So you have to have cheaper methods of doing it. But when you have cheaper method of doing it, you are obviously going to have the loss of information. So, PM sampler is high volume sampler, you can use measurement you can measure it using a 4 digit balance, but then you are losing information because your sampling period is now 8 hours minimum sampling period of 8 hours in a urban area where you have a reasonable amount of dust.

If you go to a very pristine area, you may not get anything in it, you may have to run it for 24 hours to get something. So, you see that the measurement protocols are all dependent on what is available for measurement and where you are measuring and so therefore, the standards are defined based on that, so this is all very interrelated and each of these will change as you get more and more research and development happening on the instrument side.

Somebody says I have an instrument which will measure PM 10 for 1000 rupees. Everybody will shift to that now, because you can get wide network of these instrumentation and that is it. And if you can prove that it is correct accurate, then that will be the new standard now. so it is in conjunction with what is available currently technology that is available currently, this is called as a high volume sampler.

Now this is a very specific company. That is why it is called as an RSPM. People design this based on the impactor, here it is a cyclone in this particular instrument. It doesn't have to be a cyclone, can be anything and it uses a large filter paper which is a sheet that uses a glass microfiber filter of 8 by 10 inches which is like an A4 size sheet, large filter paper.

And you can sample 8 hours and 1000 liters per minutes, large volume you can imagine how much of air is going through that so the amount of particulate it collects is significant. So at the end of it you weigh the filter paper before and after and you get total mass divided by total volume. So you have total volume. So, 1000 liters multiplied by 8 hours into 60 minutes per hour you get total volume in meter cube in liters, total volume is available here.

And then whatever is a weight that you collect on the filter paper, you divide by this number you will get concentrations typically, the concentrations of PM in air are reported as micrograms per

meter cubed, all standards are recorded in this unit microgram not milligrams per liter micrograms per meter cube, very small amount.

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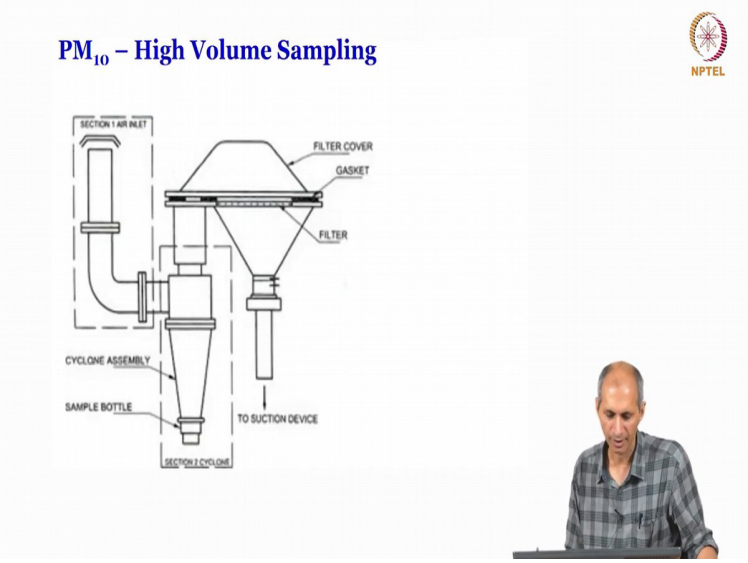

Now, this is the design that depends on the impactor.

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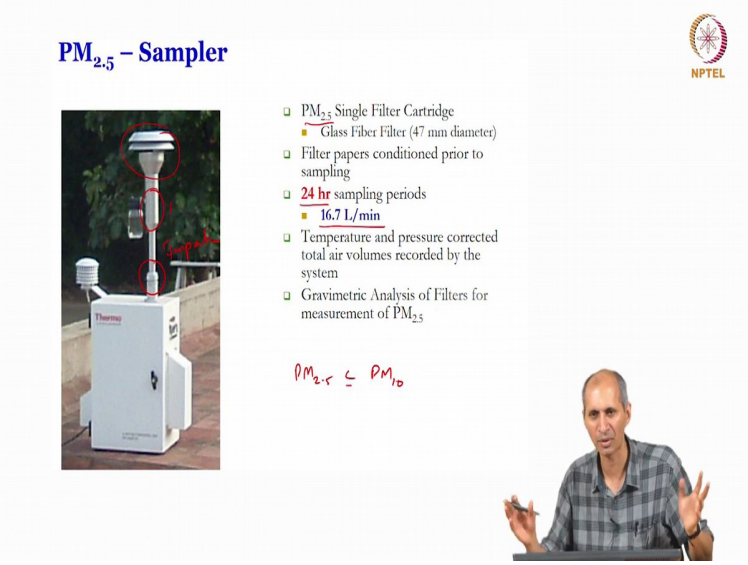

So, this is the other kind of in samplers that that is used, this in this case impactor is here. So, this is the air intake and the impactor is somewhere here, impactor is in this, there is a pump inside. So, this is a PM 2.5 sampler where you can see that because of the design of the impactor the sampling is 24 hours and the flow rate is 16.7 L/min and these are related because the impactor works at a certain flow rate you have to sample for longer that is one. Second is you are also

looking at PM 2.5, the PM 2.5 is less than or equal to PM 10, you cannot have PM 2.5 greater than PM 10, you will be violating mass balance somewhere or you have a major error in this thing. PM 10 includes PM 2.5, so, PM 2.5 is should be less than or equal to PM 10. So, therefore, whatever you collect in the large PM 10 impactors, PM 2.5 is a smaller amount, so, you have to sample for longer in order to get something useful, something that you can measure.

So, PM 2.5 is all 24-hour sampling intervals measurement, so, you cannot do anything. So, I cannot get any information on a lower timescale it is all 1-day average, 24-hour average only. But this is ok because it again depends on the objectives. The way we use this data is we are looking at long timescales, we are saying what happens this year, next year in 10 years, what will happen if this industry stops polluting, this industry starts polluting and so on.

These kind of things are all what we are discussing, when we are looking at ambient air sampling. There is a lot of particulate matter in the air, our first question is who is causing it? What is the source of these pollutants and therefore, you also want to see whether this is going to last long. This is an average this is not just a single event or keeps on happening every day, this is related to the way in which the pollutant behaves in the environment. So, we only have an average value of thing that is useful sometimes.

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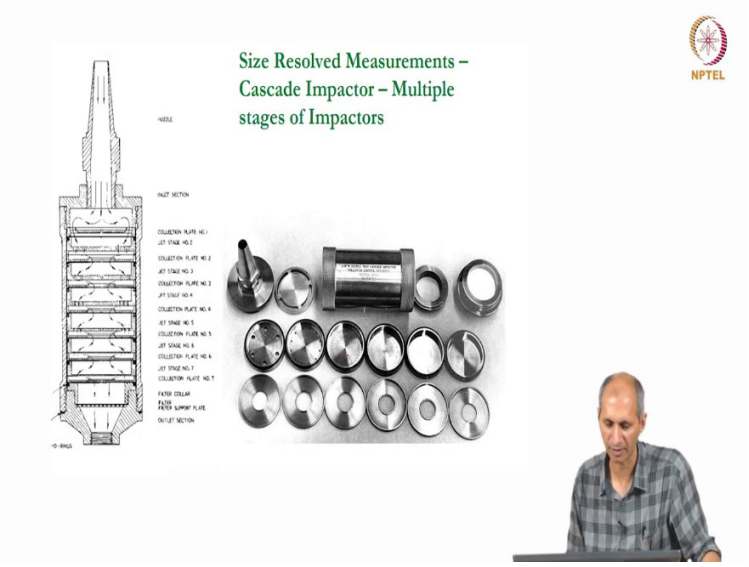

We have a next class in extension of this when we want particle size distribution. What we are looking at in the previous 2 slides is PM 10, PM 2.5 one that is it done, but what if I want a distribution, I want distribution of particle sizes in different sizes how much is there in each size, then I can decide whether. So, this is what is called as cascade impactor, cascade impactor is just an impactor but you have multiple impactors that one place after the other. You can see this schematic diagram here that it is going in the first one, there is the first impact that goes through this one. And again, it goes through as I mentioned, it goes through the center somewhere, then it goes again, outside then in centers again. So it keeps doing this in the last stage there is a filter paper. So, here I am not discarding all the intermediate stages, I am taking the intermediate stages and measuring it how much is there in each stage. So, I am collecting it so, I can as well measure it.

So, I can put some filter paper or some medium there and I can do gravimetric measurement there. So, you can see that there are significantly smaller and smaller openings in this row. If we change the trajectory and it also adjust this. So, this can be one and you can have slightly larger impactors as shown on the left side figure so, this is called as a cascade impactor.

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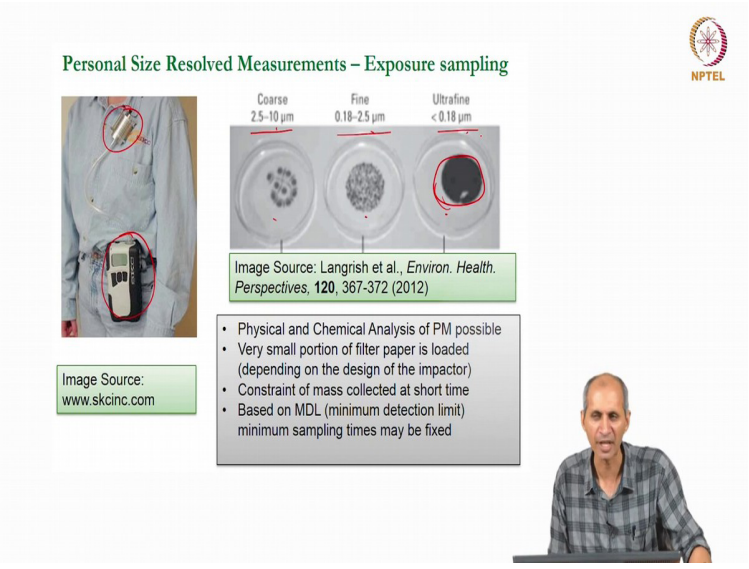

You can also have sizes of cascade impactor this is commercial equipment you can see this here is a small size as cascade impactor. People put this and work for 8 hours they will work and there is a pump here you can see there is a pump and filters in each stage will look like this and you

can coarsely define based on the impaction design you can say 2.5 to 10 microns, 0.18 to 2.5 microns and less than 0.18 microns.

So, you can have some broad classifications and you can see that as a size keeps going down and the amount of particles also is going down. So, this indicates that very large amount is less than 0.18 microns, but you cannot classify it further it all gets stuck on the filter paper. This depends on where you are, it depends on distribution of particles in that area.

It will always not look like this it will look the reverse sometimes large particles will be very big and smaller particles will be very small and that gives you an indication as to what is the nature of particles, it seems a very painful thing to do especially when I have so this is some of the instruments that is used.

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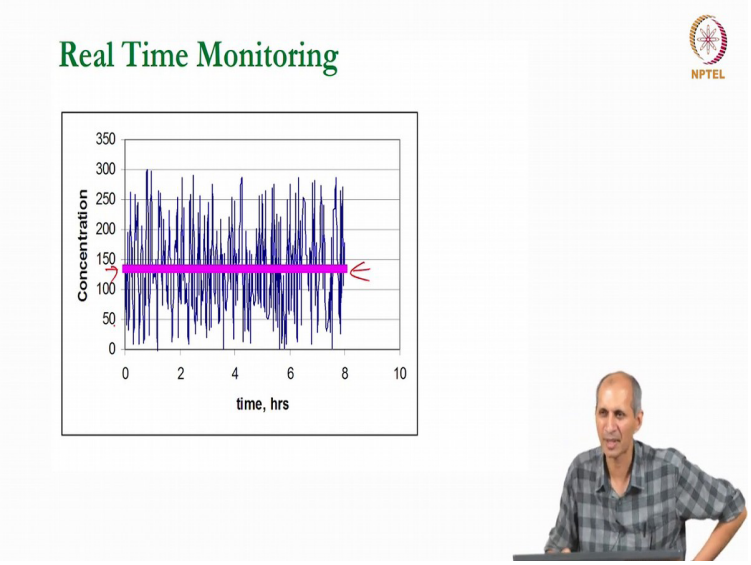

This is a problem so when you are a regulatory agency you really like to know real time information; you would like to know what is going on real time so that you can focus your energies on fixing where the problem is which is a biggest source of pollution. And, like in investigations is really like, you know, proper investigation or you are looking for clues and you are kind of connecting with what is the cause of these things.

So the blue line here indicates the real time data and the pink line indicates average, so I have an 8 hour average I have this concentration, 8 hour average, so 125, 130 or something, but I can see that throughout the day, the concentration is going up to 300 and coming back down to 50 or 0, all the way this is possible. So people are looking for real time monitoring all the time.

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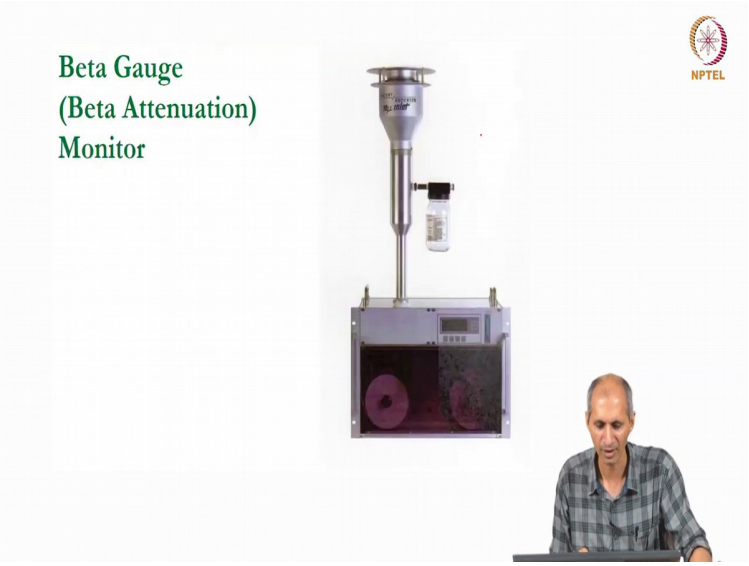

So there are a lot of instruments people are trying to develop to do real time monitoring. And one of the things that people do in the CPCB's monitoring station, in regulatory agencies is to do one of them is called a Beta Gauge monitor.

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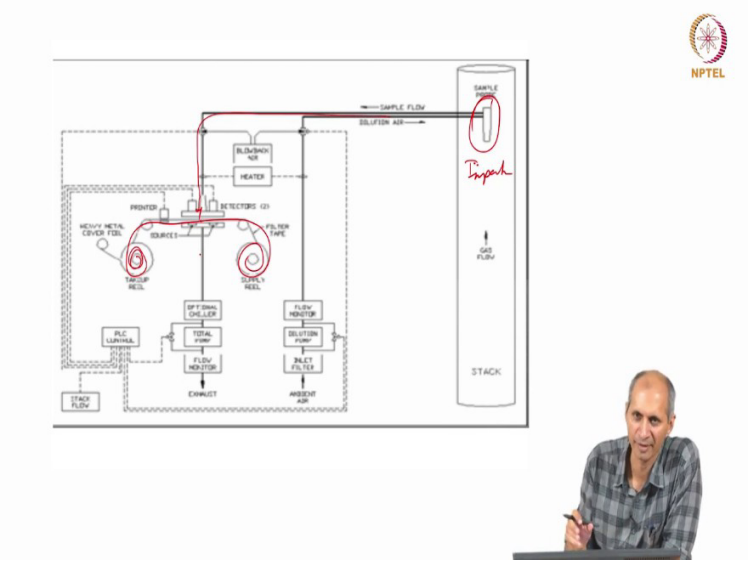

Basically what it what it looks like is this there is a roll of filter paper, the filter paper rolling here, there is a sample inlet that goes in through here and deposits on the filter.

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So, there is a small amount. So, for a certain period of time there is some deposition and then the sample moves to an optical detector, the optical detector send some light or some wavelength and it measures what is the difference change in the attenuation which attenuates more if there are more particles, and attenuates less if it is like absorption what we saw scattering or absorption.

Basically it will look at transmission and if there is a lot of loss in transmission, it means there are a lot more particles that is all simple as that. So, you have to calibrated it against that. The particle mass is calculated against the transmission and then you say if this much is a loss in transmission, I am assuming that this is a particle because you are already classifying it. here, you are removing all, you are doing PM 10 you have PM 10 impactor here.

So, what is coming through is PM 10. So, you can measure PM 10 in real time, and depending on the sensitivity of the transmission loss, I have a minimum sampling time I will wait there for 10 minutes, 20 minutes, half an hour, 45 minutes, whatever time it takes for me to collect enough material that will give me sufficient minimum detection it has to be determined and the sampling time estimator.

So, you see all of these things are important in the design of equipment for real time analysis. So this is one thing that is used, there is another equipment class of micro balance tapered element oscillating micro balance, which looks basically it allows for the deposition of particles on the tip, which will oscillate, and, based on that they will calculate what is the amount? So this also is it is every reused every accumulator which means that the change will incrementally change.

So, it is like putting a small thin film and particles keep depositing and the thin film will bend and the more bending which means that more particles. So, you can incrementally say 5 minutes and bending 5 minutes this much then bending so you can get distribution as long as you are able to detect that change. In this case, it is changing the detection of the vibration or some force, the force measurement or some such thing. They are all very sophisticated instruments. You can imagine that this is going to be more expensive than your high volume for 4 digit balance obviously.

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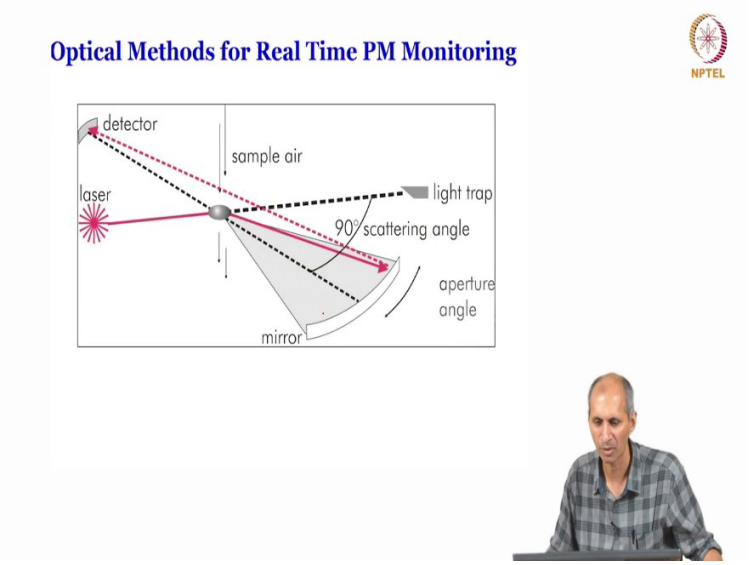

There are other methods of doing real time analysis. I am going to ask a question at the end of this discussion and you have to be prepared for that. There are optical methods in which there is a laser and it is based on scattering principle there is a particle light hits it, it scatters and is based on the scattering law, the amount of scattering and angular scattering depends on the size of the particle. So, different detectors are kept here.

In a full design, there are a lot of detectors that are kept at different angles and you can find out which is the, what is the size based on the scattering angle and you can also measure the composition concentration of it, count the number of particles.

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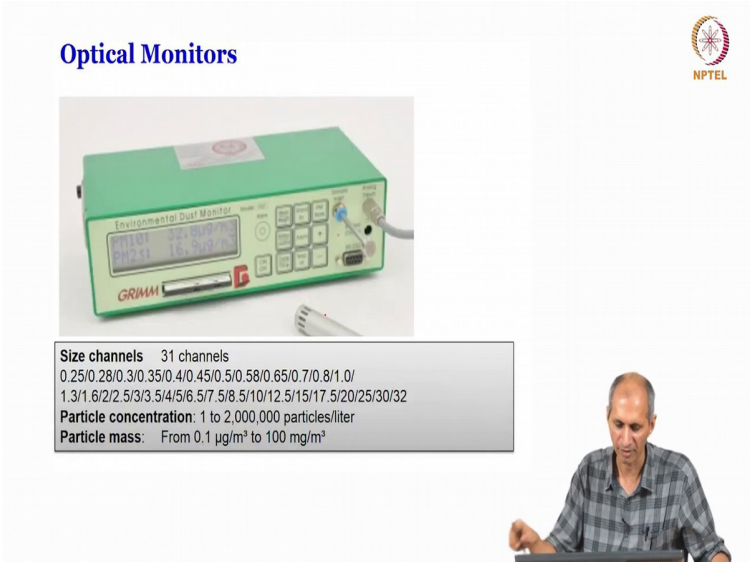

The real time monitor, this will give you very good data because it is measuring it as it is going through, particles are going in and scattering is happening continuously lasers hitting it and you are getting numbers you will get numbers like this and there is a filter at the end of the system which will collect some amount.

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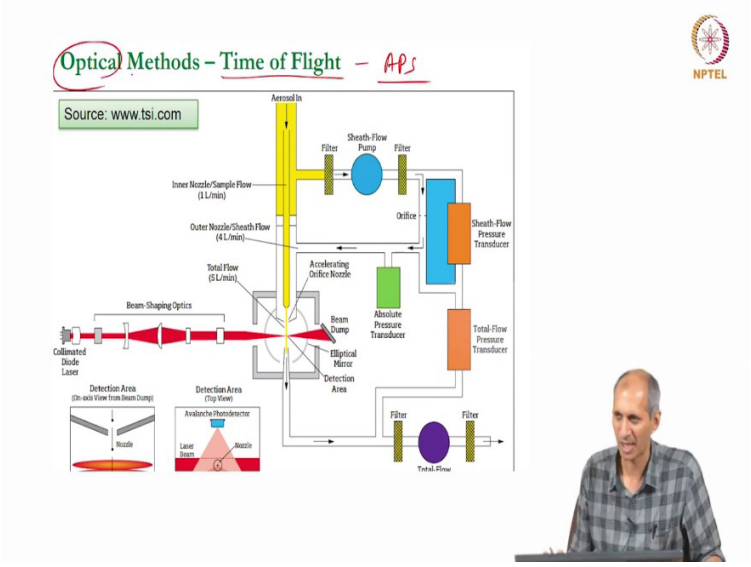

This is a next level of optical instrument. So, this is based on scattering this one there is another instrument which is based on what is called time of flight. This is called as an aerodynamic particle sizer. And as the name suggests this exactly does what the aerodynamic diameter definition is it takes the particle and it finds out what is the momentum of the particle, how fast it is moving a certain size.

And then based on that it calculates, what is the size of the particle? So, there are 2 lasers it calculates how much time it takes for a particle go from one place to another place, and it is a very sophisticated equipment called as APS, this is not an optical method. This is aerodynamic method.

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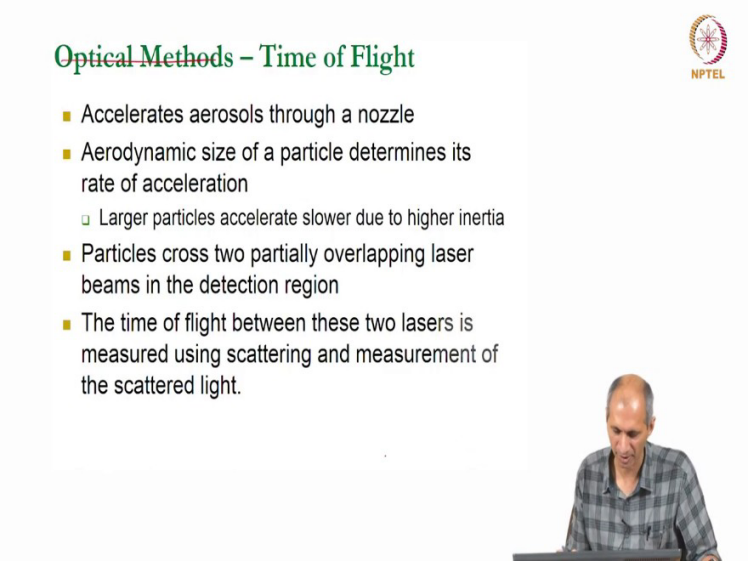

This is aerodynamic method. Now, you have these instruments this is real time. Why would anybody want to use a PM based gravimetric measurement when you have these available you are getting real time data you are getting, you know, without much thing, no processing required. It is very easy for students to use it, they will take this thing, put it there and numbers are coming and you just have to plug in a USB drive or something and get the data that is it done.

No work is involved. There you have to take filter paper weighed, go and measure it come after 8 hours, take it out and you are getting 8 hour average loss of information or in a cascading impactor you are taking. Why would you want to still do that? One is a very obvious reason.