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Agitators and Mixers

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Professional Development Training Course for Registered Engineers

Agitators & Mixers

Tape 1 – Side 1 (Disk 1 – 01 track 1)

This is titled Mixers or Agitators. It is prepared for Professional Development credit for engineers for their annual licensing requirements. It is three hours in length and is being prepared by Ed Hardin, a professional engineer in the State of North Carolina.

Tape 1 – Side 1 (Disk 1 – 04 track 4)

This course is being prepared in essentially two portions. The first tape will deal primarily with the function of liquid mixing, which will principally deal with the mixing of water or light liquids with rotating devices. The second portion of the tape will look a little more to the inter-mixing of liquids and solids and some solid mixing, depending on the length of time available. Also, a portion of the second tape will cover the mixing of pastes, plastics, and possibly some mud or solid mixing, as is useful in feeding some processes.

Tape 1 – Side 1 (Disk 1 – 06 track 6)

The general areas that I will approach with this are principally liquid mixing. I speak of liquid mixing basically in a water or light liquid medium and exclude from this very high viscosity mixing, such as plastics and material grindings and some other activities there. Possibly another course might be appropriate for that sometime in the future. Generally, I'm also going to be talking about rotating devices, but not to a great extent about kinetic or inline mixing devices. We will not be able to address the specifics of power calculations and power determinations for mixers. Although, there will be some very appropriate comments about general power requirements for mixers as we move on through the history and the discussion of the systems. The principal purpose for preparing this tape is to discuss the variety of mixer applications that can be seen in industry and some of the reasons for the selection of one type or another mixer in a given application. It is being provided to you with the hope that these guidelines may offer some benefits to you as you look at operating mixing systems you are working with or are considering in the selection of a new mixing system.

Tape 1 – Side 1 (Disk 1 – 07 track 7)

The principal purpose for preparing this tape is to discuss the variety of mixer applications that can be seen in industry and some of the reasons for the selection of one type or another mixer in a given application. It is being provided to you with the hope that these guidelines may offer some benefits to you as you look at operating mixing systems you are working with or are considering in the selection of a new mixing system.

Since we have identified that our primary focus is going to be on the relatively light liquid mixing, the thing we have to recognize as the preeminent base for this type of mixing is going to be water as a continuous medium. Of course, water is something that we've all been exposed to and involved in for a long time. It is a very broadly used and very functional liquid for handling a wide variety of process requirements in the chemical industry. We can look at water as a base, mixing as an industrial function, and look around at a wide variety of applications.

Of course, the intent here is to suggest that even though something doesn't necessarily appear to be water-based, as you consider it, you will probably recognize that it is more water-based than is first obvious. One of the key industries where a lot of mixing is involved, and there are some specific requirements that will be discussed later, is paints and coatings, which primarily use water as a carrying medium. Although the solids loadings get very high and the viscosities do go up somewhat, they definitely don't approach the conditions of melted plastics, but water is still quite often the continuous medium in the mixing of paints. This is much more true today with latex paint bases, which use water as the continuous medium versus older times when a variety of oils were the continuous mediums, but even those are relatively light loading mixing functions.

There's a great deal of mixing involved in the polymerization industry, particularly solution and suspension polymerization where water is the continuous medium. So, we're essentially talking about water mixing. Water treatment operations, which has obviously much in the way of mixing in successfully treating that. Waste treatment, again, the same processing. Ore processing and much suspension of ores in liquid solutions where water is primarily used as a basis for passing them through sometimes dissolution, sometimes digestion functions, and also quite often over various separation methods from settling tanks to even as small as many of the little jigging presses that are involved. Of course, the floatation devices use that and, from a water standpoint, water borne ores are quite often put into grinding conditions of a wide variety, from ball mills, to rod mills, to other types of vibrating mill arrangements that use water as the basis for carrying materials through them. The mixing of various treatment and application materials, both before and after, to improve or recover the ore particulars.

Material preparations for processing often require a lot of mixing. As we mentioned in ore processing, mixing in materials as the ore goes into various grinders does enhance its separation as well as make it a little easier to process. Certainly things in crystalline processing, such as sugar, salt, and all of the variety of things there, do have a lot of mixing activities. Pharmaceuticals require a terrific amount of chemical processing that is the basis for pharmaceutical production. Mixing and agitator activities are certainly widely used there. Specialty organic processing, much in the oil industry, and adding materials to them, but these things, particularly for the oil industry, are tending to look a little more toward the static mixers and possibly even the inline mixers that are often agitator type units just mounted in the pipeline, but still a light liquid carrier.

As we mentioned before, there are a lot of mixing activities that are not going to be covered here. Those would include the mud mixing that would be used for brick making. That usually gets into a very pasty, thicker material and a whole different type of grinding. Some requirements of

ceramic mixing are typical to some things we'll talk about later one, but we won't address ceramic mixing. Also, things like iron, steel, and the processing of molten metals and electric furnaces, which is an entirely different kind of mixing and not necessarily those kinds of functions that we'll be reviewing. These solid mixing needs are similar to the background of much of the other types of mixing, but have an entirely different type of requirement.

I'm going to lead into further activities on the agitators and mixers by looking at the history. We've gone through the discussion that there are many industries in which mixing is a key function. We can look back at much that we know about mixing and say that it was developed out of some of the old alchemical and natural processing things that were done by agrarian societies as they developed through time. A very significant thing about mixing, and leading into the selection of mixers for industrial applications, was the recognition that a gear drive could be used to control speeds and provide the power into a mixing device. There are a plethora of manners in which gear drives are used to direct mixing and make that transfer of power from a driver of one kind or another to a shaft that controls a mixing element.

The development of the mixing industry parallels the requirements of agrarian activities and early alchemical processing and laboratory processing. Everyone tended to use the similar kinds of things as activities started. Of course, there are the many anecdotes of the fellow who started a chemical business with a 55-gallon drum and a canoe paddle. Those types of mixing, while often practiced in times past, became applied around industrial activities, mostly from the standpoint of needing some mixing, knowing that it's been done in this way before, then making a mixer work in a new application.

It took some time for a development of applications of other mechanical methods of providing mixing to develop in industry. Many of the early mixers were very large paddle or driven materials of various kinds and, while for light liquid mixing, things like anchor agitators and some other sweep mechanisms are not very often used now. They were originally and then we started moving into other things as propellers became popular for maritime applications. Their transference as small sized units into functional mixing apparatus also developed. Then the mixers themselves started working down from very large paddle type bases to turbines and then on into the more power-efficient units that are available today.

One of the things that we have to recognize in mixing is that we're dealing with a very difficult to define requirement. Mixing to many people means a lot of different things. To some, it's just enough to be able to get a uniform condition where uniform is a very difficult to define requirement. One thing that's kind of fun to look at from that standpoint is the very popular baking mix that's out. They talk about mixing dough for preparing a bread-like product and they actually state on the label not to mix it with more than 12 or 13 turns of the spoon or you will over mix the dough and it will not perform properly. Well, this is also a little like what we get into with liquid mixing.

Sometimes all we're looking for is just enough blending or combining of materials to provide a relatively similar amount of materials passing down through a pipeline that will then allow later processing. Often this is involved in multi-phase situations where we're specifically looking to get the same quantities of different materials to further processing with a minimum amount of

energy involvement. Sometimes this is done on a continuous basis and sometimes it's just done by putting different quantities of material from different pipelines into a common vessel and then doing a little bit of mixing as some of the processing is started.

Other aspects of mixing from a statistical basis then start becoming more and more important. It is more significant to get uniform mixing when you're dealing with the processing of something like a suspension polymerization. The reason is because you're looking at maintaining a relatively uniform particle size during the agitation function. You're looking at making sure that all of that material passes through all of the system with uniform distribution within things like the catalysis that is initiating the polymerization. Of course, keeping it from agglomerating so that you don't get hot spots inside and color arrangements, but we are now moving on up the scale in terms of uniformity.

Passing a little bit farther up, there are things like manufacturing latexes. The mixing function, as well as other things, helps provide us with a basis of maintaining a uniform particle size that is critical to the quality of latexes as they move forward. Then, we begin moving into things like plastisols, gels, paints, and other things where, when we speak uniformity, we're truly speaking of being able to take very small samples and still acquire and achieve the constant analysis. Also, a very smooth or easily spread condition so that when we mix these materials and put them into use applications of various types, we can get the same kind of condition throughout the mixture as we move forward with it. So, our requirements for mixing definition start changing as we move into these more critical product application conditions.

Often, product requirements dictate these improved definitions or requirements for the mixing. Paint spreading; glue uniformities for liquid glues in order to be able to get consistent performance; adhesives that might be applied to any kind of material; and the coatings that we see now on papers for printing labels that go through the computers. All of these things give us some different definitions of the uniformity of mixing and the specific affects on the statistics and the statistical sufficiency of the mixing.

Of course, in order to achieve a lot of these things, after it goes through the process and our various preparations and transfers, the final situation is still a filtering to attempt to remove any final particles and other things that might have an affect on the consistency of the surface or the performance of the material as it's used. Even though we go through some rather strenuous exercises in order to get a consistency of mixing, we still must treat products as they pass on to the next stage very carefully.

I've made reference to past practices, alchemists, or past exposure in traditional applications of types of mixing things that have died very hard in the mixing industry. They are still around. Many types of mixers that were formed for a particular application have been stretched, squeezed, modified, and so on, to try and make them applicable to another process where another mixer might be more easily applied and more effective in its use. However, we see this as a competitive situation in the industries where many times somebody starts making something in a particular way, they get success with it, and move forward. Then, somebody else comes into the same or similar business using an entirely different mixing situation. Their processing is either better or worse and they either survive or die along the wayside. So, we continue watching the

ideas of mixing and what happens to them. However, some old ideas that are still around may or may not need to be completely discarded. Certainly, certain types of very high energy costs, mixing activities, and multiple shaft mixing arrangements on low speed and high speed anchors that might be used in some moderate to low viscosity mixings, may or may not continue to be appropriate because of the cost of development of things like this.

There are a couple of other things that might follow along that line that would be appropriate to discuss. For this you might want to begin looking now at the several pages of mixer design and configuration ideas that go along with this tape. A long time ago, there were many situations where they would put what was called a stabilizer ring on the bottom of high-speed propeller mixers used in small to moderate sized tanks. Essentially, this was just a very smooth, flat cylinder that was bolted or welded to the bottom of or outside edge of an agitator blade. Because of the flat outside surface of the cylinder, the cylinder acted somewhat as a liquid bearing in order to be able to prevent some of the problems of agitator shaft conditions going up and down through speeds.

Quite often, the reverse of that has also been done. In some situations, actually bottom entries, people have worked very hard to put center bearings and bottom bearings on shafts in order to maintain their position. Of course, all of these things can add to the complexity of the vessel that's being designed as well as add to the maintenance and process affect consistencies of working with mixers. If a top-entry mixer has a mechanical problem, it's quite possible that in a reasonable period of time, an agitator can be lifted, drives and so on removed and changed, a new one put on, the material in the vessel still processed and kept in statistical and practical process parameters, and an effective product made. With something that goes into the bottom of the vessel, you're generally forced into the situation of having a secondary vessel nearby to be able to transfer the material out to change a mixer. Often, a situation of vessel entry might be required. So, the time between changes becomes significantly different.

Generally, we find that agitators in industry in moderate to large sized tanks are usually placed on center shafts. This generally is not a very effective way of using a propeller type mixer, even with baffled sidewalls, because a propeller tends to move materials more up and down the shaft rather than radially. Usually the center-type mixers are of a different design and quite often went into the turbine designs.

There have been articles around that the designs of the bottom of the tank could have an affect on mixing. Quite often this had to do with solids-liquid mixing in an attempt to provide a filled-in space to prevent solids accumulation in areas of mixing that didn't meet the typical agitation significance that would be around through the rest of the vessel. Of course, the idea of flush bottoms, special flush bottom valves, and the re-entry plug valves, have all had affects on mixing and mixing criteria—many of them good, some of them not so good.

As we continue to move forward with our discussion and analysis of mixing and requirements, we're going to begin now with looking in more detail at some of the typical things that we see around in mixing today. Of course, one of the criteria that we have to recognize is that with all of the things that we've been reviewing, these were developments that happened up through the 1950s with finding many of the little things that have been discussed. Around the late 40s and

early 50s, we began seeing people looking at mixing as more of a specific process method and criteria rather than just a part of the mechanical processing of material.

So, companies and people began taking the specifics of the mixing process, analyzing it, and developing new methods of handling this. There were several very significant industries that led the way in this. We're all pretty well aware of them without having to mention names, but several very key researchers began looking at mixing. They took away the idea that the most important part of the mixing was the gearbox and how to design that and started looking more at the shaft itself, the blade or the mixing unit that was being used. They were also looking at the baffling and how that was done in the vessels. They wanted to come up with more consistency and value in developing a process system that was built around the actual needs of the product and the process technology rather than technology being adapted to type and size of a particular mixer being available at any given time.

Early into this mixing was the start of the development of turbine-type blades for mixing, running analyses of how these various turbines performed. There are a variety of industrial manufacturers of mixing equipment that will provide you with booklets of articles discussing the efficacy and the efficiency of different diameters of blades. They generally indicate that a certain ratio of diameter of the mixing device itself to the tank and vessel with given baffle configurations are the most reliable for general mixing requirements.

As we mentioned, this was an activity developed around the 50s and, at that time, energy was a very inexpensive commodity. So, a significant variety of mixing blade designs, paddles, the shapes of paddles on the ends of turbine blades, and varieties of other components of the mixing system, were studied and analyzed and a great deal of data was provided. Also, something that developed very significantly in the early working with mixers was the understanding of vibration conditions for shafts. In certain situations, very moderate speeds were required, initially, and so shafts were not a critical function. As it was determined, that improvement in speed helped certain processing requirements, particularly things like the maintenance of stability of suspensions or the dispersion of gases into process applications. The higher speeds of the mixing device were a benefit here. Then, the diameter of the shaft became critical because at wrong speeds, the shaft diameters would periodically allow too much vibration if they were too light. Of course, they're very expensive when they start going up in diameter.

Many manufacturers began using a variety of blade configurations on their turbines through this time. The flat-bladed turbines were certainly the most convenient and most easily manufactured and connected to the turbines. Quite often they would then be curved, angled, or a combination of flat and angled blades was used, in order to provide vertical pumping and movement of materials as well as the shear and mixing that was of interest for process requirements. Of course, with turbines and the stability that was able to be achieved by using a turbine blade, there is the convenience of being able to fabricate the turbine blades in pieces so that larger diameter mixing elements could be put into vessels through man-ways or moderate sized openings in the vessel so that the whole top didn't have to come off. Many of these things were significant improvements in what we could do with mixing and how it could be handled within process and reasonable cost parameters.

Another idea that came about in these early developments of new mixing systems related to changes and improvements in shaft seals. Of course, there was a lot of seal development that was occurring through the 50s and 60s. With the reduction of packed shafts and the introduction of shaft seals with carbon rings, many sealing parameters were significantly changed. Again, the idea of what could be done with mixing systems, particularly because of the convenience of how the shafts and the agitator materials could be handled, was something else that was greatly improved through that period in time.

Other types of agitator blades that were worked on and developed through that time, of course, were paddle agitators or plate agitators of various kinds. Certainly, the most specific requirement in this category, in my opinion, happened in regards to the glass lined vessels where the particular requirements of the glass coating of the shafts, the agitator components, and the portions of the mixing itself, were dictated by the requirements of glass coating as well as placing them together. So, the varieties of mixing devices or elements in the glass-lined vessels were somewhat less than those that could be placed in strictly as metal activities, but some considerable development was done along those lines.

Propellers were regularly used. One of the things that became very popular with propellers in the early development of mixing technology was angling the propeller. This was so that baffling requirements were reduced and the stirring could be done by improving the volumetric movement using the configuration and the geometry of the vessel itself as a type of baffling.

With all of these basic mixing functions of the turbines, paddles, propellers, and so on, one of the other things that began to come out of the development of mixing technology that was being done in early studies was the concern and the interest of the maintenance and creation of uniform mixes. Again, we're back to that statistically problematical definition of uniform, but a definition of a consistent distribution of some relatively solid components in a liquid mixture, sometimes for the whole of a processing operation, sometimes only for a portion, because the solids would then be dissolved. Of course, there are some other factors that will come in our discussion of solids that we'll address a little later on in some of the process-related discussions.

However, as we start moving on through the different types of propellers, we're not into a time period that has become very significant. That's into the early 70s. Up to this time, energy for mixing was almost a non-consideration for many processes. The cost of energy was very low and there were no particular problems with it. Now we're into a function, starting in the 70s, with the increasing price of oil and the cost of energy, that the idea of a mixer sitting there running for a considerable period of time is now getting to be a significant cost problem. So, the hydrodynamic type mixing blades were being developed.

Now we're into a question of what are the criteria? What is the basic understanding of the new mixing blades? They have been developed to be energy effective and through the early 70s where mixers that I saw designed that would use 35 and 40 horsepower motors and rather significant gear boxes in the driving of a very nominal or casual type blending, mixing arrangement, and something that was considered typical for the time, has now been changed to a blade and drive arrangement that gives the same quality of mixing. Quite often now with the 7.5

to 10 horsepower driver, a smaller gearbox, a lower rating, and the savings that come in from that, as well as some other arrangements. The blade itself is significant on that.

The understanding and the relationship of material movement to baffling and the way the mixing is handled within the tank, also contributes a lot to these systems. Combination systems, particularly in situations where gas mixing or a light liquid addition mixing is significant to the process have now become of significant interest. Sometimes there are a mixture of blades that are used, particularly in order to assure that as the vessel itself is being drained, that there is a small mixer continuing a little bit lower than normal and near the outlet in order to prevent solid separation and buildup just as the vessel is being emptied.

A little area of discussion that we'll touch on for a bit is the idea of what's called high-shear mixing, which is also often done in these low viscosity conditions. There are a couple of examples in the handout papers that I've provided you of mechanisms that do this high-shear mixing. Quite often, they are a relatively flat blade, driven at very high speed, with not much in the way of protrusions toward the end, but with an awful lot of them, quite often a saw-toothed like edge or a multiple component edge of small materials, are used at the end. This gives us an opportunity for some significant liquid shear of materials to occur across the many little blades that these are.

This is now the end of tape one, side one, and certainly the cassette tape would need to be turned over or pass on to the second CD disk. Thank you.

Tape 1 – Side 2 (Disk 2 – 01 track 1)

This is the beginning of tape one, side two, of the Professional Development Hours Course, Mixers & Agitators. Again, this is prepared on both tapes and CDs, so this may also be the beginning of CD 2.

We ended our discussion on side one of the tape with some comments about high-shear type mixing and saw edge type mixer blades. There are several photographs of some pieces of mixing equipment that are used for that purpose in the package of mixer reference photographs and sketches provided with the course. We'll possibly talk about those in a little more detail sometime in the future. This is an area where the specifics of uniformity and process requirements tend to be more appropriate to the discussion than the function of mixing alone.

It's now appropriate to begin our discussion of some specifics of the application of the types and methods of mixing that we've laid the background for. One of the things that should be considered here is that a lot of this is based on the industries that I was particularly exposed to. There may be some alternative opinions about how certain portions of agitators work in other industries, but I think in general I should be able to give you some interesting ideas about the mixing elements and what affect they can have on your systems.

Certainly, because it is such a universally applied unit, I think it's appropriate for us to start with the turbine type agitator, particularly the flat-bladed turbines, and make some comments there. One of the most significant comments that I will bring up at this time was demonstrated to me

quite some time ago very dramatically as part of an investigation that I was pursuing. A significant and key factor in the development of a blade like this is to recognize in the physics of the mixing blade itself that the volume of material that is pumped by a given turbine blade is a function of the diameter of the blade, its speed, and the size of the impeller components that are there. The turbine blade is an impeller much like in a pump in many ways and certainly it's a very large volute for the pump, but it is an impeller as in a pump. In looking at that configuration and the formulas that have to do with the volume pumped for this situation, the volumetric pumping rate is proportional to the cube of the diameter.

I mention that specifically because the next idea that's involved with looking at an agitator or turbine blade is to recognize power consumption, which we've already made a few comments about. The physics of the power consumption of any agitator blade is related to the diameter also, but it is related to the diameter to the fifth power. So, a minor change in diameter of the blade will have a hundred times greater affect on the power consumption than it will on the volume of material processed and pumped, particularly in the turbine agitator blades, but this is a general criteria for agitator blades.

The key factor here is quite often during a design or application, depending on the material that's being handled, a drive or power selection will be done in order to be as efficient as possible and a system may run into an occasion of being borderline in its application as it goes in. Of course, the first decision or question that would be brought up is, "Well, fine, we've got to get a new gear box with a larger motor and larger gear box. We might even need a larger shaft." The cost involvements that go with something like this are very significant. I suggest and offer to you the experience that I had in an occasion where something like that occurred. By removing a quarter or an eighth of an inch from the outer edge of the turbine blade, the power consumption dropped off so dramatically that the mixing affects, or the power consumption affects were the most significant criteria at the time, were reduced back to within the capacity of the drive system to be able to operate functionally and reliably for long periods of time. However, because it was a relatively small change on the turbine itself, the affect on the process criteria was almost insignificant. So, this is one very good way of being able to use and investigate the use of turbines and turbine-type impellers in systems.

The other functions that are critical and important in dealing with turbine-type agitator blades are the manufactured or physical considerations of the blade itself. Earlier we discussed the idea that the turbines can usually be taken apart into various pieces in order to be able to fit into relatively small openings and vessels. Of course, this means that changing the applications of turbines can be done very easily regardless of whatever type of impeller was in a vessel initially. The changeover to a turbine, or at least the addition or modification of a turbine, can be affected very easily without completely dismantling a vessel. This depends on what agitator was in there previously and what condition it's in. In those cases where a large, strange type agitator might have been in a large vessel for various reasons, whether it be erosion or corrosion, which was destroyed to the point that it could be taken out in pieces, but would be very difficult to replace with the same type agitator, something in the way of a turbine agitator installed might end up becoming an appropriate replacement.

A key point that should also be of interest and concern in looking at turbines, particularly metal turbines as they're applied in liquids is the specifics of the materials from which the various components are made. A turbine type agitator is usually a flat blade with relatively flat blades at the end of the unit and a rather substantial hub of one variety or another where the turbine agitator is connected to the shaft. The methods of manufacture and fabrication of these units can vary quite a bit from vendor to vendor. The blades themselves may be welded to small structural components, like an angle iron, with holes and boltings drilled to be able to mount the blades and connect the angle iron to the disk of the turbine itself. Then, the turbine disk itself could either be welded or bolted to the hub assembly.

However, I would suggest to you that if you're dealing with a material that is specifically corrosive in unusual ways, the consideration of the metallurgy may become quite important. Rolling of materials or the manufacture of the flat sheet from which the turbine based disk and blades are cut and fabricated may be somewhat different in physical conditions, particularly in the metallurgical time, temperature, handling, and heating and cooling conditions. Significantly enough from the manufacture of structural components made out of the same basic material and also different enough from the manufacture of the heavier blocks of components that might be used to make the hub that grain size situations, annealing characteristics, the surface characteristics of the material, pre-machining and post-machining, the surface reactivation of the materials, can be such that a turbine blade can be put into a corrosive environment all made out of the same materials. You'll find that the base disk of the turbine blade corrodes away and the hub and blade ends are found untouched or any arrangement of alternatives on that. I particularly saw a function one time where an agitating system had a blade and base disk that had no apparent corrosive affect, but the hub was pitted and almost looked like a sponge. There are multiple conditions that come into this. There are questions that have to be brought in of what kind of vortex was being created, what kind of condition were the baffles in, or did you in fact get more air and oxygenation of the surface of the hub because there was too deep a vortex.

Certainly all of those things come into play, too, but I do mention that, on occasion, these kinds of problems can be observed with the variety of metals and particularly the variety of sources of metals that are used for turbines blades because different sizes of sheets of different materials could come from different suppliers. As I'm sure many of you are aware, whether you've experienced it or not, two manufacturers of a given alloy don't necessarily have exactly the same concentrations and conditions for the materials they are preparing. A minor component and the particular alloy on the high end from one manufacturer and the low end from another manufacturer when brought together can, in fact, create a galvanic couple that may be a significant factor in some future corrosion problems and is something to be concerned about as the use of this kind of equipment moves forward.

Some of these same comments would also hold true in looking at the application of something like a propeller blade. Again, the blades themselves, if they are different from the hub material, could run into corrosive problems. The blades themselves and how they're bonded to the hub might be a question sometime in the future. Most manufacturers today are pretty consistent with their development of blades with the molding, grinding and cutting methods that we have for making so many types of propeller blades, from outboard motor blades all the way up through submarine power blades, are so widespread in industry that usually a block of metal is turned

into a blade and a lot of the fabrication problems are greatly minimized. However, be aware of some of the questions that can come in and be of interest of those questions and problems and possibilities when you're working with someone about selecting and applying a blade such as this.

Certain specific criteria of performance of the types of mixer blades can have a significant affect on processing. One of the things that should always be recognized and considered is that a turbine type agitator using a basic flat blade or flat base plate with blades at the end will tend to create two zones of mixing; one above the flat base plate and one below. Certainly, there's going to be a lot of counter transfers that will occur in a lot of the mixing here. Generally, you'll end up with some significant consistency, but depending on the relationship of the blade diameter to the vessel diameter, if you happen to be toward the higher end of the blade diameter versus vessel diameter, you might end up with a partial separation of the actual mixing regimes that exist in the vessel. An open-type turbine with a smaller base plate will allow for somewhat more axial flow. The use of turbines with slightly canted blades will promote additional axial flow and greatly affect the possibility for separating the two mixing regimes.

The use of curved blades on agitators as shown in several of the diagrams end up becoming something that I think is more a personal preference than it is process based. The significant affect of blade activities and performance is generally going to be found to be very close to the end of the blade. The efficiency or affect of flat blades versus curved blades might be noticed a little in power consumption. However, the greater probability is that a long curved flat blade versus a plate with relatively small straight blades on the far outside edge would cause slightly more physical liquid shear in the mixing on the longer than on the shorter bladed typical turbine arrangement. Again, this is something that people are going to develop opinions of and relationships with depending on their particular process requirements.

In the diagram package that has been provided for you, there are some demonstrations of a variety of turbine impellers. Certainly the key ones that we're talking about are the basic flat blades as shown in item B, but all of the other varieties have certainly been tried. I would personally argue against the one that is shown as the tilted blade based on my experience with mixing. That kind of arrangement offers too many potential problems with bearings to make it worth their consideration for most mixing functions.

I draw your attention now to one of the photographs shown in there of a gentleman standing behind what is identified as a two-blade adjustable pitch propeller. This is fairly typical of the general design of a relatively modern hydrodynamic style impeller. While these blade angles can be adjusted, often in process, the design of this type of impeller is also very significant from the power consumption standpoint. Generally, this type of impeller gives a much lower power consumption still with good volumetric transfer, good mixing, and good variety of turnover in a well-baffled vessel. It is one of the general types that is now a very high-efficiency mixing blade and is often used in industry in a variety of sizes.

Certainly some of our comments before about being concerned about the blade itself, the connections between the blade and the hub unit, and the manufacture and fabrication of the hub unit from a metallurgical standpoint, would be of some considerable interest on this type of

agitator. These are widely used and, over the last several years, I've seen several units of this general design in the 18- to 20-inch diameter range. I've also been exposed to the use of this type of impeller as a 10- and 12-foot diameter blade used in a 36-foot diameter, 80-foot deep mixing vessel that was used in a crystallization process.

With these background comments of the configurations and some of the metallurgy of the mixer blades, let's now turn to discussing the affects of changes in blade design on impeller performance. One of the things that can easily be recognized is to go to curves of power consumption for blades, such as those provided by many manufacturers, and certainly available in the summary article on mixing that was done in *Chemical Engineering Magazine* in June of 1964 where some of the early data began being distributed. They show in there that turbine blades, whether they're flat blades mounted on a plate or just blades extending from a hub unit, that the flat-bladed type turbines are those of the highest power consumption for any given Reynolds number of performance. As the blades begin being curved and turned so that there is more axial pumping, the power consumption drops a little bit. So, the critical function at that time was understanding power performance.

For those of us who were involved in the mixing industry at the time, our interest was always in the performance of the blades and agitator systems for the products that we were manufacturing. Our concern involved making sure that the material as prepared and processed through any given mixing unit was going to demonstrate in laboratory tests and customer applications that the mixing we were doing was appropriate to the results that we desired. So, our concern with actual power consumption was not as significant as being sure that we had a sufficient sized driver for the agitator system and a sufficient gear reduction system to be able to provide long-term performance. So, this was where the varieties of bends, turns, vertical sizes, and configurations of blade tips and blades on impellers began spreading widely into curves, flats, and the uses of other things.

Gas distribution was also a significant concern as the agitator systems were more and more applied to the use of introducing gases for reactions into systems. Tip blades and configurations to enhance mixing were tried in many ways. As many of us have seen in impellers, there seem to be occasions where the curve of the impeller blade was appropriately scrolled in the reverse of the direction of turning the impeller. In other words, if the impeller blade was turning in a clockwise direction, the scroll of the blades or the surfaces of the impellers themselves were retreated back toward the counter-clockwise direction in order to get efficiency and better performance on NPSH and so on. Some of these same kinds of tricks were applied to agitators, particularly in cases where the agitator might be fairly small and turning in higher speeds in relationship to the vessel in which it was used. Those conditions would result in higher or deeper vortexes, depending on your intent in defining the vortex arrangement. So, we continually look for process performance as it moved forward.

Closed impellers and fitting them in between plates also became very significant. Using plates that ran all the way to the edge of the impeller blades were tried. All of these things provided minor changes. Many people became enamored with a particular solution that they devised and I'm sure found ways to make them work. However, in general, I think that if you went back and looked at the industry, you'd find that while one person in one portion of industry was using a

particular blade at a particular speed, you could find the same product performing for customers in exactly the same way, but were made under significantly different impeller conditions.

One of the amazing things to me through this developmental period was to run the comparison between agitator blades and the way they were used in a metal fabricated vessel through that period of time. It was amazing to see the variety of turbine blades, axial screw type mountings, and so on, that became important and a means of discussion of performance versus glass-lined vessels where the common form was being used by several manufacturers and everybody seemed to be very comfortable with using that and accepting its performance. Now, in many cases, this was a function of there being no other choice, so everybody had to adapt to those kind of configurations. The conditions of agitation did not seem to be affected that much by the physical configuration of the impeller itself.

We made a brief discussion about blade length and height conditions as you came to the edge of the turbine and the difference in affect on power and pumping as a function of the diameters. It's appropriate to review that just for a minute. The volume pumping is more affected by the total vertical height of the impeller and the direction of the mixer axis. Whereas the power consumption is much more significantly affected by the diameter of the impeller, the difference in the power consumption, and pumping is a function of the diameter either to the third power for volume pumping or to the fifth power for power consumption.

Given those arrangements, there are a variety of uses for the impeller blades, size, and baffling. Today, most people use one-twelfth the diameter of the mixing vessel for the baffles and generally try and keep the baffles slightly off of the walls. A separation of maybe three-quarters of an inch to an inch was allowed in order to prevent the accumulation of material right in the corners of the baffles as they're connected to the vessel walls. This also provides a relatively easy cleaning situation. Also, you can actually mount a clip onto the vessel wall and have a changeable, adjustable, or removable baffle for whatever reason that might be appropriate.

Again, physical configurations of the agitator turbines and blades become significant. Whether they are welded, bolted, in sections, or in small components, depends very much on the vessel that you're going into, how you're going to remove it, what kind of performance you achieve, whether some of the materials you have might be abrasive or tend to wear on the impeller, or whether the component or the completed assembly might end up being coated before it is assembled and put together. All of these additions and modifications to the blade will have multiple affects on its maintenance performance, power consumption, and process performance. These are items of information that become particular to any given industry and, obviously, bear some study and investigation to be sure that the units you're using are performing in the way you want them to perform and achieve the desired results.

Any discussion of mixing usually involves comparisons. Quite often the comparisons are of dramatically different operating systems and different operating criteria looking always for a uniform result. To this end, and as we approach many industries as suggested before, you can find diversities of opinion of the types of mixing used, but you're going to also find that complete changes of types of mixing sometimes become very important not only to the overall project development and determination, but to the desired result and product performance.

Following along with this, I'd like to begin a review of some comparisons of mixing for different process industries and how the mixers affect the performance through various parts of the processing.

A material that's probably very easy to talk about from a mixing standpoint and the overall affects is something like paints. Generally today, most paints are made up of a latex base. These latex bases are often generated in water. They prefer a very nicely divided and uniformly sized particle of the base material that is the effective paint film that finally coats the surface. So, materials like alkaloid latexes and other latexes become a good basis. Various mixing systems become very important in the preparation of these, both from the standpoint of the consistency of the mixing regime and maintaining a consistency in a vessel into which material is pumped or transferred during the actual manufacturing. A variety of manufacturers of latex bases use combinations of partial charges to initiate the polymerization with additive materials and further polymer additions, continuing throughout the development of the latex, in order to maintain their ability to hold a uniform particle size and provide a good base material for future additions.

Certainly, most of us recognize that all paints also have solid fillers in them. The uniform particle size, going back to the basic physical chemistry of mixing and dispersion, certainly offers us one of the reasons why small uniform particles help quite a bit in the inclusion of the solids in the system. The high surface area of the smaller particles provides much greater possibility for the uniform distribution of solids on the surface of the particles, which results in a more uniform film formed in the final product. So, the combinations of good mixing and good performance in the preparation of the base material, initially, and then in the distribution of the solids that are added in, are important.

In the addition of any colored materials or modifiers, and as many of us who have sat in paint stores recognize, there is a base material with the solids well mixed in, nicely filtered, and packaged into a tinting base of some kind. Then they are put into a machine and shaken in order to achieve the color variation. So, paints go through a significant variety of mixing conditions from the time that they are started in their preparation as polymers until they are finally in the can, in your house, and ready to be applied to the walls. Again, the methods of achieving this mixing vary from company to company and industry to industry with a great portion of this being done with turbine type mixing, but some of it with a fancier mixing. Of course, for those of us who may have gotten involved in reading about the Vermeer painting of the "Girl with the Pearl Earring," a few years ago, the discussion of mixing of the pigments from the very early years in a mortar and pestle arrangement with the oils are significantly different than what we're doing in volume of paint development today. Yet, many of the artists' paints are still done in the careful and small batch preparation methods.

We'll move onto a discussion of water treatment, going from a product that is used in very small quantities now to one that's used in very large quantities. From a product like paints where many things are mixed together to water where the intent is to use as little as possible and come out with clean and pure water. The mixing systems that go into water treatment become of considerable interest. In many cases, we find that very small solids additions are put into tanks into relatively concentrated conditions, maybe into the one- or two-percent range of materials that are then blended together in very large volume vessels with a minimum amount of mixing,

but still an arrangement of feeding the material in such a way that there is dispersion of the products. Then the treatment of purifying of the water is enhanced with very large, very slow moving agitators in order to be able to keep the treatment materials mixed with the water, but minimize the break up of flocks and settling conditions that actually perform the removal of the contaminants in the water. So an overflow from a gravity-settling situation can achieve very clean, pure water. Again, as we mentioned for final purification, it is usually passed through a variety of filters before it's passed on and distributed.

Going from the extremes as represented by the paints and water treatment, we can now move on into one of the very interesting portions of mixing technology in industry where a material is prepared and then must be held or inventoried for a period of time before it's passed on. Often, this is for a washing and blending, which is sometimes done in several stages, sometimes with the intent of allowing a separation of the solid in the vessel, and then remixing after some material is drained or decanted off. As many of us have experienced, this is a rather touchy and delicate operation to perform because you want to be sure that your agitator is not bound up by the solids that settle around it. So, usually, at least my experience has been, if it's a heavy material and a high specific gravity, it is separated from the washing material in one way, or another before it is re washed or remodified.

A typical example of something like this processing would be a large vessel that contains a slurry of a prepared solid or cleaned solid from some product that is treated for a while. Then it is passed through a centrifuge for the removal of the solid with the liquid being recycled or discarded as possible and the solid being separated into another vessel or container for either further washing or possibly for feed and drying. In using a washing vessel such as this is, the volume pumping now becomes as significant as the actual power and mixing arrangement. This is because, in many cases, the material is to be suspended in a liquid and if the volume pumping is not maintained in sufficient quantity for this, you'll find that there are concentration zones throughout the vessel. Those concentration zones, depending on the specific gravity of the material, would be denser in the lower portions where there is more circulation of material and of much less in the upper portions where circulation and mixing is somewhat less because of separation from the agitator blades or the mixer blades themselves. So, they're a lighter concentration.

This has often become a problem in those cases where the feed material is used to feed into a centrifuge because you will run into a significant concentration of solids in the early charges to the centrifuge and significant potential for plugging the feed lines. So, often in these cases, if there are conditions like that, then an increase in volume pumping or an increase in the rotational speed of the impeller would tend to improve the uniformity of the dispersion, cut down on the potential for plugging the lines feeding into the centrifuges, and provide an overall improvement of general processing. The higher speeds then run into the condition that possibly a heavier gear box would be required or possibly an improved drive motor would required, but this now is where the consideration and concern of the specifics of mixing type become critical.

This is the end of tape one, side two. Thank you.

Tape 2 – Side 1 (Disk 3 – 12a1)

We'll now begin a discussion of solids mixing and the certain criteria that we discussed in liquid mixing that applies also in solids mixing. Just as a quick review, it's distinctly possible to have over-mixing. This sometimes results in stratification of materials if done too intensively and somewhat depends on the kind of mixing device that is being used as well as the material being handled. One of the references goes back to the comment on biscuit mixing and the fact that there are only a few strokes that were defined on the package side in order to make good biscuits. Anything further than that and you create problems with the mix.

The other side of that is also a serious concern and that's the problem with under-mixing. Under-mixing carries all of the questions and concerns that we discussed in liquid mixing and it very much depends on the material and the further processing or use of the material being prepared. It takes us back to our question of statistics. A mix that is 98 or 99.9% complete is certainly a very good mix for many applications. However, if it is an application that requires a further spreading, transfer, or very limited further processing, such as a pharmaceutical, then it's important that the mixing be 100% complete and reliable so that there is a uniformity of distribution throughout all of the solids that are concerned.

In talking about solids mixing, we can have many kinds of combinations of how solids are mixed. Certainly solids and solids being mixed together is a typical function. The different ratios will have an affect on that, which we'll mention a little later. Solids with minor amounts of liquids are also a concern. High ratios in either direction of the above of solids in liquids or liquids in solids present some special problems. Mixing having to do with absorbent materials, particularly if they're in mixtures with liquids or materials that might be affected by any liquids that are carried in the absorbent material. Mixing of reactive materials is a very interesting subject, but we may not get as deeply into that. There were some exposures I've had in the past of mixing things like the propellants for solid rocket cases, which can become a matter of some considerable concern. It would certainly seem like there is little in the way of problems with mixing inert materials and would generally be covered under the solids and liquids or solids and solids mixing, as noted above. Mixing of compatible or non-compatible materials brings us back to the question of how good a mix is required from a statistical or process basis. We could go on and on with looking at the various combinations of mixing possibilities and reviewing specific comments on some of them, but we'll talk more about those as we move on through some particular comments on the several types of mixing.

Another criterion of interest in looking at mixing from an overall standpoint is a stage in the total processing system in which we find a mixing stage is necessary. Certainly, as with liquids, some materials just require minimal dispersion to start and further processing will complete the transformation. The same thing might be said with solids. There are times when a minimal amount of pre-mixing, which might be called joint feeding, is necessary for materials in order to create a mixable material later on, something that can easily be turned in the processing. So, the different mixing criteria or mixing methods might be considered two different stages of the same mixing process in one case or it might be considered the only necessary mixing process with further processing being done by a different kind of equipment. This would be a more typical application in some plastics mixing where a minimal amount of preliminary blending of

materials is required with an extruder or some other type of blending or processing intensive mixer that would provide the final total mixing of the materials.

Somewhat less mixing might be required for materials that could be further processed in other treatments. A pre-mix batch of some kind in color processing that just required a certain minimal dispersion of one, two or three materials as a base. Then some coloring or further modification materials added as a result of a final intensive mixing that would be used to present a uniform product for further sizing or packaging in sale.

As we briefly mentioned in the beginning, preparing something like a powder mix that would be used to prepare pellets in a pharmaceutical operation or materials that might be used for injection molding would probably require a more intensive and more statistically and process complete type mixing. This is so that the product that is made in the final pellet or pill making operation...

Tape 2 – Side 1 (Disk 3 – 12a2)

...meets all required specifications for content and appearance.

As a fun item, I'll throw in a comment that may be more appropriate in the coming few years that solids and solids mixing may become significantly more of interest as we might move back into further or expanded use of nuclear energy for electricity generation. Particularly in the use of what's called mixed oxide fuels to be assured that a uniform and consistent quality of oxide blend is available for the preparation of what is usually a pellet form of the uranium containing materials that are used for the fuel element development in manufacture.

In discussing solids mixing, I'm going to separate the processes generally by methods employed for particular types of combinations that are desired. Of course, there are many ways of looking at the differences that occur in mixing, but I think this is a reasonable one and we can get through the required processing by talking about them in this manner.

The first mixing type that I'd like to get into is what is often referred to as autogenous mixing. This is mixing of the materials themselves with relatively little else done in order to effect a movement or distribution of the materials as they are being mixed. There are a number of materials that tend to fit into this kind of mixing. Certainly things like coal, ores, and gravel and sand fit into this criteria. In many cases, the kind of mixing that is done is almost unrecognized, considered only as an afterthought, and is a result of general transfer and movement.

Of course, this is where we might split a couple of hairs in discussing the idea of whether something additional is used to move it. Just packing material onto a pile and taking the material off affects a type of mixing and can involve a smoothing out or increasing of the uniformity of the material being processed. Manufactured materials often lump on storage and are processed in a very simple rolling, turning, or handling operation in order to break up those lumps just at shipping or packaging. This is with the anticipation that a reasonable shelf life or holding time is not exceeded so that the material doesn't tend to lump again. Sometimes this also involves the addition of some kind of a surface modifier or lubricant in order to promote future handling.

Some details on this would go into the use of materials, such as waxes or other drying materials, that would help to prevent a uniformity of movement. Also, one of the things that might use at least a recognition of autogenous blending would be where materials are made in a common plant, but by different processing lines. Then, the methods in which these are brought back together again in storage bins or a storage pile and then recovered from that pile affect an autogenous kind of blending of the material being processed.

A simple example of this might be something like a lime kiln processing that I was exposed to some time ago where lime stone, the raw material, was brought from several different sites on a recovery location to a common pile. It was then fed from there into the feed mechanism that led into the kiln itself for the preparation of the lime. Certainly, there were minor variations in the rock because they were relatively close, but it depends on the criteria. These mine sites were within a mile or two of each other as they came together. So, there were relatively common rock types as they came together. The minor blending that occurred in the transfer and feed pile did help to prevent any single truckload or transfer portion of the rock from creating a problem with later materials made.

We can now move into a general description of the mechanically assisted mixing. A typical concept of this is something that has arms, ribbons, or fingers of some kind inside the blending unit that affect, improve, or tend to enhance the mixing affect. This is quite often the first consideration as a mixing step or stage is considered in a process, but it's not necessarily always the best and many aspects of mechanically assisted mixing sometimes add complexity to the system where it's unnecessary. I remember in particular a function that was always a bit of a problem in one particular application where an enhanced type of blending was tried initially for a blending stage. However, it was found that the area around the shaft, as it entered the vessel, became a concentration place for very fine materials to gather and then start to be sheared and drawn into other aspects of the processing, sometimes breaking into a lubricant containing area and then dropping back into the product and creating further problems. So, consideration of something like that possibly occurring is something to mark down and recognize as a process moves forward and consider what the potential effect would be with something like that occurring. This may be a reason for doing some special test to determine whether this is the best solution to use initially.

Looking at mechanically assisted mixing, several specific types of equipment come to mind. Certainly one of the first things is a typical item that's called a ribbon blender. This is usually a very simple containing vessel, often a longitudinal half-cylinder, and often with somewhat elevated sides, closed in on each end, and the shaft through the center on which there are mounted screw-type or ribbon-type flights that cause some partial movement of materials inside. Sometimes there are several ribbons arranged with a movement direction encouraged. Actually, one on the outside in one direction, next one moving in, with the thread or flight arranged in the opposite helix so that the material is partially moved in the other direction. Also, sometimes with something else in the center to affect further movement in a certain period of time that moves this material back and forth and the time is investigated to determine when a suitable mix is achieved.

In some cases, the ribbon blenders might have auxiliary units. There might be breaks in the ribbons where something else is inserted into the side of a holding container to augment or improve the mixing function. Certainly, one of the things that always comes into the idea of a ribbon blender is the loading and unloading methods. The loading method can usually be simply considered as a top loading item and dropping material in. This may be convenient or inconvenient, depending on the quality of the material or solids qualities of the materials. The closures, the methods of connecting materials or transfer items to the blender may be more complex than desired. Certainly, methods of being able to close the materials into the blender prevent further entrances and also becomes of interest.

The unloading function could be a bottom-drop door, the removal of a top completely using a vacuum to unload from the top, or the intermediate consideration of a door on one end of the vessel that can be opened and closed and the use of the extreme flight on the mixing ribbon itself to move materials to that outlet or drop door. This leaves you with the question of how empty does the blender need to become between processing stages. If a little bit of residual material in the neighborhood of half to one percent is not a problem, then something like that method might be suitable. Again, it depends on the quality of the manufacture of the ribbon blender, the approach of the ribbons to the sidewalls, the potential for future back-mixing materials, and so on, but that type of exit is often used.

The next variety of blending that we'll discuss is generally what I refer to as a tumbling blender. These are made in a variety of configurations. One of the simplest designs is what is called a double-cone blender. In many cases, it, in fact, is two conical shapes that are put together often with a short, flat cylindrical section between them, and at the apexes of each of the cylinder, there is an entry or discharge door. Sometimes there is a door on each end, but, in some cases, there's a door only on one end, in order to be assured that material is either loaded or unloaded at any given instance and that the material is not introduced during an unloading cycle. Some concerns about that problem do mitigate the idea of having the single entry only.

A second variety like that is the blending of two cylinders, which is often referred to as a pant-leg blender. It is a pant-leg or V-shaped unit and the V then can be used in either of several directions with loading points either at the apex of the V or at each end of the leg. Certainly, if the connections or doors are used on each end of each leg, then often both doors need to be opened for emptying. If a door is used only on the apex, then the ability to use only one door for feeding and discharge is possible. Often, in this blender as it turns, the axis of rotation goes directly across the junction of the two cylinders and the V is in the normally read position and would turn over with the single point pointing down and then up in sequence like that. The material tends to move back and forth between the two vertical cylinders and against the walls and you get the blending in that method.

Sometimes an eccentric type is used of a single cylinder. Very often this is used with drums where a drum is put into a unit, clamped in, and the drum is just rotated on a skew axis so that the material in the drum moves along the sidewalls and creates a kind of rolling action as the drum is turned. Larger units are also used like that. As a little sidelight, sometimes coating and wrapping operations on fiberglass tanks are done in that configuration.

These types of blenders make themselves available for a variety of other things to be done in them. Often a double-coned blender, in particular, is used as a vacuum dryer in addition to being a blender. A rotary union joint is used on one side and a vacuum connection applied. Sometimes the walls are also heated so you can get a combination of activities in a piece of equipment like that. Certainly, the questions of what types of materials are being processed in the cone become very significant there because if you are, in fact, taking out a vapor of one kind or another, the quality and characteristics of the vapor are now very important to make sure that you recognize the condensation conditions that exist. Also, whether a small filter of some kind would be needed on the inlet to the vapor removal mechanism for any other materials that can come out with it. How often would that filter need to be changed and methods for changing it. Conversely that kind of joint and connection through the rotating shaft could be used to spray a liquid into a blender of that variety. Some of the same things are also possible in the pant-leg and eccentric varieties. The shaft ends up being a relatively fixed item that can be connected to a rotary joint and that inlet into the vessel used for the various introductions or removals for venting or for liquid introduction.

Many accessories can be put into these types of blenders. As I mentioned, heating capabilities on the outside is certainly sometimes a convenient method for washing that can be introduced through either of the doorways or mounted on the vessel itself, again, using rotary units. Often times, these vessels also have auxiliary units mounted on the walls themselves with a rotary capability of feeding power to the unit and then introduction of blending blades of various varieties into the side of the vessel to augment the natural blending operation of the unit. Again, the requirements for adding situations like this go back to the process requirements of the material being processed or the final use requirements of the material being processed and determining how significant the blending must be before it is packaged. This then relates to what the further processing will be of the material of interest.

There is an addition of a variety of unique mixers that are important to the blending operation. Many people, as I mentioned in our introduction, have developed mixers that specifically fit their material or have developed blenders based on their belief of how their material needs to be processed, as it was originally processed. Certainly, the function of grain grinding as it was done in mills of long ago had an affect on deciding the methods of using mixing and blending because there are a number of processing methods that use that type of arrangement for blending. We'll start off, though, talking about some things that are a little more mechanical.

There is a variety of mixer that is used on the market that is generally a large cone. Inside this cone is mounted a small screw conveyor. The screw conveyor turns inside the vessel, often inside a cylindrical tube of its own. This whole mechanism of the screw conveyor and the cone are rotated within the larger conical vessel in a planetary method. So, both the function of the movement of material by the screw conveyor, usually from the apex of the cone, which is normally pointed down, raising it up to the wider upper portion of the cone, and the screw conveyor then rotating around, creates a blending and mixing that is rather specialized.

There have also been arrangements where multiple axes are used through a center shaft to allow blades inside to rotate in either a common direction at different speeds or in different directions. You get significant internal cross mixing and blending and a material movement action by these

additional items inside. There are many materials that are processed that use a mill type, as we led off into this mixing arrangement, either as flat plates or a bowl in which two vertical mixing units are rotated. Usually, this is a kind of mixing where a shearing action is very important to the blending and tends to have more involvement in the preparation of mud like materials, such as a drywall paste or a variety of filling pastes. These quite often need this combination of processing functions. You get a blending because of the wheels moving around inside the larger bowl, but then the scraping or smearing action of the wheels as they turn on the bottom of the bowl and on the material there tend to smooth out and give a more uniform blending of the material.

The trough type container that is typical for a ribbon blender is often used with other internal blade arrangements. One of the early functions used in this way, other than just ribbon blenders, is often referred to as a sigma blade. It tends to look somewhat similar to the Greek letter, sigma, and I believe that's the reason it's called that. It can have the blades very close together. Usually, the arrangement is somewhat like a waveform with square corners and a combination of some wiping and turnover with these alternating blade sides tend to create material moving back and forth. These types of blenders have been used in a wide variety of applications. Everything from mixing very hard materials, as I saw it being done for preparing carbon paste, which is very much like an asphalt, and used for the preparation of anodes in aluminum plants to mixing things like toothpastes, dye colorants, that are then later pumped to packaging functions. The requirements of these blades and the drive power that goes into them tend to make them rather expensive because of the fabrication requirements, smoothness, and so on, when they're used for the high-value added products. The very large sizes of them, in some cases, also require special handling when they're used for rough mixing.

Many other varieties of the trough-type mixers are used over time. One variety is called the pug mixer, which tends to have fingers of different kinds inside the trough and connected to a central shaft. These are used where a fairly simple mixing is used or required. Preparation of a thick slurry is rather typical, particularly with a slurry that is going to be used for further processing in some other ways where the only important thing is to get the solids and the liquids somewhat mixed together so that they can be transferred on in a relatively simple method to further processing. Pug mixers are often used in a more continuous type application where solids and liquids are continuously fed at one end and discharged at the other. Of course, the variety of pug mixers that are developing slurries and pastes like this range both up and down from the intensity of the pug mixer to something as simple as a screw conveyor where liquids and solids are fed together and passed on for even more simple mixing than that promoted in a pug mixer to places where the mixing needs to be a little more intense and the solids are more difficult to handle. I've seen ball mills of different sizes used as mixers and this goes back to the variety of the conical shapes, the rolling action, the materials inside, and certainly the question of appropriate solids and liquid feed and feed rates, to get the materials into the mill, and in many special designs on the discharges of a ball mill. Screens, often called trommels, dating back to some of the original applications that tend to be more European, or other methods of recovering materials with recycle of materials that might get through relatively ungrounded. Many of the paste and slurry preparation methods tend to rely on relatively simple mixing methods to feed the materials into the system.

Another relatively unique consideration as a mixer, which may not necessarily always be primarily used as a mixer, is something like a fluid bed. The materials are rather well distributed inside a fluid bed. The air or fluid actions tend to create a lot of rolling or moving inside the bed. So, a fluid bed, whether it be a liquid or solid, can often also be used as a mixing method. Reviews and investigations of this type of mixing would probably be a little more significant than in other areas because there are problems of control of residual materials in a fluid bed and how long a material resides in the bed before it is fully taken out. These things are always of interest when you're looking at a mixing problem. If an age or shelf life problem does not exist, fluid beds are a very good way to get mixing. They're also a good way to achieve a treatment of a variety as you're going through this.

There was a water treatment application that I investigated one time that used mixers to blend together a wastewater and treatment chemical before processing it into a settler and separating function. For a while, some of the vessels that were used were relatively large. There wasn't a significant amount of mixing that was required, but these large vessels would quite typically and quickly accumulate a separation of solids that were brought in with the wastewater. These materials would congregate at the edges and without too much difficulty would end up being a problem for the mixing or blending blades that were turned in the larger tanks. In this particular application, the vessels were changed a bit in configuration. The mixing was made a little more severe than was required by the process, but the changes brought in by the more severe mixing kept all of the solids in suspension so that they did, in fact, pass on to the settler where it was intended for them to separate. Thereby, a significant maintenance problem was avoided in the large, slow moving mixing vessels where they had to be taken out of service and cleaned quite frequently. The smaller vessels with the more intense mixing did not require that cleaning. They continued to operate for longer periods of time. The process itself became somewhat more stable and effective in the removal of the solids, separation, and further discarding of the solids by removing it from the bottom of the settler mechanism. It also improved the efficiencies in recoveries of materials that were passing on through the waste system. Some recovery of values was affected by the method of separation and the fact that many of the materials collected were not in a state where they needed to be discarded. They were in a state where they could be reprocessed and re-graded without too much difficulty.

Tape 2 – Side 2 (Disk 3 – 12b)

This is the beginning of the final section of Agitators & Mixers. As a tape, it would be tape two, side two. As a disk, it would be either the second half of probably the third disk.

We're going to continue on with the idea of solids mixing and various varieties of solids mixing. We've discussed up to now autogenous mixing, blending of various varieties with mechanically assisted equipment, and some various types of mechanically assisted equipment. Now, I'd like to review and discuss the idea of a mechanically static mixing, which actually relates to two cases. One case is the desired and preferred mixing, blending, and involvement of materials. The other would involve the undesirable blending of materials and these things happen and I talk about this as being mechanically static mixing, but they happen in holding vessels.

Let's kind of dispose of the idea of the undesirable functions first. In any given tall, vertical vessel, any kind of container holding materials, as material is put into the bin, the point of discharge becomes the primary location of the movement of materials. In cylindrical vessels that are tall and relatively narrow, in other words an aspect ratio of maybe 2.5 or more to 1 of height to diameter, there would be a normal rat-holing affect, as it's often referred to, or funnel hole in the center of the vessel. The material that is on the top of the vessel will almost preferentially become material that discharges from the vessel as it's being put in because the feed tends to work down the center.

Now, if the discharge point for the vessel is not physically in the center bottom of the vessel, you'll get the same kind of affect along the wall area where a vessel discharges and that will occur also in square or any other shaped vessels. The material that is specifically in the area of the discharge point will discharge immediately and will create a zone over the top of it of a lightened or more easily flowing material. Materials that are farther up will generally pack down and feed into that zone and preferentially discharge. Sometimes this is good, sometimes it's not, but I spoke of it initially as generally an unpreferred condition because it does create a confusion of materials as they feed in and feed out. Often, some materials that are fed into a vessel can sit at the lower areas of the vessel for long periods of time without being turned over. So, periodically, it's good to fully empty a vessel in order to assist in that problem.

There are a few other things that have been done to help that problem in a number of areas. Of course, the research that's been done by Jenike and Johansen has provided an awful lot of information and valuable guidance on how to handle situations like this. Vessel design considerations can have a big affect on this. The development of pressures in the bottom of solid vessels has led to the inclusion of strengthening rings and stabilizer rings toward the bottom of vessels. If these are put on the inside of the vessel, in some ways they can reduce a tendency for small feed funnels. It can improve the capability for feed funnels because the cone section or the discharge section of the vessel will be separated from the main holding quantity of materials in the vessel by the stabilizer rings inside. So, the material feeds down through a small donut and the hole of the cone area tends to become a somewhat larger feeding area. It reduces the tendency for materials to sit dead in the low corners of the vessels. If these stabilizer rings are put on the external side of the vessel, then, of course, there's no affect on it.

Other things that are done in static vessels or in vessels that are like that in order to improve feeding are called live bottoms. This is going to take the vessel out of the mechanically static category, now, and put it back into an actively discharge promoted piece of equipment. However, a live bottom on a bin will certainly help considerably in causing uniform turnover of the materials that are in the bin.

The second portion of this in the area that I said is generally a little more favored is the idea of a mechanically static vessel used as a mixer with the condition where a vessel is often supplied with a number of drop tubes that are set at different heights in the vessel. Then, each drop tube is fit into a collecting chamber and that chamber is drained. The general characteristic is that material will drop through each one of these drop tubes into a small collecting chamber and then this small chamber will be a blending kind of leveling function so that material is taken from all levels of the container quite regularly. This promotes the idea of turnover in the bins and

movement. The placing of these pipes becomes somewhat of an interest and somewhat a technological concern. So, the attempt to use something like this should certainly be reviewed and discussed with people who normally prepare and build this type of equipment.

Certainly, other things inside the vessel that would help conditions like this would be separating plates and multiple discharge points on the bottom of a vessel with possibly a rotation of uses in the bottom of a vessel in order to get a continuous turnover of materials and the prevention of accumulations. Of course, the function here is the idea of whether you want to use one vessel with a few dividers in it and multiple bottom outlets. Does that in some way provide an advantage in the arrangement development of the particular plant that you're working in? Would it be better to have a variety of vessels each with its own outlet so that each one can be processed and accessed individually in case there is a need for a repair or adjustment?

Large storage areas also tend to fall into this idea of mechanically static. It has long been a practice of people in the utility industries to be very concerned about their distribution of coal reserves if they are using a coal-fired system. To make sure they turn this over fairly regularly, begin feeding from one end and loading the other, and vice versa, and moving it around the variety of situations that are there. Number one, of course, is the inventory situation of the materials, but the second thing was maintenance of the quality of compaction in the pile itself. If this is not maintained and protected uniformly, often in deep piles, particularly of coal, but certainly of some other storage or combustible materials, hot spots can develop. This is a potential for the creation of an anomaly of unseen fire or, of course, a loss of a good deal of inventory.

Certainly other things like cement plants, limestone kilns, and a variety of other materials that are manufactured where large volumes of materials are kept in open storage. The idea of managing and controlling how that storage is done is something that sometimes doesn't become immediately evident or recognized as important in the early operation of the plant. It's down the line that something like that comes in. Certainly, many handling systems as they exist today with very interesting feed and distribution systems for very large storage and transfer facilities help with this material turnover, particularly those that are mechanically conveyor fed and mechanically physically recovered. Again, you have the mechanically assisted kind of function, but a very good opportunity for picking up materials in a particular area and making sure that there is a continuous time involvement of all the materials that are put into the storage.

Something like this would probably also be of significance in some of our major paper plants. The accumulation in storage of wood as it is put into the holding yards for feeding the plants is an item that I'm sure is of interest because the wood sitting around for a longer period of time would begin to decompose, break down, and become unsuitable for the development of paper. So, if you're working into something where a material that potentially decomposes over time, you have to consider your materials, determine if that is a possibility, and if it's appropriate to consider the idea of preventing deterioration simply because the material is left alone.

From an accounting standpoint, we're into another significant problem regarding all of this, too. Many years ago, changes came up in how people looked at inventory situations and we got into LIFO and FIFO and the various related functions of those things. So, this also is something to be

aware of in your plant development. For some things, this is very important. Those of you who are involved would certainly recognize that. For other things, it may not be quite as important. Things like some sands, particularly depending on its usage, or possibly alumina and a few other items along that line. It would not be as critical to be sure that there is a continuous turnover as long as the storage is kept relatively isolated and not particularly affected by external sources that would bring in the possibility of dirt or contamination accumulation in a portion of the plant.

The next area of process solids handlings and mixing or blending to be considered is the idea of addition processing. We've touched on this briefly, but it still is often used in many industries where with a large material, as it's being processed, or a material being processed in large quantities, there are values in adding something to it on a small basis. In some cases, with materials that might later be fed into a mechanical processing machine of some variety, the addition of a flow promoter for the solids is of interest. Often these things are then done as the material is being conveyed along. A small feeder of some kind adds the material and then just as the major conveyor is feeding into some kind of a packaging function or in some other transfer function, just the idea of rolling over or transferring or changing from one bed to another or possibly in a screw conveyor, the addition of a minor additive like this is accomplished.

A variation on this is the idea of washing. In some cases, you can consider this in the same way as a material passing on a belt or a piece of screen mesh is sprayed with a wash material, possibly somewhere up the line in order to get a little soaking time. Then, at a point of transfer, possibly over a mesh function of some kind, whether it be a screen, hold plate, mesh belt, and so on, that the solid is then re-separated from the liquid as a washing or cleaning is affected as it goes into processing.

Certainly another function that is often used on this as a material is being fed down a line is a small additive is put on the material. It then goes into a small drum or cylinder for some turning and blending of this surface additive to do whatever its function is, whether it's to improve flow ability of the solids or to provide an additional protection of some kind for the solid. Then this can be affected pretty easily, but then it becomes important that the addition equipment be regularly inspected and have it confirmed that the feeding is uniform and the material distribution or the potential for distribution is suitable for the desired addition and the resulting final function.

The next category to be interested in from the standpoint of solids handling and possibly mixing might be the idea of those areas where there are chemical changes that might occur in the mixing. This would generally be somewhat unusual for two solids to be able to mix together and blend in an easy way. Usually there is some other function that is involved in creating this changeover. The first thing that comes to mind would be something like the processing of cement where materials would be blended together as they are fed into a kiln. They would be heated up in the kiln. There is finally a temperature achieved where there is a conversion of materials from the various feed materials into the cement form. Generally, in cement kilns, this would go through a muddy or pasty type stage, but in some cases it does not. Then, there is a cooling function to get it to the end of the kiln and the opportunity to changeover.

Some other blendings that occur of solids in a category like this where there is a chemical reaction of solids, again, might involve something like a ball mill or a related intensive mixing device like that, in order to achieve a certain material. However, another one, which I believe we've touched on this briefly in the beginning, is a function called a mix-muller. It's a very specific piece of equipment and has some very interesting applications. It has the function of turning materials and causing them to shear or be rubbed together as two wheels are turning in a bowl. So, the idea is to get a very good uniform mixing of materials. Of course, there are a variety of applications for this. The ones that I have more often seen have not been as much a solids mixing, but solids with a somewhat more fluid material being blended into it to create a kind of clay or paste material that goes into further processing.

If this is a kind of function that is of interest to you, I think this is going to bear a little more investigation. Certainly, there are a variety of people who make processing equipment like this. A function that is close to my heart that is also along this line is the application of a type of reciprocating and turning piece of equipment called a Ko-Kneader, which is very much like an extruder. It was and has been used in Europe for large volume chocolate mixing for a long time. Again, there is a butter-like material that becomes part of the processing that tends to make it a little more like a liquid-solid combination rather than a solids only blending.

In certain other cases where it is appropriate, the function of the type, the mechanics, and the specifics of the blending are quite often proprietary. In those instances, obviously, it would be appropriate to check with manufacturers of the equipment and/or the materials to see if licenses would be available or an opportunity to use that equipment in another function. Of course, it all depends on the currency and the timeliness of the limitations that there might be on the application of this technology.

Generally, I would say that I've pretty well come to a rather extensive discussion of the varieties of solids mixing that can occur. Hopefully I've provided some insights that give you opportunities to think about any solid mixing function that you're doing or might want to look at other options or varieties. I'm sure there are thousands of other cases where individual activities and process functions would bear a worthwhile mention simply because of their uniqueness, but the opportunity for transfer of technology would be rather limited. So, I've tended to stay away from as many of these small and individual functions to try and keep them a little more generalized in areas where I think there are possibilities for the transfer of ideas and understandings among the industries rather than isolating to a particular industry.

In closing this discussion of mixers and agitators, I would like to mention a few references. It's always a problem coming up with appropriate reference value to add to some of these programs, but I'm going to throw these in even though they may seem somewhat dated because they are very good and generalized. Certainly, Perry's carries a good discussion on mixing. There are other textbooks particularly in unit operations that cover a number of things in mixing. An article that was in the March 22, 1971, issue of *Chemical Engineering Magazine* on "Trends and Mixing," written by a W. Roy Penny of Monsanto Company, has a very good generalized discussion of several types of mixing. A bit more specific and related more to plastics and some solids mixing requirements was an article on the "Processor's Guide to Mixing, Blending and Compounding Equipment" that appeared in *Plastics Technology Magazine* in the July 1967

issue. While this last one may be a bit more difficult to turn up, I include it as a similar article that was done on mixing in a magazine called *Chemical Processing*, this was done in June of 1965, that has quite a bit in it written by several people. I recommend it to you maybe not as much for the idea of the discussion of mixing in the article, while some of the material may be somewhat dated, but because if you can get a hold of the article itself, there are advertisements distributed within the article from many of the individual and unique blending equipment manufacturers that can offer some very interesting insights into some specialized blending equipment.

This then will be the termination of tape two, side two, Agitators & Mixers course, a three-hour Professional Development Hour Course. I wish you good mixing and hope that some of the ideas will be of help to you in your professional work. Thank you.