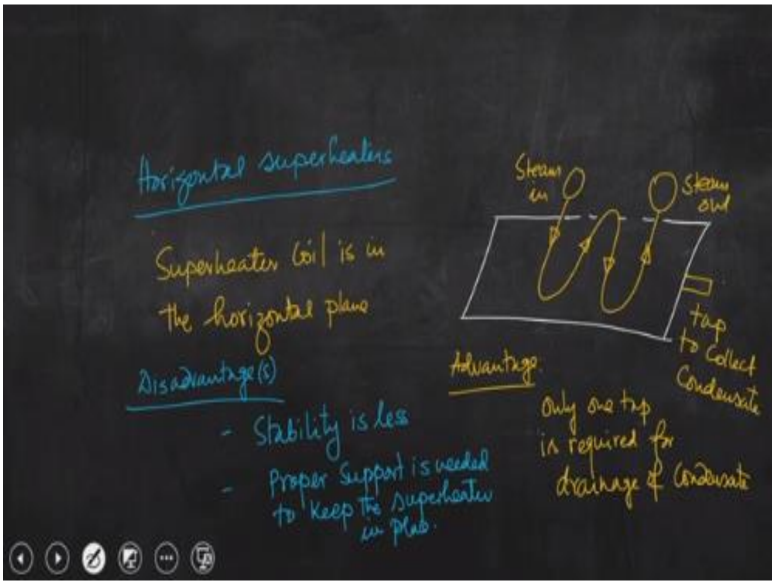

Horizontal superheater

So in this case superheater coil is in the horizontal plane. Now let us draw the schematic. In the schematic, the horizontal plane is drawn and superheater is placed. And here we have only one tap to collect condensate. Then the steam in and steam out locations are marked.

Because of this horizontal plane, we can easily take the condensate out from the superheater and only through one tap. So only one tap is sufficient to take the condensate. So basically advantage is only one tap is required for the drainage of condensate.

Similarly, we also should know the disadvantages. See in case of the vertical superheaters, holding is easy because coils are suspended from the roof of the boiler. But in case of a horizontal superheater stability is less, because the entire system in the horizontal plane. And when there is flow of steam we need to have proper support to keep the superheater in place. So first of all, placing the superheater is very easy in case of a vertical superheater because we can hang the superheater from the roof of the boiler. But in case of a horizontal superheater placing the superheater is not so easy because we need to keep it in the horizontal plane. Since through this coil, steam will be flowing, so because of this flow there will be change in momentum. So to keep that superheater in place, we need to have proper support. So stability is less and proper support is required to keep the in place.

But despite having these disadvantages, since drainage is not that much difficult in the horizontal superheater, horizontal superheaters are preferred over the vertical superheater. Because in case of the vertical superheaters drainage of the condensate is really a difficult task. We need to have multiple taps and that is also not an easy. So despite having all these disadvantages that is stability is less, we need to have proper arrangement to keep the superheater in place, but since the drainage is not that much difficult and using only one tap we can collect condensate, horizontal superheaters are preferred over the vertical superheater.

So to summarize today's discussion, we have discussed about the superheater classification depicting the schematic diagram of different types of superheater. We have discussed about their advantages and disadvantages. We have seen that fundamentally superheater can be classified based on the modes of heat transfer, but depending on the flow configuration, their arrangement, we also can classify into other subcategories.

And finally, though superheaters are used to have superheated steam, but in some cases depending on the load of the boiler, steam temperature at the exit of the superheaters may decrease. To account that particular aspect, superheaters are sometimes connected in series and that we will discuss in the next class.

So with this I stop here today, and we shall continue our discussion in the next class. Thank you.