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When Its Drying Time Again

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Professional Development Training Course
for Registered Engineers

When It's Drying Time Again

Tape 1 – Side 1 (drying disk1-ed hardin)

The title of this course is "When It's Drying Time Again." It is a three-hour Professional Development Course for use principally by process engineers, but generally for anyone who does drying as a process in their manufacturing operations.

My name is Ed Hardin, I am a professional engineer in the State of North Carolina. My background for providing this course is 15 years of operating time in several types of plants, primarily having to do with plastics. Then, plant design and construction for 25 years, specifying in starting a variety of successful dryer systems for a variety of products.

The drying information and processing review that I provide here was generally learned in classes on mass transfer in college, but possibly some insights on mechanisms from my experience will help observations of phenomenon that any of you might see in practice. My comments are intended to be for a variety of carrier removed fluid systems, but sometimes may revert to air-water. In places where this does not generally apply, I will try to note reasons. These are my opinions. Use your experience to compare and evaluate the things that you hear from me with what you observe in the systems that you operate. Hopefully, I can offer some ideas for you to consider if you're having some questions about a process.

As a general review of some of the products that I've been related to, some of my initial drying involvement had to do with polystyrene beads, generally of a sized nature. That was followed up by some flash drying of vinyl chloride products with some of its attendant questions being discussed later on, as well as some cases where drying was used as a preparatory or initial portion of some further treatment of materials.

In looking at the question of drying, I think it appropriate to first discuss and remove some possible misconceptions having to do with drying and materials being dried. One misconception that we should consider is the idea that many people believe all liquid is on the surface. Certainly, in many cases, this is the primary liquid that we wish to remove. However, in some cases, we are also involved in attempting to remove liquid that has, for one reason or another, permeated within the physical boundaries of the particles that we're working on drying.

Sometimes, we're also attempting to remove a liquid that is partially or completely chemically bound to the particles and solids that we're attempting to dry. This is running into questions like working with hydrates and, of course, things that have a very strong water affinity because of their strong hydroxyl nature, having the very surface and van der waals forces for water and other hydroxyl type materials. Again, there may be specific situations that you have reference to where you can recognize that this is not always the case.

A second item to consider is that once water is removed, it is always gone. This quite often leads us into some truly difficult times. In many cases, a material is hydroscopic and, when it is dried, it must be treated and processed in some way, or packaged in a specific way, to keep it from reabsorbing water or any other liquid that may be around it. Protecting against situations like this is certainly going to be a product and industry specific kind of activity, but don't assume in any given situation that once you've had the opportunity to remove the water that you won't have to worry about it again or any other liquid that happens to be with the material.

A third misconception relates very closely to the second one and that's the misconception that dry means that all of the liquid is gone. As we've just discussed, there are conditions and times where some materials are either very tightly absorbed within the particle or chemically bound within the particle. Then, later testing will show the presence of materials that we may or may not want to have as part of our finished product.

A further misconception to be discussed and considered is the idea that a product is protected when it is packaged. Certainly, we all recognize that there are varieties of packing materials. A paper bag will do a very good job of containing many materials, but, as we're all well aware in many cases now, we see these situations wrapped with a protective plastic film and they do very well. Plastic bags are also a very good way to provide protection and containment in shipping. Certainly, these can offer additional protections for some materials, but plastic films are not always non-porous. There are either pinholes or structural types of material that will allow certain things to pass through and others not.

This was the case in one product that I have worked with in the past where a specific type of film packing was used as an inner bag in a very complex drum. Recognizing that the material was such that it would let water escape if some happened to be there, but it would not allow the evaporation of some other vaporizable materials that were part of the finished product. It worked very well, but its location and selection were as serendipitous as they were important.

A further activity to consider when looking at drying is a need to first evaluate how dry something must be. A significant question would come into what further processing needs to occur for this material. A quick example would be ground up limestone that's used for home soil reconditioning and amendment. Certainly, that's done in paper bags and sometimes in plastic bags to keep it from being processed, but this is a material that's going to very quickly be spread around on the ground. So, its perfect dryness or very low water content would not really be required. Something in the half to three-quarters of a percent of water may be more than permissible in the drying condition. This is the kind of thing that should be adjusted in reference to selling to the public to recognize for them that when they're paying for it, they're paying for the relative dry weight and not strictly for water.

A second thing to evaluate in looking at what ultimate reduction of liquid content on a material is necessary goes back to somewhat the same question of why it must be dried. If there are conditions where the material is just going to be re-slurried, it may be able to be packaged in such a way that it can be handled and re-slurried easily without a great deal of water removal. If material is to be mixed into some liquid for further processing, it may be appropriate to do liquid displacement immediately at the end of the manufacturing process and ship it in a particular liquid carrier in order to move both the liquid and the solid. This may be a simple way to protect the material against other activities and have it partially prepared for further processing needs.

In these discussions, it is generally my intent to review several types of drying, make some particular comments on how each works, and discuss the other factors having to do with a particular processing method. Comments might be made on the specific driving forces, whether that would be a physical separation that may occur in some screening type operations or a temperature or concentration driving force that is used for separating the water and other liquids. Another thing that we will try to cover is how the water and other liquids are part of the material to be dried. We've made a few comments about that, initially, but there may be some appropriate comments on that later on.

A further item to consider, particularly in relationship to the removing of water from materials, is the psychrometric chart. We're very fortunate to have such a detailed study done on the air-water system and have it so conveniently available in so many forms, but quite often there are some questions about what different parts of the chart mean and how they can be used and why. Some of these we may have an opportunity to comment on, but specifically a question to deal with early is the idea of wet bulb and dry bulb temperature.

A dry bulb temperature is generally very easy to understand. It is that temperature that would be achieved in just placing a thermometer in some kind of a flowing stream or existing location where a temperature needs to be measured. Whatever temperature comes into equilibrium is our "dry bulb temperature."

A wet bulb temperature is very specific. It is the temperature that would be achieved if the liquid being considered was just at its evaporation temperature under the conditions of the processing stream being used. In the case of air and water, the specific conditions would be that if the measuring liquid bulb of the thermometer were coated with a cloth that was saturated with the water to be evaporated and a stream of air were passed over it, the humidity in the air would effect the temperature at which the water on the thermometer would evaporate. If there were 50% relative humidity in the air, we would find that the equilibrium temperature of the thermometer would be at one particular condition for a given temperature. If the humidity of the air happened to be 20%, we would find a different wet bulb temperature. More water would evaporate more quickly in the lower humidity air. Therefore, the equilibrium temperature of the water around the bulb would be lower because of a higher rate of evaporation and a greater removal of heat from the liquid contained around the bulb.

This is one of the things that makes determination of a wet bulb temperature a very tricky little process and something that is very time specific. You must be sure to continue to have some liquid surrounding the wet bulb thermometer when you take the reading so that you know you have an equilibrium condition. The old sling cyclometers were something that had to be used three and four times in order to be sure of that when you were doing a test like that. Quite often, temperature monitoring and selection processes now are able to give you a very good adaptation and correction for that. In other cases, there are direct ways of reading the humidity in the air that make some of those questions a little less of a problem than in the past.

A couple of comments out of Hougen & Watsons volumes on basic and preliminary chemical engineering are appropriate to this discussion. They describe the condition this way:

> The equilibrium temperature attained by a liquid which is vaporizing into a gas is termed the wet bulb temperature and is always less than the actual dry bulb temperature of the gas into which evaporation is taking place. If the gas is initially saturated with a given vapor, then neither vaporization of the liquid nor depression of wet bulb temperature occurs. It is therefore convenient to use the depression of the wet bulb temperature as a measure of the degree of unsaturation of the mixture of gas and vapor. This is a valid procedure providing the heat of vaporization comes only from cooling of the ambient gas by the liquid.

A further comment on the wet bulb/dry bulb situation is the recognition that the ultimate carrying capacity of the gas depends on the temperature at which it exits the drying process. It is very easy to heat up a gas as it goes into a drying process and recognize that you can increase the drying capacity of the air or the gas stream being used. However, once a liquid begins evaporating into the gas stream, the latent heat of evaporation absorbed to change a liquid into a vapor will seriously depress the overall temperature of the equilibrium stream and come back to the limit of the removal capacity of the carrier stream.

When a material is being processed with a gas stream, it is very easy to refer to the occurrences in the dryer in the processing unit, but we have a further question to relate to. It carries several connotations with it, but as the vapor stream and the carrier gas is removed from a processing unit, it may carry some solids with it. Therefore, it may be necessary to provide either a filter or some other separating means for recovery of solids carried in the carrier stream. In addition, the contents of the carrier stream must be considered. Quite often, some treatment and permitting is required—certainly permitting for all of the exit streams—but some treatment of the exit stream may be necessary for removal of any non-compatible materials. This is something that will not be a subject of our discussions here, but must be recognized that some further processing may be necessary on any of the carrying gas streams.

Possibly a first item to consider as we look into the actual process of drying is some of the specific requirements of using a dryer. One of the first in relation to that is being able to get material into the dryer. Quite often, the physical characteristics of the prepared material make it very difficult to do this. Certainly, if you're favored enough to have a relatively free flowing material when you have done the preliminary separation of liquids from the material to be dried, feeding into the dryer can be easily accomplished in a number of ways, including things like screw conveyors, vibratory feeders, and some other activities similar to that. Of course, these things also add a potential for difficulty in the dryer in that the sealing of the entry to the dryer now becomes a matter of some interest and concern. Every extra leak causes an additional load on some portion of the vapor or carrier gas handling equipment for the dryer. If it's a relatively open screw conveyor, there can be quite a bit of leakage.

Separating material to feed into a dryer is quite often done in centrifuge. There are a variety of centrifuges, from the various solid bowl and basket type horizontal shaft centrifuges to the vertical shaft centrifuges. The quality of the material coming out of these units can vary greatly depending on the material being handled. Often, though, screw conveyors are the way of transferring from the discharge of these units into a dryer stream of some kind. In addition, some materials can be easily injected or blown into the dryer with a combination of either the gases to be used for the drying or a separate gas stream of limited quantity used just to transfer the material into the dryer.

Of course, once the material is dried in the dryer, there is the question of removing it or getting it out. Depending on the dryer, there are a number of ways of handling this. Hopefully by this time you do have a free flowing material and the discharge and transfer of the material from that point becomes somewhat easier. Another thing that does become a matter of some importance on occasion is the question of trying not to get material out, particularly at the wrong time or place. Seals, internals structures of various kinds, and internal return flights of some types in rotary dryers that we'll discuss a little bit, are all things that are used to achieve that kind of return and control. Of course, the other question is what happens to the material as it is dried and if it's something that becomes rather abrasive. Periodically, there are concerns about the external surfaces of the dryer and whether the material will, in fact, wear out the surface of the dryer.

Another item that is a matter of some interest in looking at dryers, the drying process, selecting a dryer if that happens, and possibly analyzing it later, is what in fact happens to a material in a dryer. The very simple situation is material has some surface moisture, the surface moisture is removed, any tendency to be tacky or to clump together is removed with the liquid as it is separated, and the material then becomes free flowing and dry. In other occasions, as temperature goes up, a material will become tacky and tend to clump even more. That, of course, is an undesirable option and something to be concerned about, particularly from the standpoint of deciding on the kind of temperature controls, changes might be needed in the dryer, whether the material becomes clumpy only when there is some liquid available, if the liquid is essentially removed and there is a further separation that is needed in the drying process, and if it can be done in the absence of surface liquid and prevent tackiness of the surface and clumping. All of these factors do have a bearing and hopefully we will have an opportunity to mention some of these as we continue to discuss various drying systems and equipment.

It is always an open question trying to decide what should be the first specific type of dryer to discuss. We could start at any one of a number of places. My choice is to start with a typical rotary dryer. There are a number of varieties that we'll discover in that, but by rotary dryer, I'm thinking principally of a long cylinder that has within it possibly several zones of temperature control. The temperature can be controlled in a variety of manners and there are a variety of heating methods in it. Generally, material will be fed from one end, removed on the opposite end, and the drying carrier vapor will generally flow in a countercurrent method entering into the dry end and being removed from the end of the wet material feed.

In a rotary dryer like this, quite regularly there are plates or flights on the inside of the dryer that tend to lift the material and drop it through the carrier medium in order to provide better solid to a carrier vapor interchange and mixing and improve the opportunity for the interactions necessary to remove the liquid and put it into the carrier stream. In some cases, the dryers are arranged very specially on the feed end where there might be some dust that is removed with the carrier medium and off into an off gas processing system. That dust is then separated and brought back to the dryer in a specialized way and will be refed inside tubes in order to give it an opportunity to move a little farther down the dryer and mix with a damp, though not wet, material and hopefully become part of the solid stream again so that it can pass through the dryer and be part of the product. The flights are generally arranged in line with the major access of the cylinder of the dryer so that they do not become an interference with the airflow or the gas flows passing through the dryer and increase the pressure drop there. This, of course, would add energy usage to the feed mechanisms for the carrier of gas or the discharge. Of course, these units can be set up for induced draft flow, forced draft flow, or a combination of both, depending on the materials being handled.

A significant item to recognize in looking at a unit such as this is that the gas carrier medium passing through will go through some significant changes as it passes from one end, the feed end of the gas and usually the discharge end of the solids, to the discharge end for the carrier gas or the feed end for the solids. The gas is usually warmer as it goes into the material discharge end or the vapor feed end. That means that its density is lower. That is the point at which it will offer the greatest driving force for the removal of solids. It will also provide the greatest opportunity for temperature effects on the material, if that is a matter of some interest or concern.

As the gas passes through the rotating circular cylinder, the dryer tube itself, the medium will usually increase in vapor and liquid content. This can cause either of two changes. It can increase or decrease the overall molecular weight. It will also usually cool the carrier gas and finally come to the gas discharge end where the vapor will relatively be at its coolest point with the most liquid content in it. This, of course, is a point at which it must be carefully reviewed and considered to be sure that we're not into a point of condensation and returning the liquid to the solids themselves.

Related changes in the carrier medium are density, which is in for a specific volume that can have a significant effect on the velocity of flow through the unit depending on the materials being processed. It will change in viscosity, which will change pressure drop and performance within the vessel. Again, with many situations, this is a relatively small change. It also changes in temperature, which we've discussed before—the combination effects of the possibility of getting too cool and allowing a condensation or staying too warm and creating problems with the material as it is being fed or the liquid itself is being fed.

We can now address some important effects that occur on the carrier gases as they pass through. One of the things to recognize in the temperature and some other property changes is the effect of the latent heat of evaporation of the liquid being removed. This is usually relatively large in relationship to the heat capacity and other temperature effects in the dryer. So, the evaporation of the water absorbing a great deal of energy will have a significant effect on the carrier gas temperature. This, of course, is one of the benefits and one of the problems of dealing with dryers. The quantity of liquid and its effect can cause many questions to arise about the quantity of gas to be used, how the material is fed and handled, and what exactly occurs in the dryer.

Water, of course, has the benefit and the problem of being one of the very highest in latent heats of evaporation, absorbing 1,000 BTUs per pound of water evaporated. Quite often, what we can see in a dryer is that if it's an air stream and water drying question, a very warm air, as it enters a dryer with quite a bit of water in it, will very quickly cool so that its carrying capacity for removing water drops dramatically. This, of course, is one of the reasons that we tend to aim toward a countercurrent flow using the warm air where there is less moisture or liquid involvement in the material to be dried as the final passage for the material for the ultimate removal of water. Then, suffering whatever we need to in order to be able to move enough gases through it to continue carrying away the water that we're looking to remove. This same thing would, of course, be true of any other liquid that we're trying to take off, although, the effect would not be as dramatic.

Another thing from effects such as this that often gets overlooked is the fact that other materials can change phases in the drying process. The de-crystallization or the removal of water of crystallization has a latent heat effect that is not significant, generally, but is important to recognize as a potential heat cost in the overall balance of the drying process. Other liquids in combinations would have to be investigated specifically for the products being processed, but those kinds of situations may exist with any other liquid removal.

We've been talking primarily about a rotary cylinder type dryer, which is often referred to as a calciner. I would rather exclude the discussion of calcining from what we're doing now because it's usually a very high temperature process and done for something entirely different. However, I will add a comment regarding some involvements I've had with calcining in the past. There was a very interesting phenomenon in the removal of water from alumina. It's very easy to consider that alumina, usually as it's made, has three waters of hydration for each molecule of alumina as it starts the calcining process. These must be removed before some finer temperature effects occur. The significant item is that these waters do not remove one after the other. There are crystalline rearrangements that occur within the process and they remove in steps. This is a very interesting series of steps to look at in several publications. It is also a guide to the kind of things that we can see in drying operations. Water doesn't necessarily remove in the way we initially think it does. It may come off in unusual steps and quantities at different occasions that are not immediately evident. Sometimes an investigation of that may help understand or improve any particular drying process that we're doing.

Generally, we've been referring to a horizontal type rotating dryer. Sometimes there are conditions where an essentially rotating dryer is used in a vertical condition. This usually reverses the fixed and moving portions of the dryer and that the shell would then be fixed. Quite often, there is inside it a group of trays or plates that are rotated with various methods of passing material from one plate to another. Materials move through the dryer, usually under gravity flow, as solids drop through the dryer and gases pass upward through the dryer.

With all of these things, the idea of sealing is still a significant item of interest. Sealing, removing extraneous air leakages in or out of the drying process, is an important item to recognize and consider. Of course, manufacturers of this type of equipment have, over the years, developed some very interesting methods, procedures, and techniques, for achieving this sealing. Quite often, plant modifications don't take as much consideration of what sealing needs there might be and things are changed in later processing. This is an item that might bear some investigation in any processing that you're looking at. Then, again, once a piece of equipment gets into a plant, the plant operating staff and the operating group quite often come to know much more about that particular piece of equipment in relationship to their material. They often add things that are unknown by the original manufacturers to improve this drying process.

I bring it up and emphasize it a bit here simply for the fact that leakages, both in and out, can be problems in many ways and that sealing would be important to you. Not the least is the possible product loss with the general concerns that we have about making sure that things are contained within the equipment, that we don't have extraneous dust losses creating problems in the workplace, or creating removal and recovery problems from treatment of the off gas streams. These are items that should be considered and recognized as work on dryers is being considered.

Generally, I would say that there is no ideal decision on whether to use induced draft or forced draft with a drying operation. The reason for making that choice will very much depend on particular applications that would be used on the dryer vessel and some of the heat supplies and off gas treatment methods. Certainly, where there is a lot of potential dust handling and creation inside a drying operation, some portion of induced draft would be suggested so that things such as cyclones, multi-clones, or electrostatic precipitators, could be more effectively used in treatment and recovery of the dust in the off gas.

From the standpoint of selection of various methods of heating as it goes into the dryer, quite often forced draft is suggested. Any flame type operation usually would have at least a partially forced draft from a primary air introduction with induced draft possibly being used for the other air that would be passing through the system for drying. Of course, the control systems would be adapted to assure that there was plenty of airflow in order to protect against flame problems inside the drying operation.

Of course, we cannot consider the idea of how air or the carrier gases used are introduced and removed without considering the type of heating that is done. Often times, dryers of minerals or significant bulk solids are dried essentially with a flame heated gas stream, which is normally air. Of course, the question then comes in of whether it's possible to create the flame inside the dryer because there is enough temperature resistance in the material or whether the flame should be created in an external operation with the air passing through and being heated before it's put in the dryer. Anyone who has a gas dryer that they use for their clothes would recognize the benefits of the usual pattern in that type arrangement. The flame is external to the actual dryer body, the air is heated as it's drawn through a venturi where the flame is, and is then drawn into the area where the clothes are tumbled. This is also quite often done industrially and is a way of protecting both the solids and giving a separate kind of package for the flame creation itself in order to provide better ways to instrument and control it so that there are no difficulties with flame or fire potential from using that type heating.

Quite regularly in rotary tube dryers, you will find that there is a multiple arrangement of tubes in the dryer. Sometimes just down the center of the dryer, sometimes created on the periphery, and often with that arrangement, the tubes then are steam heated. This gives a very good way of controlling temperature. Of course, it brings in the question that we've discussed on several occasions of affecting a seal between the steam supply, the condensate return, and this piece of rotating equipment. There are several methods that are used to affect this and, of course, the rotary joints are a very typical situation for that. People who make and use these dryers will, of course, explain that very carefully to you as you consider that type of drying operation.

In some circumstances, externally applied heating methods on a given rotating shell have been used. Certainly, the embossed plates that we have available to us now give us an opportunity for doing things like that. The carrier gas passing through then becomes primarily a removal medium for the vaporized solvent with the solids being heated on contact with the shell. Often then, some heating of the pass through gas is not required. Certainly, the idea of using an electrical external wrap on this type of equipment is also possible.

With these discussions, we're coming very close to the end of the first tape. So, I will discontinue at this point and take up the final portion of discussion of rotating type dryers at the start of side two of tape one.

Tape 1 – Side 2 (drying disk2-ed hardin)

This is the beginning of tape one, side two, discussion of drying and various types of drying in a PDH study course called "When It's Drying Time Again."

Although the dryers that we'll be discussing now are not cylindrical in shape, generally, they have a variety of other shapes that we'll comment on. I put them under the rotary dryer types since they are operated in a rotating fashion.

There are several types of closed tumble dryers that bear some discussion. One of them is the double cone where the bases are matched together, and the apexes on each end. There is a valve that is used sometimes alternately as an inlet and outlet and sometimes a valve on each end, so that something can be removed and then very quickly something else entered by connections. Then, there is the second variety of the V, or quite often referred to as a pant leg type. Both of these have the capability of doing blending and turnover inside the vessel during the drying operation. Of course, there are a number of other opportunities to use with the closed container such as this.

A key factor to their operation is the rotary joints on the drive shaft and main support shaft for the vessels. These rotary joints can be used for a variety of activities. Certainly, connections for heat transfer, in some cases, but also sometimes a vacuum connection is used through the joint where it is a multiple function joint or sometimes a joint on each side of the shaft.

Since this is generally a closed vessel, the removal of the vapor by vacuum will depend on the vaporization of the vapor. Although it is infrequent, periodically, there are purged gases that are allowed into the vessel, sometimes controlled vapor entries, or controlled leaks, to bring material in, but usually it would be a controlled inert gas that is put in to carry the drying material away.

The other function is the variety of heating methods that can be used. Certainly, there are jacketed vessels like this, but the supply to the jacketed vessel gets a little complicated and that is something you'd want to review with any vendor of this type of equipment. The heating medium can be circulated through a jacket on the shell and also taken out on a regular basis through the rotary joints that connect one side of the shell. One of the other opportunities that is available there is to wrap the vessels with an electrical tracing. Then a sliding type contact is usually used for the electrical supply to the heating elements. Of course, then we run into insulation and so on.

One of the key factors is the operation of the valves in and out and, with some of the newer technology, valves that have mounted on them a mechanical or electrical type operation with signals sent either by radio or light. That makes these valves a little bit easier to operate currently than they have been in the past on some of these units. It doesn't make it necessary to have piping connections, use extra joints, and so on, in order to provide the driving movement for the valve.

We'll move on now to a discussion of a drying type that has been used in a variety of methods for quite a long time. We can refer to these as tray or pan type dryers. One of the key functions of this type dryer is its simplicity and reliability. However, it can take a relatively long time since the material is usually fixed once it's put into the dryer so that there is a limited contact of the material with the drying gases' vapors that remove the liquid to be taken off the solid material.

So, from this consideration, one of the things that we should look at first in this drying is the question of handling the trays, to get the material onto the trays, into the dryers, and then back out again. With many trays, an automated method is often used to distribute a feed material onto a tray in a uniform layer. This helps somewhat in providing reliability in the dryer operation. The material is then spread uniformly on the trays and the trays are slid or stacked into a frame. The frames are then wheeled into a rather large chamber that is the container for the control of the heating and carrier gas medium as it passes by the tray dryers.

These loading methods can be done either manually or automatically. There are several systems of conveyors and other distribution methods that are available to do this. If there is a relatively large quantity of material, an automated system is probably something that should be seriously considered. This type of drying lends itself to materials that might go through a tacky stage in the drying; something that would tend to stick together and have trouble plugging up or bonding to parts of any other type of drying operation. Since the material does sit relatively undisturbed through the drying process, physical changes in the solids are not as big a question in relationship to the finished product as might occur in some of the other moving type equipment.

Once a system has been developed using this type dryer, usually a critical factor is the amount of time that it takes to achieve a uniform product quality through the drying. This is often done on an empirical basis or on the basis of some testing that might be done before the unit is purchased. In any case, some continuing evolutionary operation to achieve an optimum operation would always be appropriate. The thickness of the material as it's placed on the tray, the time, and the temperatures of the carrier of gases as they move through there, are all things that can be adjusted, modified, and investigated to determine the most appropriate way for handling the material that you wish to dry or process in this way.

One of the other functions of this type of dryer that needs some consideration is the unloading. Certainly, if a material does pass through a tacky or sticky kind of condition while it's in the dryer, the cleaning of the pans and the assurance that the material is removed from the pans when it's taken out would be a matter of some interest. There are a variety of things that can be done. Usually, it's a physical arrangement to provide a rinsing or blow off of this kind of unit, possibly with an air- or gas-driven kind of spray of the solid itself to help dry and remove it from the trays. However, you would want to get to the point of a clean tray as you recycle it. One, for the efficiency of recovery of the dried material, but also from the standpoint of not wishing to effect or modify the feed conditions so that you could continue to have a uniform type operation.

Of course, all of the mechanical handling of these trays adds to the cost, the involvement, and the space that is required to operate this type of dryer. There's also usually quite a bit of additional floor space that is required for racks of trays ready for entry, as well as areas to take racks of trays after they've been dried. This is a relatively inefficient way of drying, but its simplicity, reliability, and ability to handle a rather wide range of materials make it something that is of interest in many applications.

Heat sources for this drying follow all of the programs that we've discussed before. The very simple idea of preheating the air in any number of ways, either by steam coils or an open flame situation in a chamber, are all available. It is something that needs some serious consideration, particularly where an organic solvent might be removed from a solid material. In that case, the flame would certainly want to be in a separated area if you use a direct flame heating of the material. For safety reasons, quite often, something like resistance electricity or steam heating is used to achieve the carrier gas warming in these instances.

Quite often the chambers themselves are jacketed or wrapped and insulated with some kind of heating medium. Certainly, embossed plate coils, as a chamber sidewall, is something to be considered if that's appropriate for the type of operation you're looking to use. Electric type resistance heating wrapped on the sides of the containers are another way to maintain heat control and temperature conditions within the units. Of course, generally, they would always be insulated and protected to make sure that there is no personnel danger during the operation.

This type of dryer is relatively difficult to use in a sealed condition because there are so many doors and requirements for passing material in and out. To use this under a low-pressure condition, again, because of generally many flat sidewalls and the problems of supporting those under pressure differential conditions, also makes it difficult to use in a vacuum type condition. Certainly, some reduced pressure is always possible. That's a matter of argument and discussion, but there will always be some pressure reduction because of induced draft flow. This will usually be something less than 20 or 30 inches of water because of fan limitations. Further or deeper pressure reductions would require some serious discussion of how the vessel sidewalls would be supported in order to achieve this.

Of course, sealing of these units is also very important. A variety of methods of overlapped edges on flexible gasketing materials generally make it pretty easy to seal a lot of these. However, because these seals are opened and closed so often, maintaining them is an area that requires quite a bit of maintenance and observation. Changes of the conditions of these seals or losses of portions of these seals will cause significant efficiency changes in the drying operation.

Also, the insulation is important from the standpoint of containing the heat. As we've discussed in the other type of dryers, maintaining a good flow and proper temperature in order for the carrying away of the removed vapors and getting it into a treatment system where it can either be recovered or destroyed before discharged into the atmosphere is an important item for this type of dryer.

A further refinement or variation of this type of drying might also be considered as the conveyor type dryers. Instead of having a single group of pans that is moved, often the pan itself becomes a conveyor table and material is spread on it at one end and discharged in various ways at the other end, with the conveyor moving through heating chambers and some circulation of air around these chambers. Again, questions of the tackiness and the conditions of materials as they go through bear some investigation before using this type of dryer, but it is used very regularly with some food and fiber products where a reprocessing or removal of a washing fluid might be appropriate.

The bulk density of these materials also tends to argue for using this type unit. It is very easy to provide additional space to allow a material with a very low bulk density to be handled at a relatively good rate because of the passage. If it is possible to use some holes or slots in the dryer pans, this helps with the circulation of whatever the drying medium is, whether it is air or some other vapor moved through the materials, augmenting and improving the drying. This reduces some of the problems of tray handling, loading and unloading, because you're provided now with a fixed point of loading on a dryer and these dryers can be separated into multiple zones and treatment functions, depending on how much time it takes for your particular processing. They also lend themselves to modifications to add zones or treatment functions, presuming that the floor space is available.

The physical structure of the sealing and insulation and the selection of heating methods are all items of consideration in making this type of selection. One of the advantages that is quite typically available in this type of unit is that each zone going down through the dryer is often provided with its own individual temperature controls. This gives an opportunity for a variety of processing steps through the drying or liquid removal function. If some treatment might be required in there, it also gives an opportunity of making the decision to do a re-spraying within the dryer and then re-drying. Some particular items might argue for that kind of processing and it is certainly one of the functions that should be mentioned as a variation that is available with this type of dryer.

The next dryer type to be considered I will define as screw dryers. These carry into several varieties and usually are required because of a particular condition of material as it is ready to be processed. I tend to suggest the use of this type of dryer for materials that are generally made or recovered as a relatively thick mud, something that is difficult to separate the water or other liquids from as it is being processed, and come out as a very thick slurry. This very thick slurry can be pumped into a trough into which a screw type conveying mechanism is also placed and sealed, with the flights of the screws being hollow inside to allow the heating medium to circulate, both in the screws and around a jacket.

The one real question of dealing with this kind of unit is the heat transfer coefficients. The material handling function becomes the more important function in this case. If the material handling function requires this, then you should seriously consider using this type of dryer. The heat transfer coefficient is generally very low, normally in the neighborhood of 10 or less BTUs per hour per square foot degrees Fahrenheit. So, materials that would use a relatively high temperature source, like a heated oil, is something that might be used here in order to increase the overall rate of heat transfer even though the coefficient is relatively low. Materials to be considered for this would be very thick slurries or pastes; sometimes a pre-treated thick liquid dispersion if the temperature control is important on those; gums or crumbs of material of various kinds; and recovered plastics or rubbers that are still in a very tacky state.

Generally, heat sources for this kind of dryer are all external to the dryer. We've mentioned already the idea of using hot oil. Certainly, steam is often used with this kind of situation. Air is used a little less frequently because of heat transfer coefficient problems. Quite often, this type of dryer is generally open and uncovered and the troughs exposed to the atmosphere with a loose hooded recovery of vapors over the top of it. In many cases today, these things are more often closed sided, often with viewing ports, and sometimes with available access doors along the sides for certain observation and testing functions. The use of these in other than ambient conditions is usually very difficult.

The quantity of sealing with the method that would have to be used to support the covers that you would use on there tend to argue against a very significant pressure difference between inside and outside. However, the argument there is pressure differences or a matter of quality rather than significant quantity in many cases. What is considered a big pressure difference of 20 or 30 inches of water in some conditions is relatively minor compared to vacuums that could be generated in other ways. So, something that is fan induced that tends to stay down in the less than 1 to 1.5 psi range would be fairly easily taken care of under conditions like this in order to use an under-induced flow condition. Anything higher than that would be very difficult to maintain because of the structural design and the number of sealing points that are required in order to protect this against incursions of unwanted gas or airflows. Of course, if you're using a specialty gas for the drying function, then any in-mixture of air, particularly air with humidity in it, might have a significant effect on the materials that you're processing and the drying rates and performance that you're looking for.

A continuation of discussions of materials like this from a drying standpoint would include the use of vented extruders for this drying function. The various methods of heating the extruder screws and barrels are all available, along with the temperature control required there. Although, in this case, you would have the opportunity to use some significant pressure differences for some of the processing. The heating that would be done in the early portion of the extruder, prior to the vent, would allow you to achieve some rather significant temperatures or pressure conditions to separate the feed from the venting operation.

Of course, you also have the opportunity of enlarging the size of the vented area. This would allow plenty of space for devolatilization or removal of the material being processed before it is picked up by the discharge portion of the screw. It would then be forced out through whatever discharge mechanism, whether it be onto a very simple separation for recovery of material in bulk or in passing it on to either a sheet or rod type extrusion, or possibly even pipe extrusion, in order to be able to get a particular quality of material passed onto the final formation stage.

Vented extruders bring in several of their own particular requirements. One of those being the need for significant thrust bearings on the drive because of the pressures that are created in moving the material out through a die block, but this is a typical function of extruder design and development. Something for a first time buyer to be aware of is that there are heavy forces that force back through the screw shaft itself and toward the drive mechanism. This must be significantly supported by a bearing arrangement so that it is not pushed on through into the drive assembly itself.

The vents on an extruder are something that can be controlled from a pressure or vacuum standpoint. It allows the continuing concentration and handling of primarily the removed material with very little in-mixture or admission of additional carrying vessels. So, the processing, recovery, or vented air treatment ends up becoming much more simplified because of the lower volume.

This also can lead off to a very significant vacuum condition. The actual vapor conditions in the vented portion of a screw extruder can go down to very low pressures. They quite often get down to one or two inches of mercury, often even less, in order to be able to get good separation and removal of any organic or other materials that would vaporize at low-pressure conditions. Of course, this would then feed off into a typical vacuum handling operation, which will not be addressed here, but that vacuum could be supplied either by dry type vacuum pumps or liquid ring vacuum pumps with all of its attended operating requirements. This type of processing usually provides a fairly good opportunity for recovery of the vented liquid, if that is of value. Also, recovery and collection in order to remove it from the vapor discharge stream, which would definitely be of value in a permitting process and the waste discharge requirements of permitting.

The next classification of dryers to be discussed is flash dryers. A flash dryer, in my definition, is one in which the material is quickly introduced into a relatively high velocity air stream for the conveying of the material through the dryer chamber. This is done with relatively high velocity and relatively low concentration of solids in the carrier gas stream. Then, the immediate discharge is into some kind of a separation and recovery of the solids.

Heating methods and so on would be items of discussion. The first area is the understanding and discussion of how to enter material into a flash dryer. Since the material is usually moving into a relatively high velocity gas stream, the venturi effect is usually of benefit to the feeding. The feeding can be done in either of several ways. The first, and I think most typical, would be to use a screw conveyor of a material that is relatively easily fed into the high gas stream, then using the venturi effect to continue to draw material into the dryer chamber. A second way that can be used is a relatively high velocity jet of air and actually use a venturi type entry of the material into the carrier gas, essentially injecting or blowing the material into the drying or carrier gas stream.

One of the conditions that is pretty well indicated by our discussion here is the idea that the material entering the chamber should be relatively easy to separate. It should be something fairly granular in nature and relatively loose as it enters the dryer so that the drying can be affected in this dilute phase operation. Another matter of concern is the moisture level or contamination level of the material as it enters the dryer. A flash dryer is usually, as indicated by its name, something that operates on a very quick basis. Usually, it is not very long or large and, therefore, the removal of the liquid from the solid should be affected in a relatively quick manner. In this case, some testing and verification is probably a very worthwhile first step. People who manufacture and use these dryers on a regular basis generally offer that kind of assistance.

Some other critical aspects of looking at material for this type of drying is the idea of thermal stability or potential degradation—anything having to do with temperature effects on the material in one way or another. Then there is the beneficial situation that since the drying is affected usually in a very quick manner, the drying temperature quite often can be very low at the solid surface itself because of the evaporation latent heats, as we discussed earlier. Therefore, thermal degradation can often be avoided, but the balance must be investigated and seriously considered as this type of dryer is affected.

Another aspect of this type dryer is the recovery of the material after it passes through the dryer. A very simple method of recovery is a cyclone separation of the solids once they're in the dried state. This suggests very strongly that the material is thoroughly dried as it is removed from the dryer so there is no clumping or coating inside the cyclone itself. Also, there is the potential for a secondary cyclone separation and possibly some sizing, if that might be appropriate for the material being handled.

The final processing of the off gas is through a bag type dust collector for ultimate recovery of solids and ultimate removal of materials that might be discharged in the atmosphere. This is something that would often be required by the off gas discharge treatment permitting and investigation procedures that would be involved. In most cases, with this type of drying, the temperatures are low enough that special bags will probably not be required, except for a little concern during the startup period. So, there might be some consideration of putting in a dilution air capability just ahead of the bags for those startup conditions with a temperature control to protect the bags. Once the actual operation is begun, something in the neighborhood of 200 degrees Fahrenheit would probably be the maximum that would be achieved for most of the gases in a water removal condition due to evaporation temperature of the water. Certainly, other liquids and carrier gases, if they would be used, might present an entirely different set of conditions. Those certainly should be considered and investigated as the drying process is being considered.

In providing the heating activity for a dryer like this, the inlet air could either be forced or induced draft. Generally, I would think that the flash type dryer would be most effectively done with a forced draft type flow as the primary motive source and possibly an induced draft on some of the recovery and separation equipment for convenience and assurance. However, the primary efforts would be handled by a fan feeding air or carrier gas into the system. This would also provide the motive power for moving the gases through some kind of heating mechanism.

A very simple situation would be to go back to the idea of a closed dryer and an open flame very efficiently heating whatever the carrier gas stream is. The flame would generally indicate the use of air for the oxygen content and some other activities that would be appropriate there. However, the air could also be forced through a series of steam coils. In that case, it would be very appropriate to consider putting inlet filters on the fan to assure that the steam coils are not blocked or covered with any materials that might be extraneously picked up in the air. Also, the coils could be hot oil heated or possibly even with electric resistance heating. Although I'm sure that we all recognize that is a relatively inefficient way of doing it, it would still be a very effective and easily controlled method of supplying the heat to the carrier gas stream.

Airflow and pressure drop through systems like this are usually of some significance. As I mentioned before, usually the entry is in a reduced diameter or venturi type section. The reduction in diameter at that point generally causes some increased pressure drop. As the expansion and drying occurs, the combination of cooling affected from solvent recovery and reduction in volume of the gas would generally indicate that velocities could be kept constant or relatively uniform through the processing system. The entry area of the solids pickup venturi area you would certainly want to be a high velocity arrangement to be assured that material was moved through the system and not left to accumulate within the system.

Materials of construction are also something of interest in the flash dryer since the velocities of the gases and solids are fairly high. Some consideration of erosion is usually of importance. Therefore, materials that are used should be appropriate to the quality of the solids that need to be handled and the potential for the erosive conditions that could exist should be recognized, depending on the solids themselves.

From an operating standpoint, one of the key items of concern for this type of dryer is the caking or buildup of solids within one of these units. All of our comments before have been aimed at the idea of being assured that things like this don't occur. Unfortunately, we cannot always be assured that they won't. Therefore, several things are significant to think about in making this selection. One is if the material is relatively dense in the carrier stream, the potential for some kind of caking, buildup or other problems may be increased. Usually, something in the way of 3 to 5% of solids in the gas stream is probably typical for this type of dryer, possibly even somewhat lower. Generally, if it got any higher than that, I think you'd find a bit of a problem with the power supply and the fan supply. Then, you would essentially be moving into another type dryer that we'll discuss later, the fluid bed type dryer.

Caking on the walls is a matter of interest and insulation of the walls is probably something that would be used in order to prevent or mitigate some of the potential for that. A warm, dry surface is much less conducive to condensation and caking. It may even be appropriate in some cases to heat trace or wrap the walls in order to maintain a given temperature and be assured that conditions like that do not exist.

In some cases, the lower cone of the dryer as the air expands from the feed venturi section is provided with some working ports through which small scrapers, or something like that, can be used in order to check, prevent or reduce buildup. This, of course, leads to the question of some relatively large sized materials possibly being carried up through the system and needing to be separated from a more uniform product stream that might be desired. If size variation is not significant, then the large particles could pass on with whatever product stream or separated solid stream that you're looking to achieve.

One thing that this type of dryer often lends itself to rather readily is an understanding and a potential measuring point for efficiency and performance of the system. With the cyclonic separation that is most often used in the discharge from here, or even from the bag discharge, a method of weight discharge from the collection hopper, underneath either the cyclone or the bag house, can be used to assess and accumulate quantities of materials passed through. This can also give some indication of overall equipment performance, as well as a measure of production capabilities used for the system.

Instrumentation, controls, and monitoring of a system like this are usually very simple and easily applied. A few temperature measurements with some injection bulbs and some awareness of pressures within the system are all very easily achieved with instrumentation available to us today. Certainly, one of the things that is a real benefit here is the idea that most of the pieces of equipment are relatively stationary, save possibly the feed screw that might be used. So, sealing is less of a problem than with a lot of other pieces of equipment. Inlet leakage of airflows is usually greatly reduced generally because these things are relatively higher in pressure, although only a few inches than ambient airs around them. Of course, observation of outward leakages are very easily observed and fairly easily corrected in most situations. Again, the benefits of a solid piece of equipment and solid system like this reduces many of the concerns about possible extraneous airflows that could be a problem for the process and permitting and lead to material losses and control problems.

We are now at the end of tape one, side two, of the program “When It’s Drying Time Again,” a discussion of variety of solids drying systems and processes as a three-hour PDH course.

Tape 2 – Side 1 (disk3- track 1)

This is the beginning of tape two, side one, of the three-hour Professional Development Course, "When It's Drying Time Again."

We continue with our discussion of dryer types and begin discussing now a very reliable type of dryer. It is one that has become the workhorse of many industries and that I particularly favor in many ways. That might be obvious in some of the discussions we have later on, but I will admit it upfront.

The dryer type we're going to begin discussing is the fluid bed dryer. Fluid bed technology has been spread into many areas of process applications, from the combustion of coal and boilers through off gas processing for removal of materials from gas streams and additional catalyst processing to fluid catalytic crackers and all of the attendant recoveries that come along with using that kind of technology. That it moved into drying operation is kind of a fascinating couple of steps. Early in my career, I was exposed to several applications of fluid beds. I've found them fascinating and have used them in a number of operating conditions since then.

Essentially, fluid beds can be used either in a vertical or horizontal condition. The horizontal conditions are often vibrating type conveyors and have some unique characteristics. One of the key factors of horizontal beds is that the connections to the bed itself generally require some flexibility since it's in a vibrating condition. This brings in the question of sealing and reliability to prevent dust losses or other extraneous losses. Since they are a vibrating type bed, they are usually operated very close to ambient conditions. This means that feeding is nominally fairly easy and that pressure drop is usually very low for any movement of the material through the beds. It also means that the bed is part of the process of moving the material itself.

One of the special requirements of this kind of operation is some protection against dust loss at the discharge. Of course, there are some particular or special requirements at the discharge to help seal and provide an exchange of packaging units, on occasion, or a transfer out of the vibrating conveyor, which allows a sealing of the discharged solids to reduce the quantity of extraneous air that is brought into the system and has to be further treated. The inlet has somewhat this same condition because the ideal situation would be that all of the carrier gases or air that is used for the drying operation should indeed come in through the lower section of the bed and be used to pass through the material.

A particular benefit of the horizontal type bed is having a very close control of the bed depth. There is also the possibility of a very favorable control of the processing time. This is possible sometimes by creating small dams in the processing beds or by just making the bed a little bit deeper, but you can generally be fairly comfortable with the idea that flow through the bed is relatively plug-like and uniform. The material, as it is fed, has a reliably consistent time of processing through the bed to the point of discharge under normal operation.

One of the possible detriments of this type of operation is the unit is fairly large. It takes some considerable coverage with equipment, ducting, and hooding, in order to be able to connect to it. You must also allow for the vibration that occurs in the horizontal type bed for the transfer.

That’s usually done with a flexible joint of some kind, but depending on the quality of that joint, there are some provisions that must be made for the transfer of energy that occurs through that type of connection. This is true with the inlet air or whatever carrier gas might be used.

Normally the materials that would be fed into a situation like this would be fairly easily flowing, fairly uniform, and easy to distribute as they’re fed in since the only separation capability that exists within the unit is the vibration of the bed itself. Of course, you would want something that would separate fairly easily as it processes so that the drying could be uniform around all of the materials. It has some limitations from that standpoint, but the processing temperatures are fairly easily maintained and created.

You do have the operation possibility of several different drying zones and areas. You also can get into the situation of creating separations of takeoff zones so that you could have different kinds of processing gases in different sections of the dryer bed with relatively minor leakages between them. As we’ll discuss with all fluid beds, there are a variety of distribution mediums that could be used for the carrier gases as it enters. We’ll cover that a little bit later in our discussion.

The second type of fluid bed that can be easily found in many processing operations is a vertical type, which is usually a vertical cylinder. In some cases, it is a box-like structure, but cylinders are a little more typical of the operation. Under the condition of using a cylinder like this, quite often there are considerable bed depths, sometimes up to 10- and 12-feet, that are carried in these beds. For situations like this, depending on where the feed of the material starts, there may be in various ways a problem of overcoming a pressure differential in the bed in order to get materials in. This is quite often where special type feeding comes in. Again, we could go back and review the idea of screw type feeding, venturi injection feeding, possibly several other varieties, and possibly even a rotary valve type feeding of a limited discharge length if you’re assured that the material would enter quickly into the bed itself. Elevated pressure at the feed point would require some method of sealing and anyone of those types of entry techniques could be used.

A very typical aspect of a bed like this is that material is entered in one place and it is taken off in one place. Everything within the bed is considered relatively in process. The flow and mixing conditions within the bed are a matter of some concern and interest. With the larger beds, there are possibilities for flows within the bed itself, a circulation type flow. This can be an advantage or a disadvantage, depending on the material being handled. If it is heat sensitive or time sensitive under temperature, the internal circulation flows might be something that would be undesirable. Situations like this can be mitigated to some extent by creating a flow path or forcing a flow path within the unit itself. This can be done in several ways. Sometimes with vertical baffle separating so that there is an up and down motion of a plug type arrangement in a consistent bed. More typically, it is done by changing the size of the bed so that the flow is a little more uniform, although it might end up being deeper or done in several stages in order to achieve the time/temperature conditions appropriate to the materials being processed.

With the vertical bed, there is the next stage of concern and that would be the removal. Removal could either be from the top or bottom of the bed as the feed could either be above or below the bed itself under the conditions that we discussed earlier. Generally, you would find that the removal would be from an upper area after processing. Also, the bed would be sized in order to be able to create enough retention time for drying for whatever bed depth and material flow rate that is selected for the system.

Some special conditions of dryer removal might also exist. There will indeed be some pressure for the after processing of the gas that will have to be recognized. So, situations of discharges into vessels with controlled discharge rates and discharge into screws that would act as a seal for the material would bring in the question of making sure that there is either a long enough screw or a screw with possibly some vertical lift to it. This is so that the material does not fluidize very quickly through the screw because of the gases that could leak out and vent that way and continue blowing the material out after the screw has stopped, which is a rather typical problem with this type of processing.

Heat sources for fluid beds go back to the variety of things that we've discussed before. If there is any concern about fire, fire hazard, or such safety as that on the incoming gases, something in the neighborhood of a steam or hot oil type inlet control, possibly even electric resistance heating, could be used on the carrier gas flow that is pumped into the fluid bed. Certainly, a separate chamber direct gas inlet can be used. I am certain that under specialized conditions it might even be appropriate to consider a submerged burner inside a fluid bed with enough airflow to create the fluidization. If you're dealing with a material that requires considerable water removal and can withstand the relatively elevated temperatures of some possible direct flame exposure, it could be a very efficient and effective way of heating the carrier airflow being used. However, it might not be appropriate for some other gases that would be used that way.

Temperature control of the gases going in and coming out of a fluid bed dryer is fairly easy to arrange. Monitoring units in a uniform gas flow are generally a fairly straightforward and direct activity to instrument. Of course, the information from there can be used fairly simply with any type of control system, whether it be trapping the steam, direct supply of the steam, or other variations on heating that might be used for those conditions.

We've discussed previously the idea of feed and discharge conditions for the fluid bed. Certainly, this does bear some repetition and additional concern. There is always the question of determining what pressure you would work against as you're creating the feed and discharge conditions. This would be to make sure that you can modify and control these, prevent them from creating dusting or material loss problems, and prevent them from creating vapor losses that would add to any environmental conditions around the operations. You would certainly want to have treatment systems to be able to take care of whatever flow conditions exist. There will be some further discussion of that further in the tape.

A key area of operation for a fluid bed, particularly the vertical fluid beds, is the stability of operation of the bed itself. One of the conditions that has been investigated in many ways and under many conditions is the idea of what happens within a relatively deep bed. Beds can operate in any condition from a relatively uniform and stable bed that seems rather uniform in conditions. This is because the material is being processed to a situation where there is, as it's often referred to, a spouted bed where there is a simple gas flow that tends to create a circulation flow within the bed itself, but it tends to concentrate in one given area. Either one of the flows may or may not be desirable in any given operation. The question is your material, the investigations, the processing uses that you are aiming for, and the concerns and things that you can do to improve or change that.

Several publications over past years have looked seriously at the idea of what happens to bubbles of carrier gas as they enter the bed. Quite frequently, one of the things that we see very definitely and is easy to both calculate and observe is that a bubble will move through the bed and, because of the continuing changes in pressure, will continue getting larger as it moves up through the bed. So, at some point, it will either collapse and create a rather violent operation within a certain section of the bed or pass all the way to the surface where it may explode in a minor way and throw material very high into the air, possibly overloading an off gas system.

I have included with the paperwork that comes along with this tape, a one-page demonstration out of one of these articles in a publication on fluid particle technology of some years ago. It discusses that the bubbles can grow in accord with what is called the Fibonachi series. This is really a geometric progression series that is fairly easily demonstrated on the chart that's included.

For certain materials, these bubbles will tend to be broken up in the processing. Under those conditions, you may or may not have a question of changing or being concerned about bed stability. If you do have that kind of a bed and it runs relatively quiescent, then the only question might be if there is an internal circulation that needs to be considered.

At this point, one of the things that is appropriate to review is that there have been a number of occasions where fluid beds with unusual processing conditions have been stabilized in a variety of ways. Leva, in his book on fluidization that came out in the early 1960s, discussed very briefly the use of a number of items that could be inserted into a fluid bed chamber that would help improve the uniformity of the bed conditions and possibly even affect and improve the passage path and times of the material going through the beds. These have various reasons to consider or suggest them for any given operation and I would strongly recommend a review of that text to consider whether that particular kind of stability enhancer would be appropriate for your bed.

One of the things that I would very strongly recommend in many beds is the consideration of using a very straightforward and simple way of doing this and that's putting transverse screens into the bed. Generally, it's a good idea to use a screen with an opening that might be 50 to 100 times the diameter of the particle in order to offer an improved assurance of no blinding by the particles as they pass through. Something like this in the bed breaks up the bubbles, helps recreate the bed quite regularly, and improves the stability and uniformity of flow and the flow path through the bed.

On occasion, it has been suggested that the use of additional vertical surface would help this. My general view of this has been that the vertical surfaces are of interest and they do help recreate smaller and smaller beds. There are many points of discussion that would have to be seriously investigated to be assured that this would be an appropriate consideration for your particular operation. Quite often, as vertical surfaces are added, the method of addition ends up cutting down on the cross sectional flow of the bed and you end up creating a more frequent small spouting type bed, rather than a nice uniform process fluid type working area.

Certainly an item of significant interest in the fluid bed is the distribution of the carrier gas that is entered into the bed itself. Over time, there have been a variety of things used to do this, including very specifically designed nozzles, which are sometimes very simple in structure and sometimes relatively complex, trying to create a uniform distribution of air across a given plate area. Many times, the nozzles are almost reminiscent of bubble caps or valve tray caps from distillation columns. These can work very well, but they offer the potential for backflows, plugging in certain areas, and mechanical variations and difficulties related to those. However, they do offer the advantage of not needing to be very careful about the inlet gas flows, depending on the size of the actual orifice used in the unit itself. Quite often, they can be used for processing relatively large materials with an ambient air. Something that might function like this would be the drying of commercial sand that might be used for road operations. It's very simple, straightforward, and easy to maintain, and not much treatment is necessary for the incoming air.

Another function that is often used for the air distribution is a relatively fine mesh screen with suitable support, which is sometimes above it, but definitely below it to carry the physical size, and something that is strong enough to take whatever typical pressure drop. The openings in those screens would be a measure of the quality of the air treatment that would be necessary for the entry to the bed. Certainly, something in the way of a filter on the inlet of a fan or even an intermediate filter between a fan and a heating medium system might be appropriate. If you are going to the trouble of doing a cleaning of the air as it enters into the system, I would strongly recommend that it be cleaned before the heating medium in order to improve the long-term operation of whatever that heating mechanism might be, whether it is extended fin tubes, the direct flame inlet, or some other processing. Cleaned air will generally help things operate more reliably for a longer period of time.

Another material that is often used to help with air distribution is a cloth. Generally, this cloth would be relatively thick because of the support requirements of material laying on it if it comes into a quiet stage or a shutdown period in the bed. Whatever cloth that might be would definitely need some sort of under support to carry the weight of the bed under any condition in which the carrier gas might be stopped and would then settle back down onto the bed, depending on the depth, the bulk density, and the specific densities, of the material being processed and the potential for a pressure increase and development on the top of the distribution plate itself.

At this point, assuming we have found and selected an appropriate method for putting material into the dryer, we've selected the configuration of the dryer that satisfies us, we have an appropriate material for air distribution, we have support as necessary for the material in the dryer, we have made a decision as to the path of flow of the material within the dryer, we have the conditions that we're looking for in processing, proper depth, an appropriate time to be in the dryer, and that we can reliably achieve a dried material and discharge it in a safe and effective manner for recovery and continuing processing. The only thing we're left with is the treatment of the carrier gas itself.

In prior dryer discussions, we have addressed many aspects of this gas treatment. Certainly, the fluid bed dryers have all of the same conditions. So, the variety of things that can be done with air and gas flow treatment are appropriate to consider. First, is it of value to attempt to recover anything that might be contained within the stream itself? Passing the off gas through condensers and recovery mechanisms of all of the types and arrangements that we've previously discussed, including specific condensers, final vent condensers, relatively high vacuum treatment in order to be able to get that specific cooling in order to recover materials, any particular type of filtration, and the recovery of materials related to that out of either dust collectors or other arrangements. Certainly, taking part of the material as a side stream, possibly recycling it, if it is appropriate, might be something that would be considered for this kind of operation. Since it is a continuous process, some heat recovery of the gases as they discharge could be valuable in relationship to incoming air, particularly in colder climates. The operation of these interchange arrangements have to be investigated depending on the materials being processed and the materials of which the interchange could be made. Again, with the amount of energy that is put into the processing of the air or carrier gas as it goes in and goes out, does suggest that this kind of gas treatment would be appropriate in some situations.

Certainly, some kind of separation or filtering seems to be appropriate to talk about on all of these conditions. Off gas temperatures will dictate the type of bags that might be used or other aspects of the filter medium. The dust loading and particle size and velocities of the airs that pass through should be seriously considered and determined in order to achieve the appropriate selection of dust collector types for the removal and recovery of materials, rather than venting them and creating the difficulties that that brings.

If it's a forced draft system, the fans themselves generally with both of these systems, you're going to end up with a combination of forced and induced draft. Forced draft in order to be able to get the carrier gas through whatever heating mechanism is required and into the actual processing. Then an induced draft to get a balance on the system and appropriate carrying capacity to pass through whatever treatment and post bed handling that would be required for the continuing operation.

I've suggested before that, in some cases, it might be appropriate to consider liquid ring pumps for those areas where there is a great deal of vapor. This might be a way to reduce the actual quantity of gases discharged into the atmosphere by recovering a relatively large part of water vapor in a condensed portion. This would give you something a little bit easier to work with from a treatment standpoint.

Materials of construction would be an item of interest with these, as well as with most any other type of bed. Certainly, from a cleanliness standpoint, one generally drifts towards the stainless steel as a reliable way of handling this. Since most of these beds operate under relatively low pressure conditions, a thin wall stainless steel would probably be appropriate. In other situations, if it's handling a large or very dense material, something heavy might be more appropriate. Again, with many operations, if the material is to be used in rather rudimentary fashions, steel might be an appropriate consideration. Under the conditions of drying, the material inside would generally not create a great deal of rust or water effect on the steel simply because of the quantities of materials and the relatively low vapor concentrations that you might expect under many normal operating conditions.

In terms of air discharge treatment, there are a variety of scrubber type arrangements available for recovering and treating off gas systems. Quite often, these are used for a variety of functions, as well as basic treatment, cooling, or recovery of some materials in an off gas stream. They might be used as a method for eliminating any hazardous vapors or gases that might be carried in the off gas stream. This would give you the opportunity of using something that might be a light acid or caustic scrub for treatment of those off gases before they're discharged into the atmosphere.

For some materials that remove from a solid in a drying type operation, it might also be appropriate to change the condition of the off gas material in one way or another. It would also be appropriate to either recover it for processing in other stages or to use it as a way to transfer it into a stream that might be more easily processed or that might mix or coordinate with other discharges in the plant and reduce what has to be permitted as a vapor or gas discharge from a processing unit.

Generally, in any of the drying operations, the quantity of gas flow that occurs will certainly require a permitting operation. With the materials being processed, there will always be a variety of things to consider as concentrations in the off gases. Therefore, the permitting and the development of the related information can be rather complex. All of the off gas processing streams, whether it be scrubbers, cyclonic type separation, or filters, will have an efficiency concern that would be appropriate to address from the standpoint of permitting.

Of course, in all of our conditions, we do like to get down to a very low dust quantity in the discharge gases to prevent plumes and inadvertent discharges of materials. Also because we're always approaching the condition that material in that dried state is generally one of the most expensive and the closest to be sellable of any product that is developed in the plant. So, recovering it in that particular condition gives us a chance for at least the accumulation and holding of our most valuable product. If some minor reprocessing is necessary to recover it in a given physical size, we're in a much better condition to do that with a clean dry material than we are in many other conditions through the plant. So, the investigation, knowledge, and understanding of the off gases would be very important there.

We've discussed the idea of incoming gas treatment and cleanup. Although a seemingly expensive thing to do on the inlet, this can often be of advantage to us on the discharge. It would reduce the unknowns that might be in the discharge gases as we pass them on to some kind of a processing or treatment condition for discharge.

At this point, I'm going to beg your indulgence for a moment and return to the topic of air distribution. I would like to add to the comments about distribution medium a few words having to do with another specific variety of distribution. This is either a ceramic plate with relatively finely divided holes or a centered powdered metal plate with finely divided holes for distribution. One of the things that we tend to consider as we look at using this type of distribution is that the more we can distribute very small bubbles into the bed, the more reliable we can make the bed in its uniformity of agitation. One of the fallacies of this is the idea of the material itself and the fact that after the carrier gas passes through, whatever is used for a distribution medium going in, these bubbles can coalesce again and then begin to grow and become the spouting type bubbles that were mentioned earlier, whether it's ceramic or metal.

Certainly, these types of materials are very reliable and very good in many circumstances, but they will generally also require that some considerable pre-treatment of the incoming carrier gas or air be provided in order to prevent the plugging of the relatively small holes in the ceramic or porous metal materials. This same thing is somewhat true with any cloth that might be used. Certainly, the specific variety of weave that would be used on the cloth would have an effect on that. These materials can, of course, be changed out, but in any given bed situation, the draining, the removal of that bed, the modification of the materials inside, the cleanup, and the preparation of workers to enter and remove it, are all things that will add to the cost and problems of working with a special distribution material that is used simply because we think it's an improved way of feeding the bed when the actual operation does not require anything quite that complex.

Now, going on to a final item of consideration for the beds, and for any dryer system to an extent, is that there should be a very certain and reliable method of access to the bed for removal of the material if it should come to a need to take this out. Certainly, large chambers or large openings at the bottom of the processing chamber are a very simple way of removing the materials. However, as you consider the idea of removing the plate to do that, it now becomes a matter of how big a plate you wish to put there and how big a condition you wish to create as you open one of these things. A relatively tall holding volume of solids is allowed to discharge into some kind of a collection condition. Certainly, if something is mounted on the floor, the collection and cleanup would end up becoming a bit testy for a lot of materials being processed. Of course, the potential loss of value for one of the highest valued product conditions that we have in any operating plant is something that we wish to avoid.

Although it is a truism of all processing, a bit of early consideration and analysis of what might end up being a potential problem in the future is something that can save an awful lot of time, money, effort, and psychological and emotional difficulties, as a processing is required later on. Again, something that can easily be used to help this circumstance is to look to the vendor of the various systems that you have, as well as anyone else you know who operates a similar or related type system in order to get a better idea of what handling and processing preparations and special conditions you might want to look for as you consider and look to change or improve any processing operation that you have using a fluid bed type dryer.

With this discussion, we will complete side one of tape two of When It's Drying Time Again, and begin the final section on the final side of the tape.

Tape 2 – Side 2 (disk3- track 2)

This is the beginning of tape two, side two, of the three-hour Professional Development Course, “When It’s Drying Time Again.”

The next type of dryer or classification of dryers and drying functions that we will discuss is a group of equipment items that I will refer to as augmented dryers. This is a system of equipment, or quite typically a single piece of equipment, in which several functions are blended together in order to achieve a mixture of processing steps, which are combined because of materials being handled. Quite often, materials processed in this way might be very high value materials where any processing step might allow a loss, leakage, or partial destruction of material. In other cases, it might be a material that is very sensitive to exposure to various gases, oxygen being a critical one. Exposure to air might create a slight oxygenation that might have an effect on color or processing. Of course, there are a variety of other conditions that I’m sure you can identify and indicate that might include this also.

This will also involve considering the several heat sources that are available for drying. We’ll touch very briefly on some of those. It would also include those functions where a processing and remixing is going to have to be done on several occasions in order to get a washing or further purification or clarification of the materials being processed.

One of the key pieces of equipment that might be considered in this range is the item referred to normally as a Nutsche filter. This is a closed container usually with a filter mechanism on the bottom plate into which material is pumped. Various processing methods are used to remove the liquid solvent and leave the solids on the plate, but in the casing there is usually a mixer or redistributor of some fashion. This allows the material to be turned over in the dry state to enhance its processing or to be re-slurried with a wash liquid or a further processing liquid that would be drained and might be repeated in several stages inside the same vessel before the material is transferred.

One of the things that are often considered in that kind of vessel processing is to add heat to the vessel itself. This quite often is done to the support plate for the separating medium, which could be a variety of materials from screens to porous metals and special cloths that are bonded into or onto the plate surface itself. Then, also, some wrapping of a heat transfer jacket of one kind or another around the main processing vessel in order to provide some heat to the vessel. Along with this, usually a reduced pressure vapor removal system is connected so that the material can be evaporated off of the solids inside. This becomes a very convenient way to do a more thorough drying for any of several reasons, one being because it’s a change in the liquid material that will be used for re-slurrying, washing, or further processing. There may indeed be other reasons why a vapor or vacuum removal process might be used in that condition.

One of the significant items of concern with this type of processing equipment is the type of heating medium. Often, hot oil is used. It’s very convenient, gives you a variety of temperatures that you can deal with, sometimes the jackets are wrapped with electrical tracing, and sometimes steam is used. There are a variety of things that can be done. Some newer pieces of equipment are actually suggesting that they can place within it an induction coil or radio frequency generating apparatus so that you could essentially be doing a microwave drying within the vessel with the processing. Sometimes there are additional functions that are added. The vessel can be rotated or inverted. Other materials can always be added in through separate nozzles. Of course, there are methods for removing.

With this type of equipment, quite regularly they are PLC controlled or supplied with programmable logic controllers. A very serious discussion is developed very early in the selection of this equipment to arrange a sequence of operations and to be able to control the number of steps or repeats of operations. So, the electronics and auxiliary pieces of operating equipment opening and closing valves, turning on and off mixers, setting the height of the mixer, controlling the mixer circulation rate, controlling the addition rates of liquids as they go in, and making changes on the vapor rates as they're removed, all become very important aspects of the development of a description of operation that is then used for making up a program to control this. It is quite regularly done on an automated basis. Of course, this is another one of the types of process modifications that raise the cost considerably and make them more suitable for very expensive materials to be processed and under very special conditions.

The basic items of sealing and the various shafts will usually be very specifically taken care of by the vendor or the developer of this type of equipment. One question that is usually left to the processing plant and leaving a continuing problem is the processing of vapors that are removed. We've discussed this in some our prior dryer types. Solvent recoveries, removal of organic vapors from atmospheres, and collecting and processing the complete flow rate of gases or organics that are removed, all become important considerations in the overall process. Quite often, these are things that also are added into the automated control scheme of the piece of equipment even though other pieces are supplied by the plant or other contractors in order to keep an overall uniform management of the processing stages through this type of equipment.

Amplification of this type of discussion should include comments that there are a number of equipment vendors who will prepare a basic vessel that includes a variety of methods of mixing, filtering, jacketing, either inversion or working control vessels, and so on, that combine many of these same functions in pieces of equipment of a variety of physical configurations and techniques for use. Any time that a piece of equipment like this is considered for further use and processing, this certainly is an area where some very specific testing and discussions with the vendors should be used, and possibly even a rental of a piece of equipment for some onsite evaluation and use with your materials and in your testing atmospheres. This generally provides a great deal of additional information that make its application a little more reliable when it's finally brought into the field and helps give anyone selecting this a much higher level of confidence as they move forward with putting these materials into any given processing stream.

A separate and further area of discussion that I've generally avoided in discussing the function of drying is the spray dryer. I will not try to address this on this particular tape, except to mention that this also, as with the augmented dryers, involves multiple processing activities within a given piece of equipment. Because of its specialization in devising a manner of feeding the spray development, of understanding the vaporization that occurs in the spray drying, of recognizing size control that quite often becomes specific, and the additional function of usually a much higher volume of carrier gas to solids that usually accompanies the use of this type of dryer, I very strongly recommend that any consideration of this type of equipment should be supported by some significant testing and evaluation with people who have the experience of manufacturing and developing this. These types of dryers, because of their general characteristics in most cases, tend to be relatively large and handle a very significant volume of materials. Quite often, this is a reason not to consider it for many specialty chemical development applications, but there are a variety of manufacturers of this equipment with range of experience in many materials who would certainly be happy to review with you any particular applications and help arrange particular testing for those applications.

I believe I mentioned earlier in the discussion of drying functions, particularly in the fluid bed dryer, the question of bubble development and stability. I wanted to make special mention that included with the paperwork with this tape is a chart that describes and gives some formulas for calculation of typical time and bubble growth rates that can very easily occur as a gas moves up through a bed of solids, particularly under fluid bed conditions. This recognition is something that can be a big help to you. Of course, to recognize the rapidity with which these bubbles can enlarge themselves can be very helpful in your understanding of why certain things are occurring in particularly a vertical fluid bed processing system. I hope that this is something that is of interest and value to you. Included with it is a listing of the article. I am including the information and some investigation of that article so that it might provide additional valuable information to you as well.

I would certainly suggest that the one who goes into the drying of solids, particularly in the use of fluidized solids, would consider making themselves aware of the book by Max Leva, Fluidization. This is a book in the McGraw-Hill Chemical Engineering Series that, while having been developed quite some time ago, still includes some valuable basic information and some discussions of early processing and investigations that could be very helpful in the overall understanding. I believe that it has been updated and revised in recent years by other people in further editions, but the basic information along with any additions would also be good.

The American Institute of Chemical Engineers also puts out several symposium series publications dealing with particle technology, handling, and sizing methods. These can also provide good additional information in your evaluations and understanding of fluidization, drying functions, and the processing and handling of solids.

Also for your reference and convenience, particularly because in many cases, people have the opportunity of using computers and the spreadsheet programs that often help with many calculations, it’s nice to be able to do a direct determination of conditions relating to drying. Therefore, I have included a copy of an article that discusses finding air properties quickly where some formulas are given. So, if certain pieces of data are available, namely wet and dry bulb temperatures, the calculations can be made very quickly to work into curve developments. This might save you an awful lot of investigating time in the field and data collection in order to get a better understanding of your process.

As is typical with these refresher reviews and courses, there is also included along with the tapes a questionnaire that reviews some general ideas that are presented in the tapes. This, of course, will need to be completed and returned to the course management group for you to complete the requirements for the professional training and receive the time credit for this drying course.

Again, I would emphasize that all of the information that's here is based on my experience and has a great deal of background based on my opinions of processing and how materials that I have particularly worked with were performing within these kinds of equipment. I certainly hope that this information has some value to you in helping you understand what can be done with the overall function of drying and what might be occurring in any particular drying process that you're investigating, using, or may require your attention.

There are a number of tests, samples, and observations that can be made at any given time that will help this. I have not attempted to identify these on each piece of equipment. Certainly, as you work in the field, you would have a much better idea of what you can do with your equipment than for me to try and offer a specific program. Again, my hope is that some of the ideas that are presented here will help lead you in the direction of solving any problems that may exist or improving the overall processing of any material that you're working with.

I thank you very much for your attention on this tape and look forward to the opportunity to possibly offering some suggestions for other processing on future tapes.