Environmental Air Pollution

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Lecture No. 37

Source Emission Monitoring

Before I set right our this thing, what I want to talk to you is something called....

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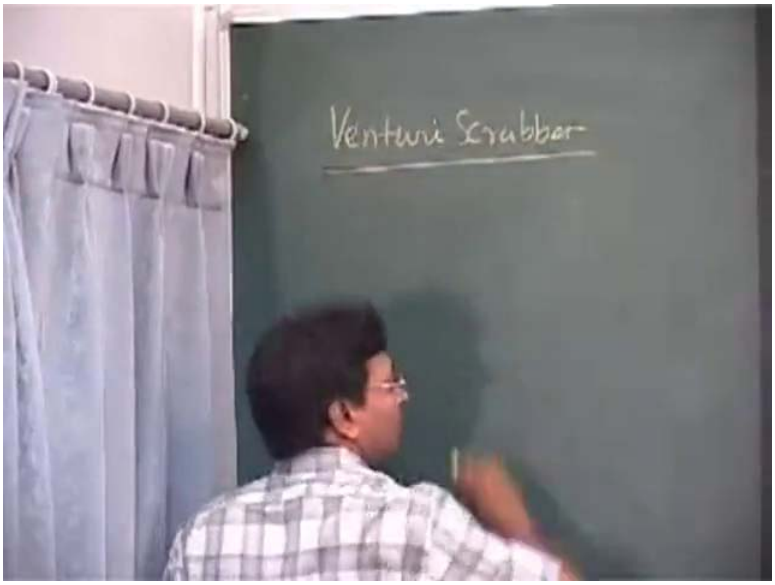

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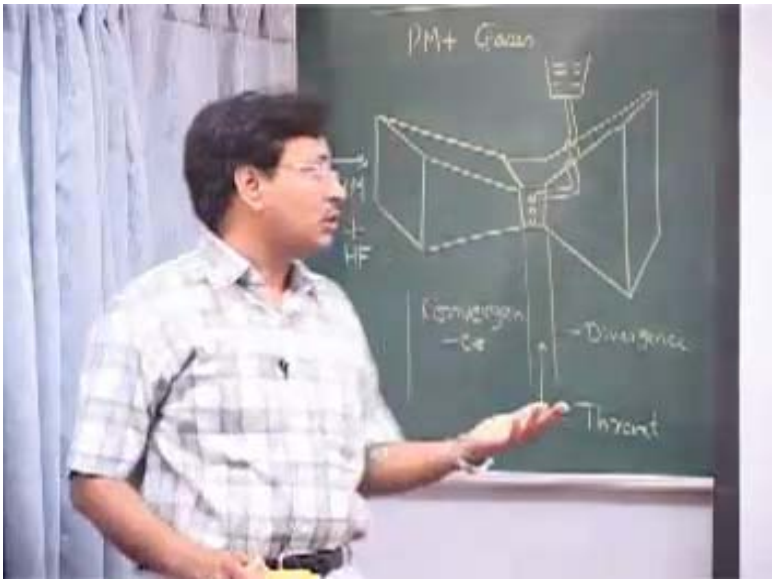

We have talked about the devices that can control particulate matter or dust. Now, we want to control both. In this thing, you can control both particulate matter plus gases and the system looks like this. Unfortunately, I do not have the figure for this. This is an approximate drawing and this is called Venturi scrubber. Here, you pass your particulate matter and gas. For example, let us take the gas as HF; I am just giving an example – it can be other any other gas. This part of the Venturi is called convergence, this is called divergence and this is called throat. The challenge is of course the particles that are smaller in size – it is difficult to remove.

In here, you have little openings and I am making some drawing that may not look very good, but the meaning has to be clear. You have the scrubbing solution, which can be water or some other chemical. What you do is that you bring this scrubber liquid and with these holes, you can go a little bit inside in the depth and you can drip the liquid – water or whatever is the scrubbing solution. For HF, what could be the scrubbing solution? For HF, if you recall, it is Na_2CO_3. Do you remember we talked wet scrubbing for aluminum plants? So ordinarily, this could be water or Na_2CO_3 depending on what you want to review.

Here, you have the particulate matter and HF. As it goes through the convergence area, it acquires very high velocity – obviously – and the particles are released. These particle water droplets will be fairly large particles – maybe 0.5 mm, 1 mm, whereas the particles that you want to remove are very fine particles – something from 10 micron meter to about 0.5 micron meter, smaller particles; you could remove the larger particles very easily with many methods. Here, two things happen: as this thing comes in the divergence area, the velocity of these water particles or the scrubber particles will be smaller and the velocity of the gases will be faster. If you go in the convergence area, what will happen? There will be a relative velocity between the water droplets and the particles that are travelling. Who is travelling faster? The particulate matter is travelling faster, whereas the little droplets of water are travelling slowly. When there is a relative velocity between two things, what is the result? They collide, right? When there is a relative velocity, if somebody is moving at a higher speed and somebody is somebody is moving with a lower speed, the thing coming in at the higher speed is likely to hit that one.

What happens in this process is that there is a relative velocity in this range. Because of this relative velocity, there is an impaction of the particles onto the water droplets and the particle will become part of the water droplet. Then, many particles can go inside one water droplet

and so in this way, what happens is that the smaller particle are encased in the larger water particles. How do we accomplish this? This was accomplished because we could generate or we could give a relative velocity between the particles that are travelling through this and the water droplets or the liquid, which is a matter of your liking depending on what gas you want to remove.

So two things are certain: the particles are being encased inside the water droplet and there is an opportunity for the gas, which may be HF, to react with your scrubbing liquid so that HF will be removed because you are giving them enough time (this can be long enough); you are giving them enough time to react so that HF is neutralized. HF is an acid, it is like acid and so it gets neutralized. Now what happens is that all the particles have almost become the size of water droplets because they are sitting inside that. Once the size is large, it is very easy to remove. Then what we do? We provide another simple cyclone after this. So by virtue of this, what have I done? I am not getting complicated ESP or bag filters. Here, I am removing the gaseous as well as the particulate matter but what I really need after this is to put another particulate removal device and that is what I want you to understand so that we can remove the particulate as well as the gaseous matter. This is called the Venturi scrubber because this is in the shape of a Venturi. Do you have anything in the physics part that you do not understand in what I said? I will send some material to you through email, but what I want is that you understand the physics. Simple thing but then you need to understand. As you go down, there will be no more relative velocity and the particulate matter as well as the liquid droplets will travel at the same speed. So the efficiency of your collection or hitting each other will reduce with time. This is what is the Venturi scrubber.

The other thing I have not talked to you about is SO_2 removal – you can also use SO_2 and use another liquid, for example, slurry of calcium carbonate – calcium carbonate or sulfur dioxide will react; I will send that part through email but I want to talk something else, hopefully if this cooperates. Normally, most of the textbooks do not spend so much time on this but in my opinion to understand this thing is again very very important. If you are going to be a part of an industry and working on air pollution and helping to improve air quality, you will invariably encounter this situation – there is no doubt about that. So how do we do the stack measurements? How do we know what is the pollution that is going out?

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Some picture is shown here. Again, this is not a very clear picture but what you see here is a little platform and then you see a person standing, there is some kind of a beam or bar and something is hanging on this bar – this can move in and out, like there is a guide rail. This is the weight you see here – that can move back and forth. This is how the sampling is done but we will again get into the physics part.

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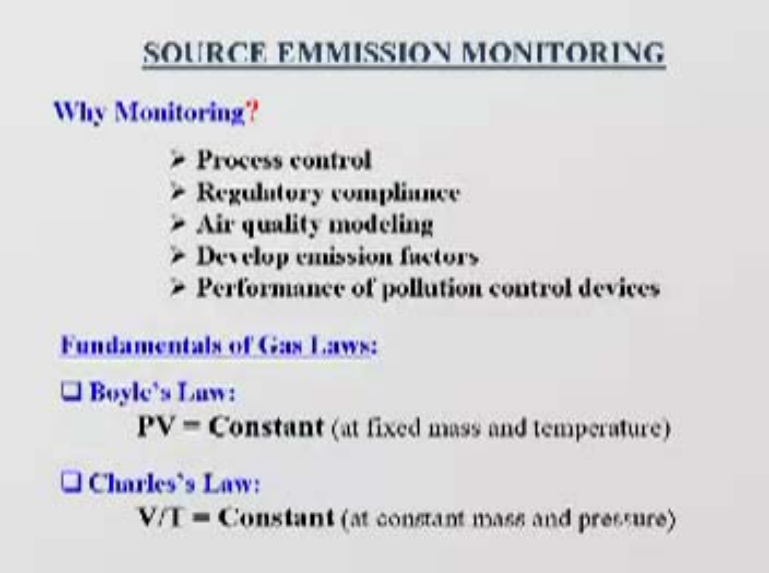

Why do monitoring? Why is stack sampling required? I will pass this on to you through email. Suppose you are a chemical engineer and you want to see the process control, you

want to see that the percentage of carbon dioxide should be so much or you want to see if a chemical compound is being formed or not; if you are a combustion engineer and you want to see what is the oxygen level, you see if oxygen level is low or high and you want to increase or decrease that, is it not? All process control people would like to see what is happening inside the stack or inside the duct.

Regulatory compliance: Pollution Control Boards will say, “Let me see what are your emissions” because there is a law that you cannot discharge more than certain concentration of particles or gases, so they will require stack measurements. Air quality modeling: for modeling, what do you need? You need the emission quantity Q – the big Q that we were we were writing all the time in the formula. Where does that Q come from? Either it comes from the emission inventory or if you want to be very very accurate, you actually go and measure it because emission inventories are always estimates; if you want to write the actual, then you go and measure. Development of the emission factors: emission factor you want to say and you want to check the performance of the pollution control device; you have an ESP, for example.

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We spend a lot of money in there and then you want to see how well it is working, so you will see one stack measurement here and you see one stack measurement here; you see the difference and see how efficient your ESP is.

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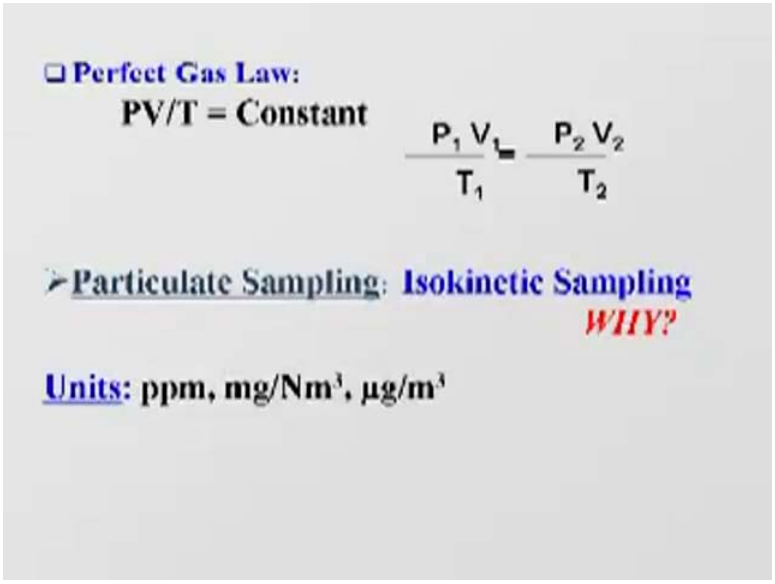

We need to know certain basic things to do stack sampling – you all are aware of that and we will not spend any time on that. Now I want to talk to you about something you have not heard but something very important – our lecture today will be focused on that particular thing. When you talk about sampling, there are two things you can possibly sample: the gases and the particles. Because of diffusion, the concentration of the gases is uniform all across the chimney, but you will see that the particle concentration will vary from location to location – that is point number one. What we do is that we sample the particulates by something called isokinetic sampling. I will explain to you what is isokinetic sampling, but you have to answer certain things before we do that.

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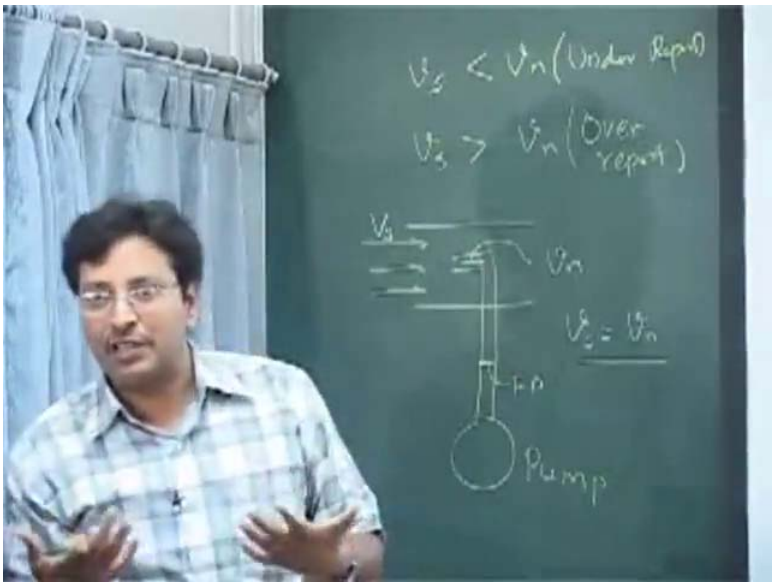

Suppose this is my duct or chimney and I put a sampling device to take the sample. Here is my let us say pump and here is my filter paper. What I do is suck through this, take the initial weight, final weight and measure the flow. Suppose this is my velocity inside the chimney or in the duct (Refer Slide Time: 13:29) – that is let us say velocity$_{stack}$, it is V_s and you are sucking it through some velocity and that velocity here in this one let me call that as V_n. When $V_s = V_n$, you call it isokinetic sample because the kinetic energy here, here and here is the same. It is very important to maintain the isokinetic sample. Now having said it is very easy, you will ask why it is important.

If my V_s is greater than V_n, what will happen? Will I collect a representative sample or will I make a mistake in the sample? I will make a mistake in the sample. You are sucking with a smaller velocity. So will I report higher concentration or lower concentration? Lower concentration. Lower concentration, but then the question is why lower concentration? Because particles are escaping. Where are the particles escaping? Are particles escaping outside or inside? Outside. If they are escaping outside, then I am collecting less, so I must report less. Is that what you are saying – that you will report less or you report more? Report less. Report less. Is anyone with me when I say you will report higher? Why? Because sampling velocity is higher. Sampling velocity is lower, stack velocity is higher but you are sucking at lower speed.

The answer you said is just opposite and you have to understand why it is so. When you are sucking, this is your sucking velocity. When sucking is smaller, what will happen? We will answer in the next slide – that is situation number one. The other situation is.… What I am saying is, we will clarify, over-report the particulate concentration and here, you will under-report. Generally, the feeling is that you are sucking with high velocity and you would expect more will come – that is the general tendency but this is not true and that will become clear with the next slide so that I do not have to make the picture again and I will explain in a moment.

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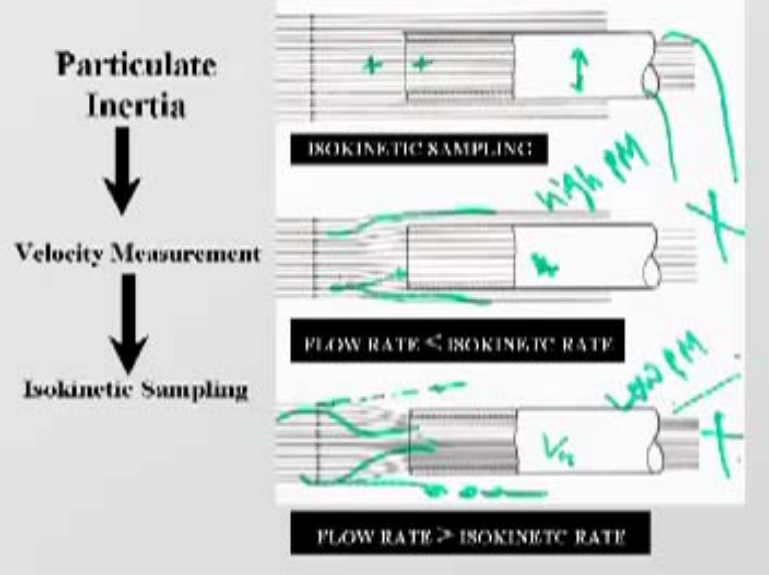

You have to think that the particles have inertia. Here, the velocity is the same here and here. Now, you are saying here that the sucking flow rate is lower, so which is my case? This one, right? Sucking flow rate is lower, this is higher. You see here the same thing. What is that? My flow rate. Flow rate isokinetic sampling rate is higher, so I am under this condition. What will happen when your sucking isokinetic rate is higher? All the particles are sitting here. When you are sucking higher, you are able to suck the gases inside, correct? But the particles will have their own inertia and they will continue to travel. See here. Again, what is that? I have high isokinetic rate. Suppose I am sucking with the higher velocity. When I am sucking with higher velocity, all gases close to it will enter but the particles that were there in the stream of gases they will say gases of less inertia could go into the nozzle but particles will continue to follow their trajectory. Let us talk about the extreme gases, this stream, there is a particle sitting here. When you said isokinetic rate is higher, you suck in with higher this

thing, so the gas will come inside this. When the particles are sitting here, it will continue to go like this and escape. Is that clear?

We have [18:28] sampling because you are taking more volume of air but whatever the particle was for that volume, you have not captured that in your filter paper. You have sampled the corresponding gas but that corresponding particle has escaped. Simple thing but does everyone see that point? Clear? You have to be absolutely clear.

[Conversation between student and professor - Not Audible (18:56)]

Particles will generally have inertia compared to the gases, so very fine particles below 0.1 or something you can treat them as gases – that problem may not be that severe, but in the stack the particles can be anywhere from 150 to 1 micron. Somebody had a question.

[Conversation between student and professor - Not Audible (19:20)]

How it is under-reported? It is under-reported because you have taken the gas volume but the particle mass has not come. If you had taken all the gas, all the particles, that was fine, mass upon volume (Refer Slide Time: 19:36), so you have been able to suck the same volume but this mass, the particle escaped. What is concentration? It is mass upon volume, milligram per meter cube. This was the mass that was here – that escaped, whereas the volume you have sucked through because you had very high velocity. Clear?

What will happen in this case? You will under-report. The situation is like this, for example. Then, you will over-report because the particles will continue to move but the gases will escape. Then you are getting more mass but the corresponding volume you are not – that is the physics that you have to understand. What has become most important for us is the right measurement of velocity and ensuring that the velocity inside the chimney is the same as the velocity at the nozzle. The job is done but life is a little bit more complicated than this.

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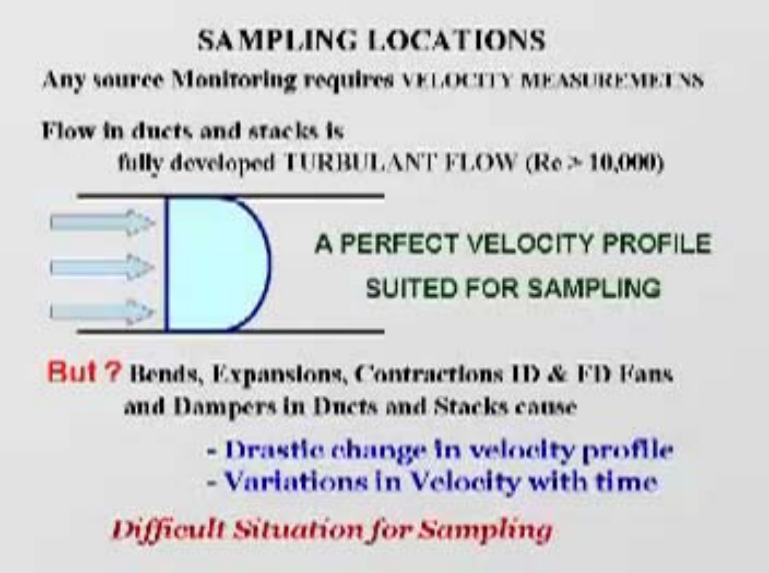

If I see the velocity profile in the duct, which is normally turbulent (in the duct, the flow is always turbulent for gases), the profile typically looks like this, not even parabolic. What you see is for water [21:01]. For quite a distance, this is 0 and then you get this. In that case, if I take a few points one, two, three, I get the velocity profile. I need to have good knowledge of the velocity. If I make a mistake about the velocity, my sampling is doomed, but unfortunately, this is a very ideal situation and we do not get that.

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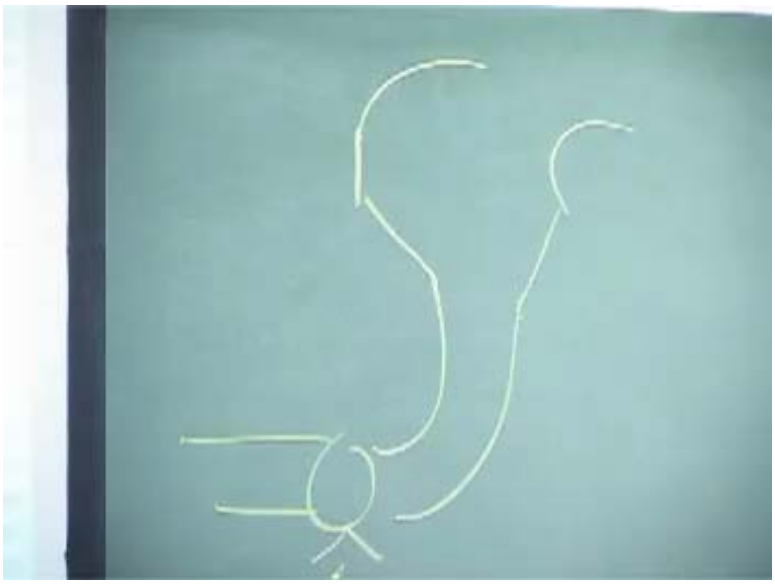

If you go to the power plant, if you go to the chemical plant, you see the ducts are like this, there is a fan here, the ducts turn like this and then suddenly, there is an expansion in the duct and then again, it goes like this and then again there is a turn. Unfortunately, this kind of velocity profile cannot be maintained if things are turbulent and changing and there is a cyclonic action and there may be a damper to cut down the flow. So if I keep on taking the profiles, my profile will never be like this – only under very ideal condition. What disturbs the velocity profile are these things: bends, expansion, contractions, ID fan, FD fans, dampers, ducts – all these things cause your velocity profile to change. Therefore, I cannot make the measurement at just one point – this is a challenge for me that I still get a good velocity profile. It means I should take more measurements of the velocity. In that case, I should take more measurements: one, two, three, four, five, six, seven, eight, nine, so that I get the complete profile. If I have a very good picture like this, maybe I will take one, two, three and I am happy. Unfortunately, it is never like this when you go into the field and I will show you what is in the field. This is actual measurement I did and I will show you what happens there.

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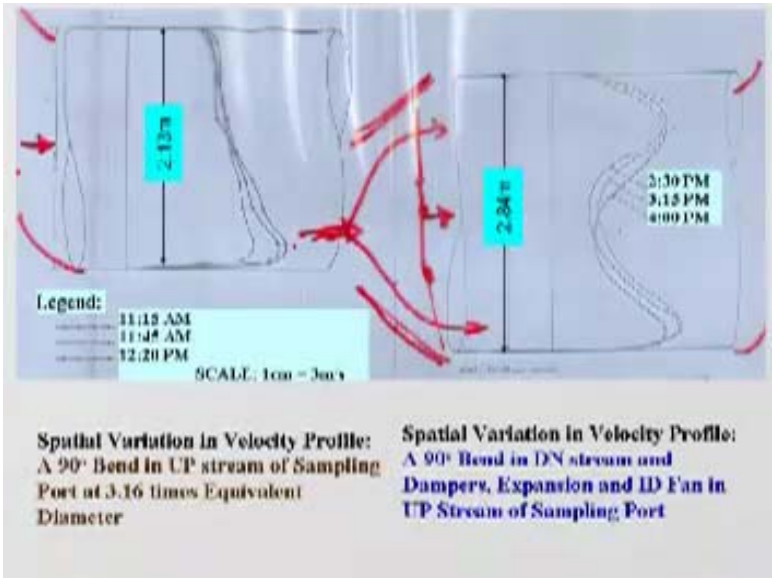

What you are seeing here is a measurement done at various times. Here, the velocity profile will not be a perfect profile as you think. The reason why it was there the velocity profile a 90-degree bend in the upstream this was a bend that is actually like this and this was done in a power plant called Bajalpur Power Station.

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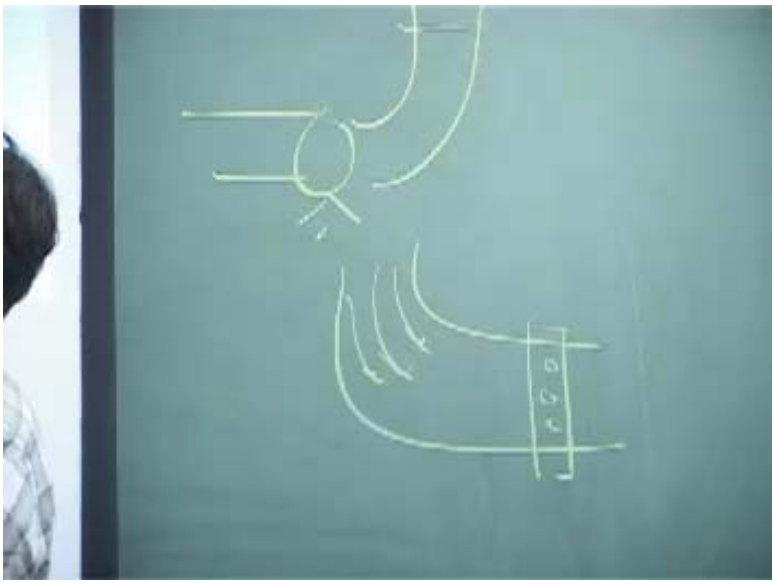

There was a bend like this and we were doing the measurements; it was a duct, horizontal duct and we were doing the measurements here. Once you do the measurement, you see that things are pushed on to this side. As a result, the velocity, which should be 0 or something, was highest at that point. Suppose I have taken only one point, I will make terrible mistakes and we do not want to do that. This was another situation in the same plant but another chimney there, so you see the flow was just reversed. What was the problem? Spatial variation in the velocity profile. Why? A 90-degree bend in the downstream and dampers, expansion and ID fan in the upstream, so there was expansion in this.

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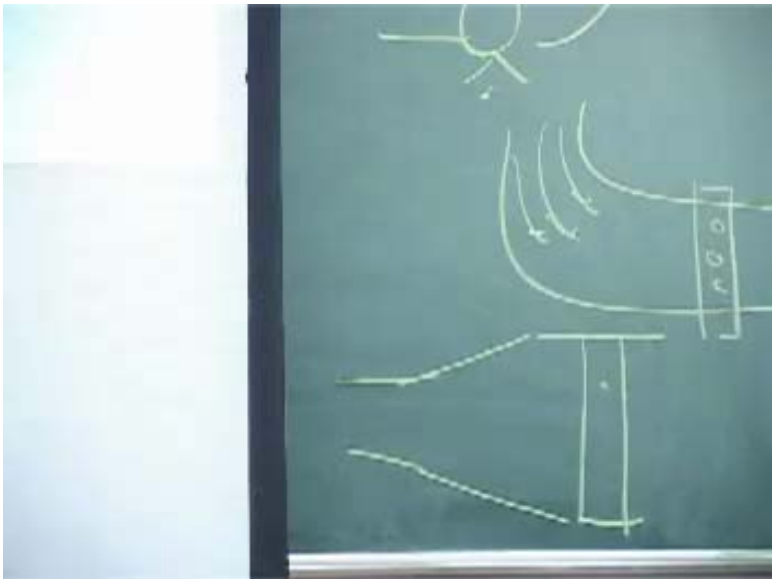

It was coming like this and then there was expansion; there was a duct here and then it followed and we were taking the samples inside the duct, so there was expansion. Once there is expansion, the velocity increases at the ends and it was decrease less. We have said that velocity measurement is most important or the key thing, but then the actual situation can make things very difficult. Before going to the sample, we must determine how many data points want to take. That is decided by what is there in the downstream and what is there in the upstream at my sampling location. If there are very long ducts, you have nice ducts, you can do with minimum number of samples. If you agree that we have to decide about the number of samples, how do we go about doing that?

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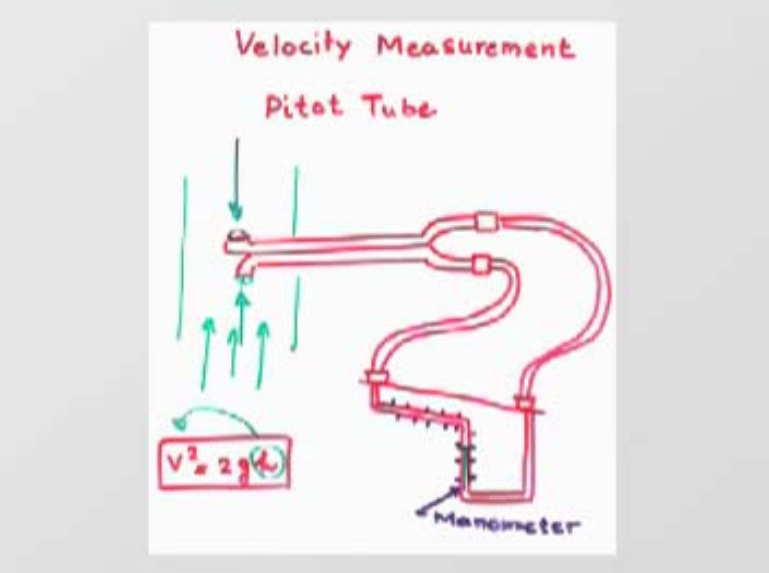

This is a little picture to show how to measure the velocity. You just have to understand the principle. This is called the Pitot tube. The Pitot tube is one thing inside the chimney. There is an opening here and there is an opening here. Then, there are gases, they will put pressure here, the atmospheric pressure will come and the pressure difference is nothing but velocity h. There are certain formula and corrections, but the underlying principle is this. You see the change in the delta h and that is this delta h and I can find out the velocity. This is just the principle part. The things may be little different – constants are there: Pitot tube constants and things like that but this is what we call as the Pitot tube and this is called ‘s’ type of Pitot tube. But then, the question that we are trying to answer is how do we decide the number of data points?

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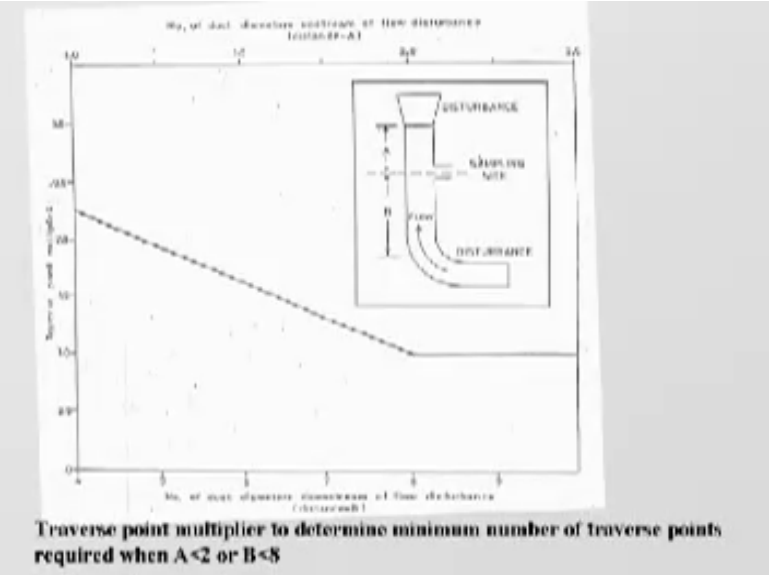

Traverse point multiplier to determine minimum number of traverse points required when A<2 or B<8

Look at this picture. Suppose I am doing the sampling here. Somewhere here at distance B, there is a disturbance and at A, there is a disturbance, there is expansion. So what you do is that you see in your.… If I am going this side, my flow is like this, is this direction my upstream or downstream? [26:49]. Upstream and when I am going this side, this is my downstream. Then I see where is my disturbance and how far is my disturbance from my assembling point. So in terms of the diameter, how many diameters do I have? Suppose if my disturbance in the upstream is let us say 8 times.

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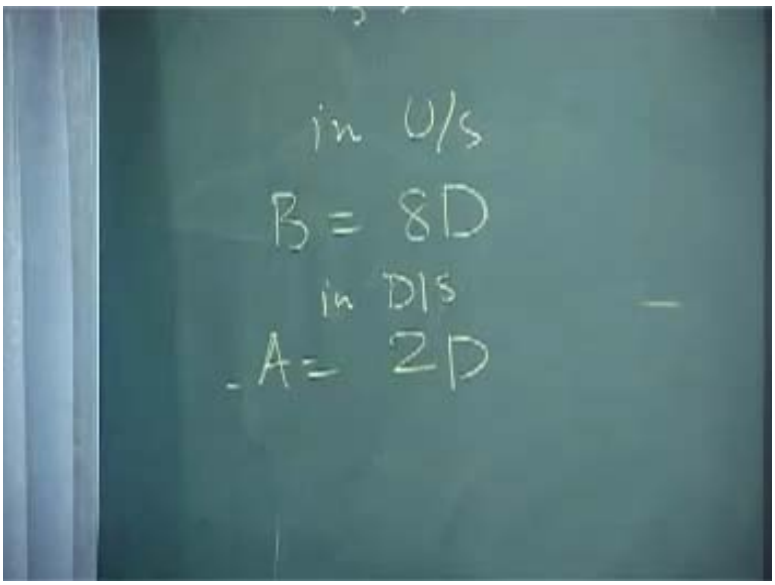

My disturbance is B – we call it B in upstream. It means I am somewhere here, right? Suppose my A is 2 times in downstream, you have to see the scale up. This is 2, right? I can bring it down to this 8 and 2 and you get to this point, you can see that I get to this point and this is what is my ideal situation. It means if my disturbance is at a distance more than 8 D, I have no problem and if it is more than 2 D in the downstream, I have no problem, then the factor that is important is 1 – the multiplying factor is 1. I will explain to you where this multiplying factor is to be used if I extend this equal to 1.

Suppose I have a disturbance and my disturbance is, let us say, only a distance of 6 D, it means I am measuring somewhere here, then this distance is only 6 D. Then, I go from 6 and go here and get a multiplying factor of 1.5. Where is this multiplying factor to be used? There is a rule that you have to have minimum number of velocity measurement points, so you multiply this one. Suppose the minimum was x, but you have the disturbance; you said 1.5 times x, so that many number of measurements you must take inside the chimney. What is that minimum that you have to multiply with this factor? It becomes clear in this one.

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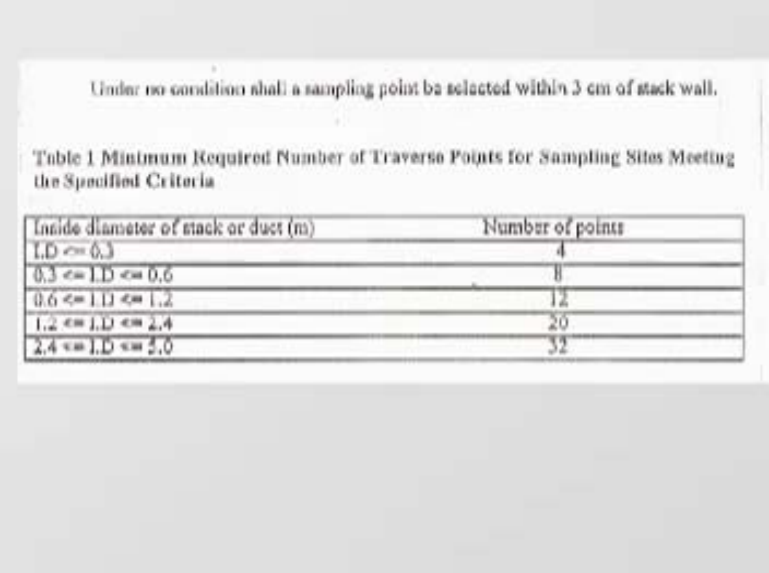
Under no condition shall a sampling point be selected within 3 cm of stack wall.

Table 1 Minimum Required Number of Traverse Points for Sampling Sites Meeting the Specified Criteria

Inside diameter of stack or duct (m)	Number of points
1.D <= 0.3	4
0.3 <= 1.D <= 0.6	8
0.6 <= 1.D <= 1.2	12
1.2 <= 1.D <= 2.4	20
2.4 <= 1.D <= 5.0	32

Depending on your internal diameter, these are the number of points, minimum number of points that are required, provided you are meeting this criteria; if you are not meeting the criteria, then multiply this minimum numbers with the factor that we got. Suppose we got 1.5 and your duct diameter was let us say 1.2 – internal diameter 1.2, required 12, we multiply

this by 1.5, so 12 into 1.5 are the minimum number of points that I need to take inside the duct to do the velocity measurement. Is that clear to everyone?

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Let us take the example here that ID, the internal diameter was 1.2 and the factor was 1.2, so for this 1.2, minimum we require is twelve points, but unfortunately, because of disturbance we got the multiplying factor as 1.5, so this becomes something like this. 18. 18, good, so I need to take eighteen points inside the chimney to ensure that I get a good velocity profile and I will not make mistakes. Is that point clear? Now, the next question that automatically comes is where do I take those eighteen points? There are infinite locations inside the duct or inside the chimney. I will show you where those eighteen points can be taken. This is a little table that you have to spend a little time understanding. I do not think you can read it so well there. This is your traverse point number and how this is numbered is like this.

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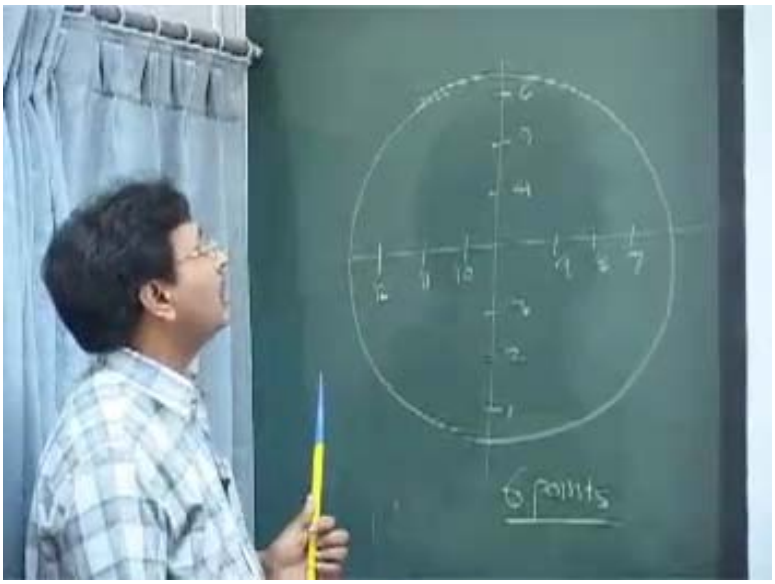

This is your chimney cross section and you divide things in two parts. Suppose this is my point number 1. We do not know where the location is but let me write here 1, 2, 3, 4, 5, 6 and then you can say 6, 7, 8, 9, 10, 11, 12. We always measure from two directions – this direction and this direction. Suppose you are required to have twelve points. So on one axis and another axis orthogonal to this, you require six points. Is that right? Six points. Where should those six points come from? I have taken an example for eight points.

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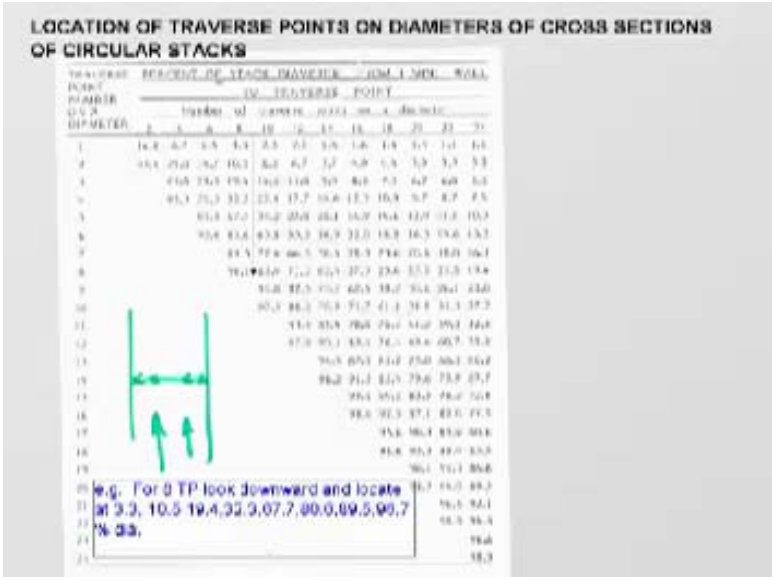

What you have to do is… suppose you are taking as…. You see here eight points. This is the percentage diameter distance starting from the edge, so you have decided that you want to have eight data points.

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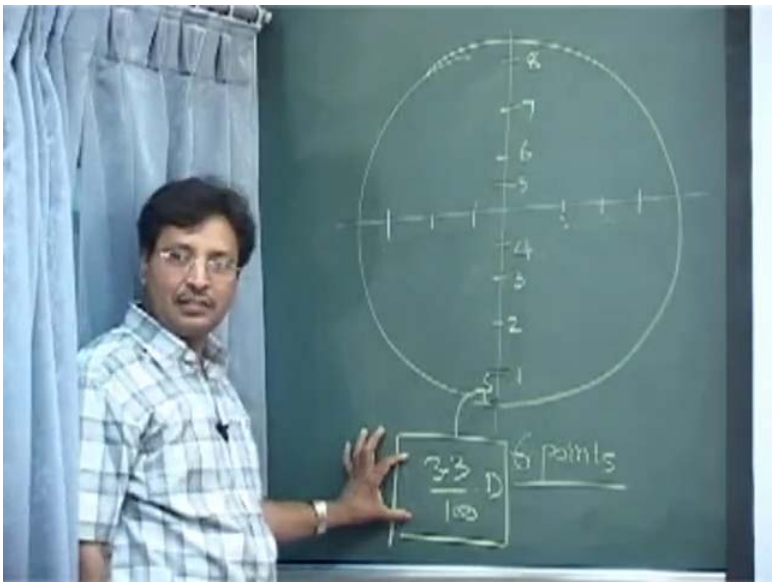

Let us make it eight so that there is no confusion here. You wanted sixteen totally and eight in one direction, so I can make it 1, 2, 3, 4, 5, 6, 7 and 8. You want eight data points. Here is your point number 1. Total is eight, so where should it be? 3.3 percent of diameter. So for my point number 1, this distance is 3.3 by 100, this distance from the inside wall of the chimney will be 3.3 percentage. I do not know if you can read somewhere, it must be a percentage somewhere. Does it say anywhere? Percent of stack diameter from the inside wall of the chimney. So you can see that this point is at this distance.

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Point number 2: 10.5. This distance is 10.2 by 100 times D, so that is this distance. Clear? Let us take the eighth point, for example: 96.7. This is my eighth point and I am looking at this distance. I do not know if you can see that this is my eighth point from here to here – that is what is this 96.7 by 100 times D. Clear? You can really locate the points where you want to take the sample. Clear? That is what I have written here exactly. TP is traverse point. Suppose you need eight traverse points, look downward and locate at 3.3, 10.5 percentage dia. Clear? This is what is again shown.

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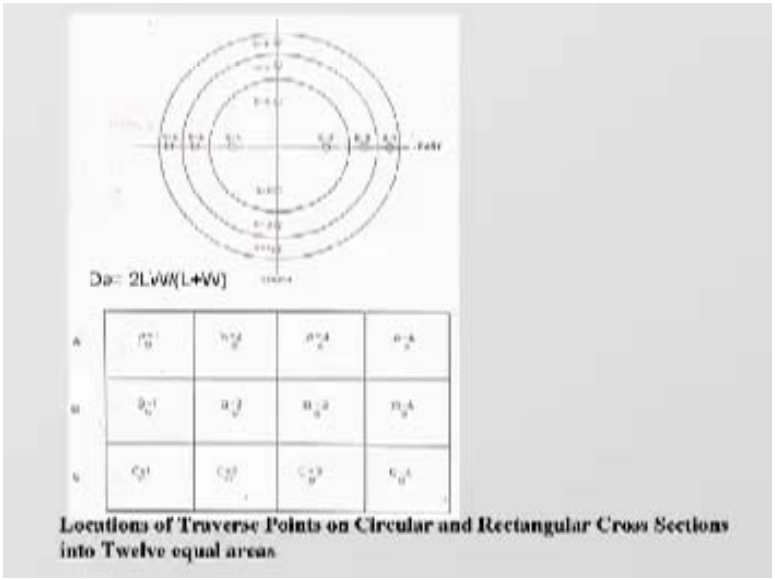

The little thing you have to be careful about is sometimes we do inside the duct, horizontal duct that may be rectangular. Whatever number of points you have, for example, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, you divide this into that many equal parts and then you can do it. Then, how will you find out the number of points that are required? You find out the equivalent diameter De and use the concept of A and B that I talked about for this particular diameter, because this does not have any diameter and the figure we showed earlier was one only having the D factor. So for this thing, you find out the equivalent diameter and then apply the same concept – number of data points required depending on the disturbances upstream and downstream. Then you can locate and say we need that many points. Is it clear that you can do that for the rectangle?

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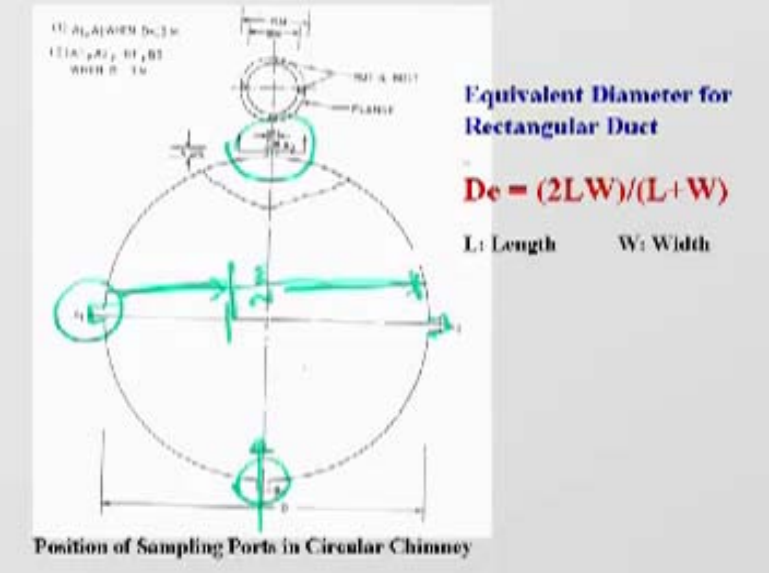

There are some special requirements: the diameter is there, what should be the opening here, etc., etc. Those are more technical and not the physics part – you do not have to worry about that. Those specifications are there because here you have to put your sampling thing inside, so there should be some opening diameter; how much should be the diameter is given – those details are given here. This is 10 centimeter and there is a flange that you can open from the nut and bolt.

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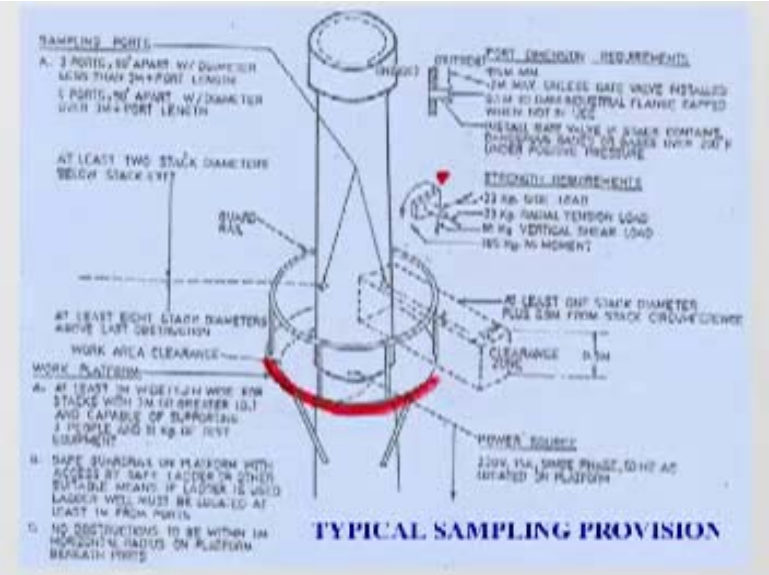

This is a little requirement of the stack – how you have to… the way it is, the loads that will come and then you have to provide some platform. Those details are there – they are always standard things that you can look into, but let us see where we have to understand things.

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There is a little opening that you see where the sampling probe goes inside. Here, you sit down with your monitors and calculators and then you have to find out the velocity on the spot because based on that velocity only you will fix the velocity at the nozzle. Unless you find out the stack velocity, how will you fix the nozzle velocity? You cannot fix.

Immediately, you take the measurements with the Pitot tube, run through the calculator or computer with the spreadsheet. Suppose you have taken twenty points, your spreadsheet will immediately give you the velocity at twenty points. Now, you know what should be the velocity that you should maintain at the tip of the nozzle if you put your sampling probe here.

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Again, this is not very clear. This person is really doing the sampling, there is a guide rod and there is a sampler that he can push back and forth. I can take the sample here, I can take the sample here, I can take it here and normally we do take at many places to get a representative sample.

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Why do we take the representative sample? Let us say the velocity is like this. Higher is the velocity, it will…. Because the energy is higher, it will have larger particles – concentration of larger particles will be more. So if I do most of the sampling here, I will still do it isokinetically but I might lose some of the particles that are larger in diameter. I want to take a representative sample. We do it isokinetically at all places but we do at many places – not at one place alone. Now how to ensure isokinetic sample? That is the key. You have done the measurements. Now how do you ensure that the $V_s = V_n$?

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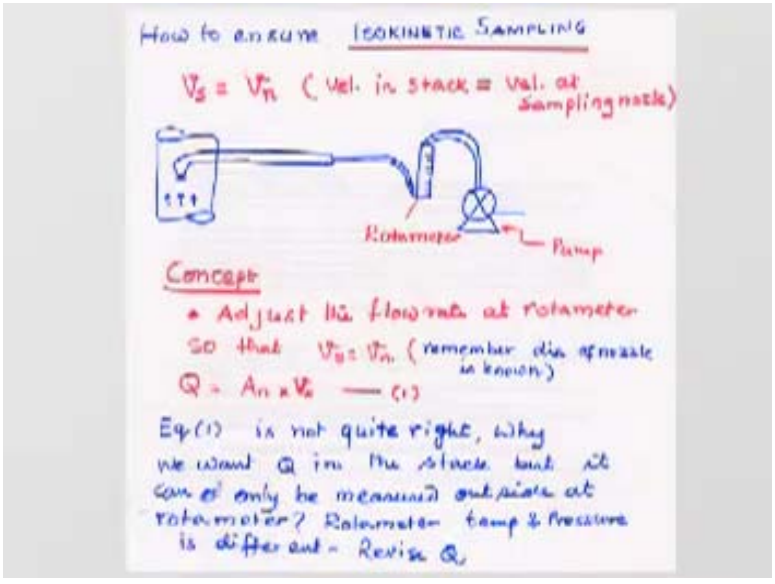

We have to ensure that the velocity in the stack is equal to velocity at the sampling nozzle. Normally, what we will do is we have the measurement, we have a rotameter to measure the flow. With what do you want to measure the flow? What flow rate are you measuring? Ultimately, this flow rate will go in your calculation as mass divided by volume; the volume will come from the flow rate, so we have the rotameter and there is a pump. Concept: adjust the flow rate at the rotameter so that $V_s = V_n$; you know the V_s very well because you have done the measurement and now you know the diameter of this one – little thing there, so you can adjust the flow rate with a little knob to ensure that this $V_s = V_n$.

If you can ensure that one…. Where do you ensure and how do you ensure? You ensure it from the adjustments you make here if you have ensured that [41:03] $V_s = V_n$. Any doubt? Then what I can do is I have to find out the Q and that I have to adjust at the rotameter. That is nothing but the area of the nozzle times the velocity – that is the flow rate. This is fixed, this is variable because the stack velocity may vary. This is fixed, so I multiply this and I get the flow rate Q. I can keep on adjusting that here, I have to calculate it beforehand. I take the Q as let us say 40 LPM, then I move this sampler to the second location and make it 60 LPM because the velocity is different here and the nozzle is the same. So you see here, I have to keep on adjusting my flow rate as I travel across the chimney. Life is not so simple; we have not done the job – concept-wise we are okay but situation-wise we are not correct. That what I [42:06]. Equation (1) is not quite right although it looks right. Why?

We want Q in the stack. Where is the Q we want? In here but where are the measurements you are doing? In here. Pressure and temperature are different here and the pressure and temperature are different here, so that Q I am maintaining, which I am measuring here has a pressure and temperature here which is not correct there. So I must make an adjustment for the pressure and temperature that I know. I can do the measurement of pressure and temperature here, so I must make the correction for the pressure and temperature I am measuring so that it becomes exactly $V_s = V_n$. Did you say that here it can only be measured outside at the rotameter? The rotameter temperature and pressure are different from the stack. Therefore, we need to revise Q. How do we revise?

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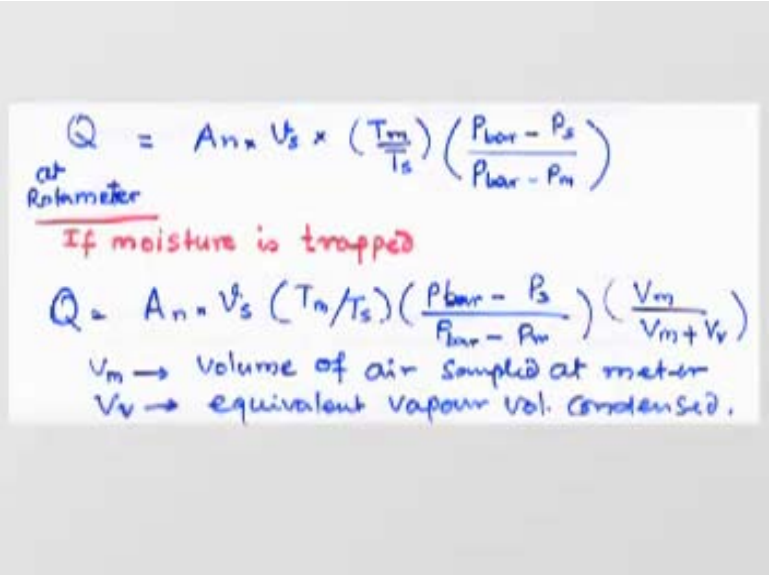

This is fixed. You can revise the volume and that volume we are measuring at T_m, so your T_m by T_s [43:24] you can see how you will get T_m by T_s because here you are measuring at the T_m but the required thing was at T_s. Similarly, you need to revise it for the pressure part – that is the P_{bar} and that is your atmospheric pressure minus P_{meter} and that difference is the absolute pressure. Similarly, P_{bar} minus P_s where P_s is the stack pressure. Now if you maintain this particular Q at your rotameter, it will ensure that your velocity inside the chimney is the same as it is in the nozzle. Is that clear to you? If this is not clear to you, I will send this to all of you. You reorganize and see if this is what it is coming out to be, because if you do it on your own, you will become clear that this is the thing to change.

There is another situation where we condense the moisture beforehand. Stacks are likely to have moisture – H_2O is one of the combustion products, so in the process when you are sucking, it can condense. If that condensation is already removed before measuring at the rotameter.… We remove the condensation because it can spoil my rotameter otherwise – it can cause corrosion inside the rotameter and so I want to trap the moisture beforehand. If the moisture is removed, the V_{meter} that you have measured must be lowered because that V_v you have already taken into consideration. This I will send to you through mail today. You have to go through this and make sure that you are getting the same formulation as I get. If not, come back to me – we can discuss and sort this out. You have become experts in stack sampling.

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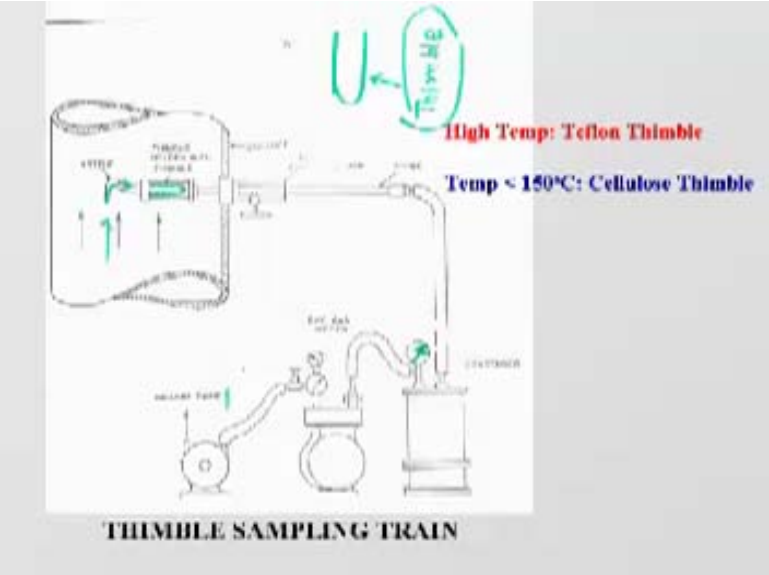

This is typically what things might look like inside. There is a nozzle here, there is a filter paper, which we call as thimble; a thimble looks like this and this is clamped here but this can move in and out. You bring it here, you bring it to the condenser because it is the water you want to condense. You measure the dry gas meter – that is the flow meter that you can adjust and there is a pressure and temperature and this is the flow that you can measure. Finally, you have the vacuum pump so that you can make sure… basically, the difference in the rate divided by the volume that you have taken – that way, you can find out this one.

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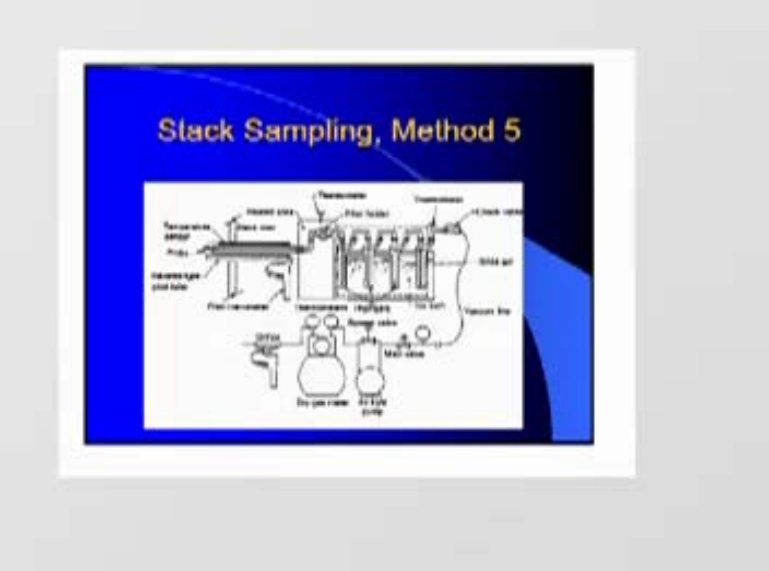

This is the last picture. Actually, it looks like this on the field. What you are doing is you are putting in the nozzle but you are also putting your Pitot tube along with this one. Why do you want to put the Pitot tube along with this? You want to ensure that the velocity that you had measured earlier is still maintained in the duct. Suppose the velocity has changed. I said with time, velocity can change but generally, it does not. You can calculate at the end of the day the percent isokinetic because you are doing it with some measurements you did earlier. By the time you did your calculation, you are ready to go with this one. Then after 10 minutes or after 15 minutes it takes for the preparation, the velocity has changed. You can say how much was the change in the velocity because you can still record the velocity because of the Pitot tube.

[Conversation between student and professor - Not Audible (47:09 min)]

At the…?

[Conversation between student and professor - Not Audible (47:13 min)]

At the point only, but you are doing the measurement at the point only. You are doing the measurement here, then after 5 minutes of sampling, you push your sampling probe at point 2 and take the 5-minute sampling, then push to 3 and again 5-minute sampling, so at that point your are re-measuring the velocity and comparing it with the earlier velocity that you had measured and say that you are still close to what you had measured. Suppose there is a drastic difference, it means your sampling is incorrect and then you have to probably repeat the samples.