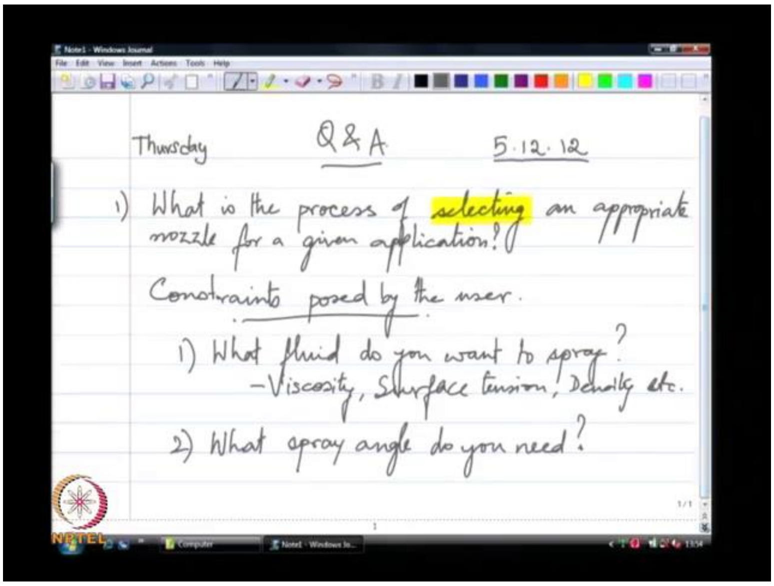
Spray Theory and Applications
Prof. Mahesh V. Panchagnula
Department of Applied Mechanics
Indian Institute of Technology, Madras

Lecture – 12
Selection of atomizers

Yes, we will take some questions and answers today; we will try to build set of frequently occurring questions and peoples smiles.

Student: we have been discussing about various spray nozzle designs what is it you know evaluating, you know for performance evaluation what is that we have given a set of different set of nozzles, how do we evaluate its performance may be incomes of efficiency or anything else.

(Refer Slide Time: 00:56)

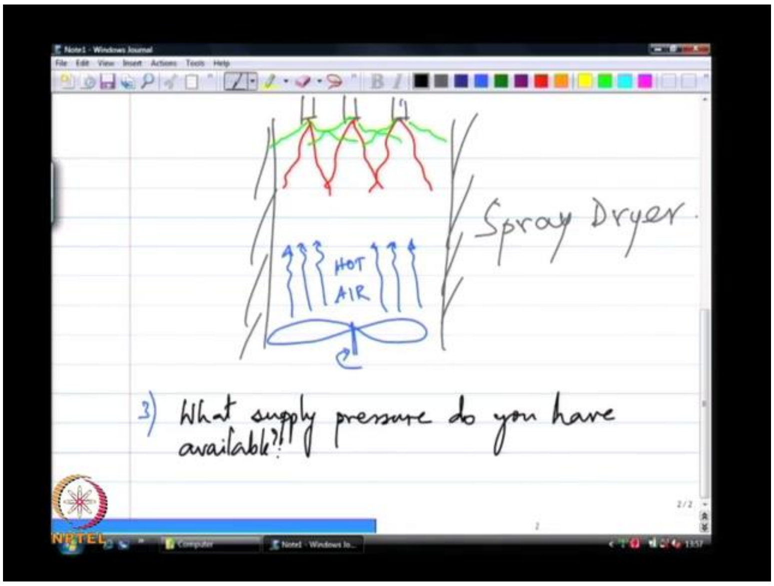


Very very important and very industrially relevant question, so I will right down the question and then, we go through of a process of answering it what is the process of selecting an appropriate nozzle, for a given application? This is; obviously, very important question now, I want to emphasize one thing I want to first emphasize this keyword selecting. So, we are not going to talk about how a nozzle is to be designed there are let us say, a 100 or a 5000 nozzles that are available we are going to look at how to select the appropriate nozzle.

Now, the constraints that are posed by the users let us talk about those first. So, if you are the one that have been the task of selecting an appropriate nozzle, these are questions that you have to ask your customer. So, let us say some proctoring gamble comes to you that says help me select the nozzle these are the questions that you have to ask the company that is come to you asking for help.

So, first question what fluid do you want to spray? And subsidiaries to this are the physical properties that are relevant, which are in the terms of viscosity, surface tension, density of the fluid etcetera. Second, what spray angle do you need? Now, why is this customer imposing to constraint? And why is it not a variable that is available to you. Very often let us say, I will I will answer this you know slightly very often you have there is an existing installation let us say this is like a spray dryer.

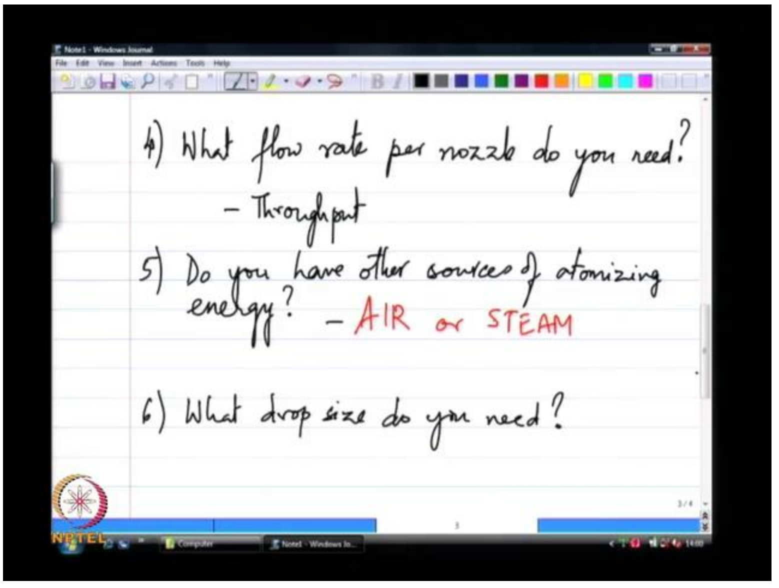
(Refer Slide Time: 03:39)



And this spray dryer has a bank of these nozzles at the head, each one putting out a spray of sorts you know if I make these too wide, then the issue of impingement on the walls etcetera becomes relevant. Let us say I have a fan here that is driving an air stream, so I am putting out hot air here and this air has to essentially, reach out to all the drops. So, which means it cannot be to narrow and the constrain that comes from the customer is in terms of let us say what size kilns you have, and depending on the proximity of the last nozzle to the kilns a wall you want to design the con angle appropriate you want to choose the con angle appropriately and therefore, you know you need to know something about the installation design. In order to answer to the question of what spray and do you need.

Next, what spray pattern may, what supply pressure will come to the spray pattern later, what supply pressure do you have available? So, that is going to determine something about the spray nozzle itself, what flow rate per nozzle do you need? Now this is usually determined from throughput.

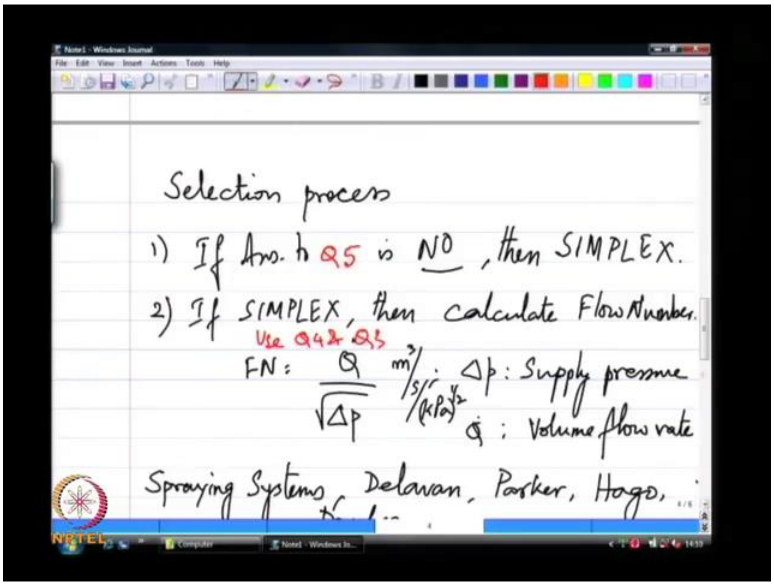
(Refer Slide Time: 06:14)



So, will again if I was a powdered product manufacturer, there is a certain throughput that I need per nozzle or per kiln. So, I need this kiln to produce let us say so many 1000's of pounds of a product per day. So, those kinds of a number can be translated to flow rate per nozzle, and then lastly do you have other sources of atomizing energy? Possible choices are let us say, air or steam at some high pressure let us say now is one last question, which you are count customer may believe is just simply Greek and Latin, but what drops size do you need? Very often you find in the industry that, drop size is something that the really have no control over I mean they really do not try to control, so it is like it is an have to thought, but we through at the asking the question especially like a said with the product manufacturer example.

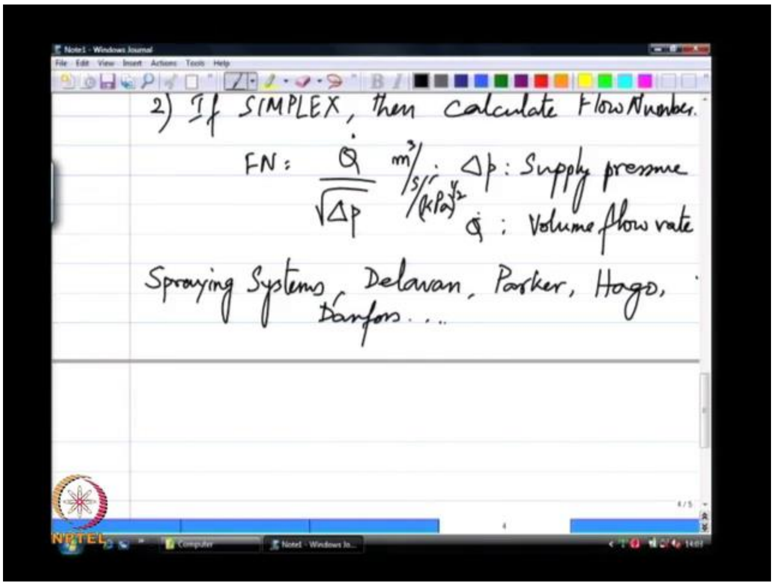
So, let us go through these questions and see how the design or selection process is influence by each of these. If you go to, the first thing once you gather this information the most the first question that is of important is number 5 the first question that, you should use in the selection process is number 5 if the answer to that is no, that there are no other sources of atomizing energy. Then it is pretty clear the choices to be pressures, so will atomizer of some kind. If they do have let us say air or steam available then you can go to an air assists or an air blast atomizer or steam assist steam blasted while it does not mean it is a same thing some kind of gas assisted atomization.

(Refer Slide Time: 09:29)



And, essentially the first, so I will write down on the steps that you can go through in a selection process, first then you are restricted to simplex nozzles as pretty much the only choice now if they. So, we will go through this one by lone let us say we want to look at simplex nozzles, how do we choose simplex nozzles? Take the flow rate that that is you have you can call this some Q dot, you can calculate a number called the flow number this flow number in very cruet terms is defined as Q dot over square root of delta P. Delta p is you are supply pressure choice Q dot is the volume flow rate. So, this is Q dot over square root of delta P; obviously, is not a non-dimensional number as we can see.

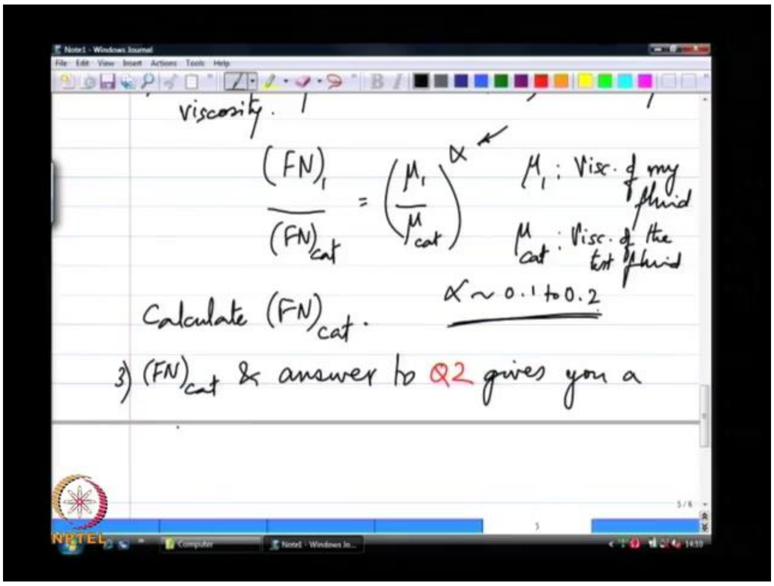
(Refer Slide Time: 11:31)



So, you have to calculate this in a set of units that a particular manufacturers catalog allows like, for some example this several manufacturers of simplex nozzles in the world I list of few; one is called Spraying systems, there is a another company that is called Delavan and then Parker and then other one called Hago this is the one called Danfors, these are all you can go find information about you can get catalogs of each of this manufacturers and each of these manufacturers would report this flow number in their choice of units.

Let us say for example, meter cube per second per kilo pascal would be one choice or gallons per hour per P s i or square root of P s i gallons per hour per square root of P s i is a perfectly legitimate unit for flow number. So, you can calculate this flow number and typically you have a selection of nozzles that give you the same flow number, but different flow rates.

(Refer Slide Time: 12:42)



So, the first choice the first step is calculate flow number, but before you can go to the catalog what you need is a sale the flow number with viscosity with liquid viscosity. In other words most of these catalogs would have the flow number or all the flow data on all the nozzles reported with let us say, water or kerosene depending on their main market segment now if you are spraying a fluid that is different from the test fluid, that they are reporting the data on you need to figure out you away to scale your flow number calculation toward the flow number would be equivalent to their catalog. So, typically this flow number 1 divided by flow number catalog is some mu 1 divided by mu catalog raise to the power alpha.

Now, the alpha itself would be a function of the design of the spray nozzle and most manufacturers gives this number alpha. So, I know my flow number FN 1 I know mu 1 the flow number of the viscosity of the fluid that I need to spray and I know the flow number I want to know the flow number in the catalog I know a mu of the fluid that be used to test off to test their spray nozzles which is mu catalogs. So, mu 1 is viscosity of my fluid mu catalog it is the viscosity of the test fluid.

So, from here I can get what flow number in the catalog would give me the, would be equivalent the one that I want to spray now, here is a big of a surprising fact, but true that for a given mu. As mu increases the flow rate through the same nozzle at the same pressure increases especially, true for simplex nozzles that we looked at and it has to do with a fact it is a little surprising because you expect viscosity goes up you expect the flow rate come down, but the flow rate through the simplex nozzles goes up because if we look at if you remember that the design of a simplex nozzle you have a swelling liquid that is exiting the nozzle in the form of a film that is sticking to the walls.

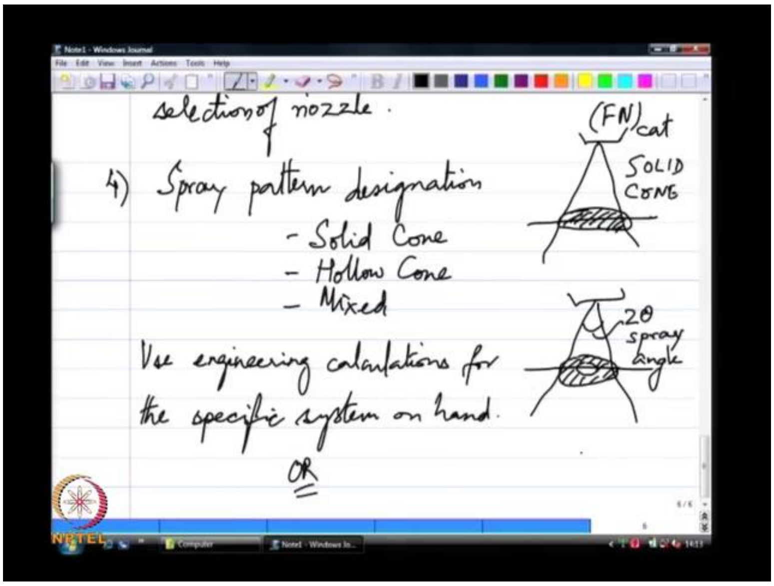
As the viscosity goes up the surely intensity dies out much quicker inside the nozzle as a result of which the film exiting is actually thicker. So, even though the axial velocity remaining the film is thicker the axial velocity remaining the same you get a slightly higher flow rate. So, these number alpha is like, is alpha is on the order of about 0.1 to 0.2 typically, so it is a positive number it is not a negative a scaling with me for the same delta P if the viscosity goes up the flow rate goes up slightly again just to make show we have this point under wraps the thickness of the film covers only about less than 10 percent of the total cross sectional area. So, we only talking of a small increase in that thickness going from let us say 10 percent of the cross sectional area up to 15 percent of the cross sectional area to give us a week exponent like 0.1. So, the exponent is only like 0.1.

So, it is very insensitive to be viscosity if any slightly it increases lightly. So, this increase a slight increase is well captured by just that small increase in a film thickness at the exit of the nozzle. So, the process starts by calculating the flow number in the same units has the chosen catalog, now if you really want to go through this let us say you have 5 of 5 different manufacturers catalogs at your disposal each one as their own unit system you will have to get the flow number in those various units.

Now, alpha specifically depends on the design show in the catalog already does not have it you can call the manufacturer in the usually happy to give you this number, but if you are at loss number like 0.15 is reasonably accurate. So, you can now get the flow number for the catalog for your actual nozzle, now this is sufficient to get started. So, the first question to go after is number is 5 once you have that use the answers to question number 4 and 3. So, we starting with 5 if gone to 4 and 3 and then we come to 2.

So, in this step number two we used question 4 and question 3 once you know your flow number will use question 2.

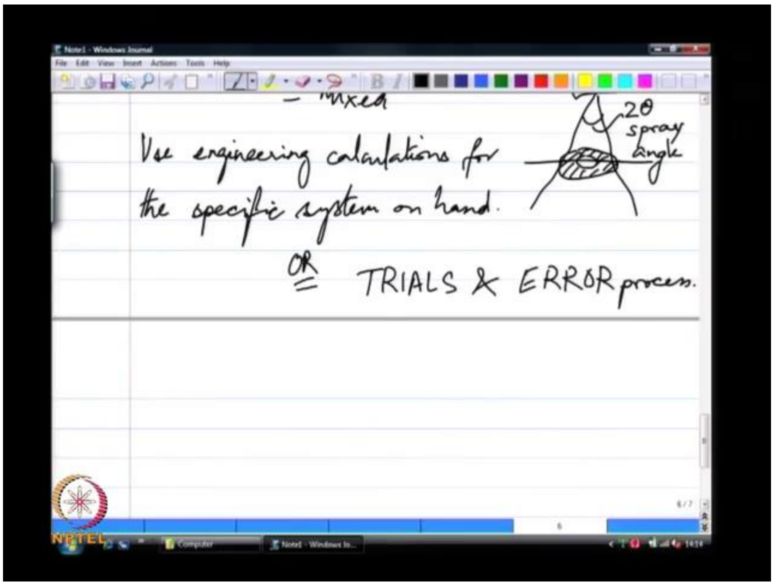
(Refer Slide Time: 19:26)



Now, at this stage most of these spray nozzle manufacturers have what is called as spray pattern designation in terms of what I have called solid cone spray nozzles or hollow cone spray nozzles or mixed spray nozzles sort of like a small medium large. So, essentially a solid cone spray nozzle would be where, if I took a disk the entire disk has drops in the cross section this is an example of a solid cone.

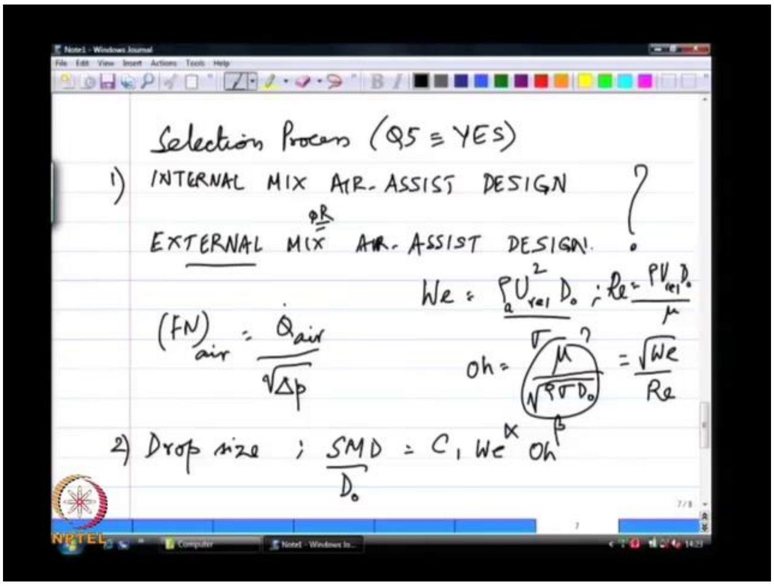
If I did this on a hollow cone spray nozzle I am expecting there would be like a donate shape. The size of donate where is between hollow cone and the mixed version, but essentially these are two variants of the spray patterned. So, for a given spray angle and a given flow rate flow number you may have 2 or 3 choices. So, the best way to go about this is one, so the way to select pattern use engineering calculations for the specific system on hand or what is the second option, one you some sort of engineering calculations to make sure you are able to get enough penetration of the air in to the spray or fix a combustor application try and see what the how the combustion would be shape by a given kind of a spray or the second option is to simply go through trial and error process.

(Refer Slide Time: 22:23)



So, you try out all the 3 or 4 different nozzles you would basically middle down from a catalog of a 5000 nozzles down to above 3 or 4. So, we have best bet mages be to try out all 3 or 4 and see which from gives you the best performance, but if the trial process is expensive like may be in some cases you may need to go through some calculations to really come down to 1 nozzle as your specification. So, this is if the answer to the first question if the answer to Q 5 is no.

(Refer Slide Time: 23:11)



We will write down the exact same process, if the answer to question 5 is yes, essentially if you look that the previous design process we did not a really get down to drop size in anyway because, if I specify cone angle and flow rate is a good chance that cone angle and flow number I really have lost all the controls over the drop size I really do not have any other handles to control drop size at that level. Whereas, with air assists atomizes I have another independent control over drop size. So, this is where one would need some more information about drop sizes.

But the first step, before you get drop size. So, I will show you how we usually incorporate drop size in to the design process or at least the selection process, but before that what we wanted to do is look at how we are going to use the air. So, there are 3 or 4 possibilities one is an internal mix air assist design or an external mix air assist design now the answer. So this is a question that we have to ask ourselves, after we know we have are available do we go down the root of selecting and internal mix design or to the go down the rout of selecting and external mix air assist design.

The answer to this is usually, based on some other considerations like safety like for example, in a combustion system it is highly unlikely to be an internal mix design because you do not want to mix your fuel vapor and oxidizer in any way of form prior to combustion, it is just not safe especially because the nozzle itself is going to be subjected to a high temperature environment. If you are in a spray dryer kind of a situation it could be possible, but generally speaking most commercially available spray nozzles are all external mix design I should not say all there are internal mix designs available commercially, but they are prone to instabilities. We will talk about those, when we will look reign maps later on this semester, but essentially if I want a very robust installation I would choosly external makes air assists design the disadvantage with that, is that there not a as efficient with the usage of air prior with, they with the air usage as the internal mix designs.

But they are less prone to instabilities. So, if I will sacrifice some efficiency for a nice robust installation, typically we go with an external mix air assist design and in these external mix we looked at a 3 or 4 designs in the earlier lectures there is rig process exactly like this you start because all of the external mix designs are essentially, like a simplex nozzle with an outer air sheath. So, I have a simplex core that I am using air outside. So, the selection process associated with selecting the air assists design starts with selecting the appropriate simplex score in the form of the flow number in the form of a cone angle etcetera. And then you can use the a similar calculation on the air side to choose the based on the spray cone angle that is you want to choose the equivalent air assist design. So, this process essentially begins just like we said air assist design.

Now once you have the, once you narrow down on the external mix air assists design you the design catalog or selection catalog usually gives you a flow number for the air side. So, what flow rate of air square rooted delta P across the air passage because, this is an external mix the air passage is like, a separate fluid dynamic passage in relation to this the fluid side. So, I can calculate an air number a flow number for the air side as well as the flow number for the fluid side and typically using these two numbers you can choose a an air assists design model.

Now, drop size because you have this additional handle of the air assists. In the air assists atomizer you can do what I have called the sauter mean diameter correlations. Typically the sauter mean diameter divided by let us say the diameter of the orifice would be in some form would be given to you in the form of correlation like this based on the weber number and the on is organ number we will write down what these are the weber number is defined as rho u relative squared D 0 over sigma rho b in the air density u relative being the relative velocity between the liquid sell in coming out and the air steam outside D 0 could be like the diameter of the orifice through which the liquid film is coming out and sigma is the surface tension of the liquid on is organ number I believe is that.

The another way of thinking of this is essentially, square root of the weber number divided by the Reynolds number, if this is an easier way to remember this. The Reynolds number also is defined based on rho u relative D 0 divided by mu. So, I can use a correlation like this to figure out what air velocities do I need because I fix the flow number of on the simplex side. So, I can the u relative is the liquid film velocity minus the air film the velocity or actually, that is the other air on air is usually moving faster than the liquid right.

So, I need to know I can from a correlation like this given an SMD that is desirable I can find W e the weber number for that given application and from there calculate what u air would be best, would give me that weber number. So, here is a way to engineer a spray nozzle for a given drop size. I am only able to do this because I have this additional handle we would realize that, and that to only mean drop size if I want to engineer a drop size distribution then it is no longer as selection process. It is a design all together.