# Solids mixing and blending

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**The success or failure of any solids mixing process depends on matching the properties of the solids with the appropriate mixer.**

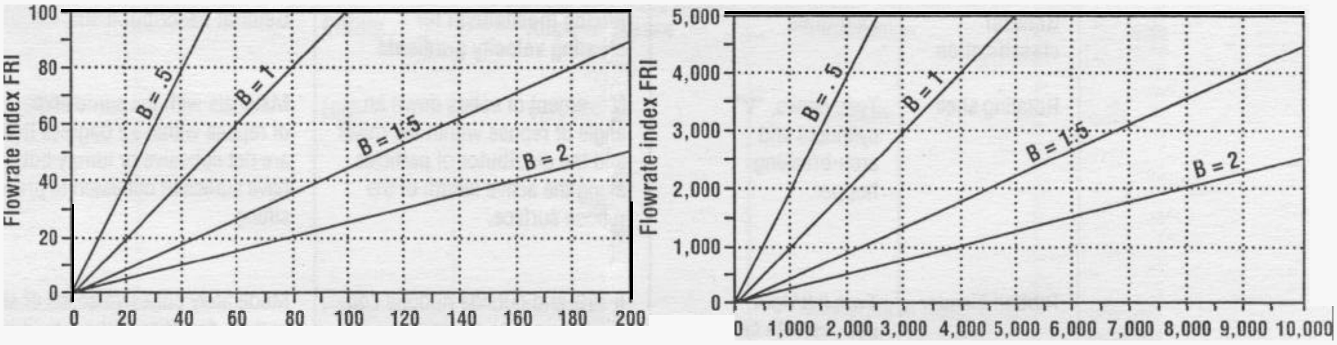
**There are two essential properties that must be known for a mixer or blender to mix satisfactorily: First, the mixer must cause velocity gradients throughout the entire mass of bulk solids. Second, the mixer or blender must not allow the solids to demix or segregate while in the mixer or upon discharge from the mixer.**

**■ To receive the nine-page "Blender selection based on material properties" white paper-JR Johanson Inc., San Luis Obispo, CA.**

**TABLE 1. BULK SOLIDS FLOW PROPERTIES' EFFECTS ON DEMIXING.**

| Demixing mechanism description | BULK solids most likely affected by mechanism | | | |
|---|---|---|---|---|
| | General description | | Property index description | |
| | Major component | Minor component | Major component | Minor component |
| Sifting demixing occurs when the finer minor components (less than 50%) sift between the larger major component particles whenever the blender causes interparticle motion. | Must be a free-flowing granular material with a particle size at least three times larger than the minor component. | Must be a free-flowing granular particle with a particle size one-third or smaller than the major component. | AI <= 0.2 ft | AI <= 0.2 ft |
| Angles of repose demixing occurs when one component forms a steeper angle of repose than the other component. The steeper angle of repose component is left behind at deposition points or points of flow initiation, while the other flows to the toe of the slope and concentrates there. | The demixing is most severe when the major component has a steeper angle of repose than the minor component. This generally means that the component has some cohesion or a very high angle of slide on rough walls. | The demixing is most severe when the minor component has a flatter angle of repose than the major component. This generally means that the component is very free-flowing or has a low angle of slide index (ASI) on a rough wall. | 0.2 <= AI <= 1 ft, ASI <= minus component ASI | AI <= 0.2 ft, ASI <= major component ASI |
| Fluidization demixing occurs when one component (usually the major one) fluidizes during the mixing action and the other component (usually the minor component) penetrates the fluidized mass and accumulates under the fluidized component. | The fluidizing component is usually very fine and feee-flowing, at least at low consolidation pressures. | The penetrating particle size is usually too large to fluidize and is significantly heavier than the bulk density of the fluidized component. | AI <= 0.2 ft, FRI <= 100 | AI <= 0.2 ft, FRI >> 100 |
| Air current demixing occurs when the minor component is easily entrained in air and is moved by the air to the edges of the blender or to a vent location where it concentrates. | Any size free-flowing particle that is not significantly affected by air currents. | Superfine, free-flowing and easily moved by air currents. | AI <= 0.2 ft, FRI >= 100 | AI <= 0.2 ft, FRI <= 10 |

**FIG. 1. FLOWRATE INDEX INTERPRETATION.**




Flowrate* (lb/min) for a deaerated solid at various conical hopper outlet diameters B (ft)

Flowrate’ (lb/min) for a deaerated solid at various conical hopper outlet diameters B (ft)

‘For slot openings length L, width 8, multiply the flowrate by 1.3 L/B

| | |
|---|---|
| Effects of greater or larger amounts of major components<br>Large percentages of major components cause the highest amount of demixing. When the mix is 50% by volume or when the major and minor components exchange descriptions, the demixing from this mechanism will not occur. | Methods of controlling demixing<br>Add a cohesive component to the mix either by adding liquid or a third solid that is cohesive in nature. |
| This mechanism is active through the range of mixtures even when the major and minor descriptions are reserved. | Add a cohesive component to the minor ingredient (low angle of repose ingredient) before combining it with the major ingredient. Avoid mixers that form angles of repose, especially rotating shell types. |
| This mechanism can occur with as little as 10% fluidizable material, although it is usually less pronounced when the fluidizable component is decreased. | Slow mixer movement to reduce aeration. Avoid mixers that introduce air as a means of mixing. Add a cohesive component to the fluidizable component before mixing with the large particle component. |
| This mechanism is most severe with a small amount of minor component to where slight accumulations at the sides of the mixer or at vent areas are a significant portion of the total superfine component. | Slow mixer movement and turn off the vacuum from the dust collector during mixing. Add a cohesive component to the superfines before mixing. Cohesion and adhesion can often be achieved by increasing the electrostatic charge on the fine particles. |

**TABLE 2. SELECTING MIXERS TO FIT THE BULK SOLID PROPERTIES.**

| Mixer descriptio | | | Bulk solids that mix well in this mix r | |
|---|---|---|---|---|
| General classification | Examples | Mixing mechanism for creating velocity gradients | General description | Indices description |
| Rotating shell | Twin cones, "V" cylinders and arch-breaking hopper. | Movement of solids down an angle of repose within the mixer and the distributor of particles along the active length of the repose surface. | Materials with the same angle of repose within +-2 degrees that are not cohesive or lumpy but have sufficient cohesion to prevent sifting. | 0.2 <= AI <= 0.6 ft, RI <= 3 ft, FRI >= 100 |
| Ribbon blender | Twin leftfright ribbons with center discharge or single left/right ribbons with end discharge. | Inside and outside ribbons convey in opposite directions, providing good localized velocity differences, but not very effective movement from one end to the other, especially with single left/right ribbons with an end discharge. | Moderately cohesive solids of similar particle densities without fluidizing tendencies. | 0.2 <= AI <= 0.6 ft, RI <= 3 ft, FRI >= 100 |
| Rotating plough | Single horizontal shaft, single horizontal shaft with intensified whirling blades between ploughs multiple horizontal shafts to decrease mixing time, vertical shaft with a high-speed rotating blade. | Solids are literally thrown about, providing great particle mobility, large velocity gradients and rapid mixing. | These mixers can handle cohesive solids and are excellent when liquid addition is required or lumps must be broken from previous storage. Friable solids will usually degrade in particle size. Fluidizable fines can be added provided there are sufficient cohesive components to mix with the fines and prevent fluidization or air entrainment. | 0.2 <= AI <= 3 ft, 0.2 <= RI <= 10 ft, 10 <= FRI; with cohesive solids it may be necessary to run the blender during discharge. |
| Screw mixer | NAUTA type with a rotating screw that moves around the hopper periphery. | Solids are lifted from the bottom to the top of the hopper and are exchanged with solids around the screw on the way up. This localized exchange and velocity profile is propagated around the entire hopper as the screw progresses. | Moderately cohesive solids that do not contain hard lumps that need breaking. | 0.2 <= AI <= 3 ft, 0.2 <= RI <= 10 ft, FRI any range. |
| Gravity flow tube blenders | Interior or exterior tubes | Solids are drawn from various levels in the bin by the tubes and recombined at the bottom to provide a mixture from the various levels. | Very free-flowing and uniformly sized materials like plastic pellets that also have a low angle of slide on the bin wall surface. If the solids have cohesion, the tubes will block. | 0.2 ft >= AI, 0.2 ft >= RI, FRI >> 100 uniformly sized particle. |
| Gravity mass-flow blender | Cone-in-cone, arch-breaking hopper. | Inserts in the hopper and cylinder cause differential retention times in the blender, causing a mixture with time of entry into the blender | Low to moderately high cohesive solids. The cone-in-cone must also have a non-fluidizable solid to prevent preferential flow patterns from developing. | 0.2 ft <= AI <= 3ft, 0.2 <= RI <= 10 ft, FRI >= 100 for cone-in-cone only. |
| Air blender | Pulsing jet at the bottom of a hopper | Solids are moved upward by the air jet, causing differential movement. | Easy-flowing solids that are closely sized and do not have a component that fluidizes easily. | 0.2 ft <= AI <= 0.6 ft, 0.2 ft <= RI <= 3 ft FRI > 100 |

| Potential demixing mechanisms rating | | | |
|---|---|---|---|
| **Sifting** | **Angle of repose** | **Fluidization** | **Air currents** |
| High | Very high | Moderate | Low |
| High | Moderate | Moderate to high, depending on speed. | Low to moderate when a dust collector is used with these blenders. |
| Low | Low | High | High |
| High | Low | Low | Low |
| High | Moderate | Low | Low |
| Moderate | Moderate | Low | Low |
| High | Low | High | High |

## TABLE 3. SOLIDS FLOW INDICES (OBSERVED OR MEASURED).

| Index description | Symbol | Meaning relative to blending |
|---|---|---|
| Arching index is the conical hopper outlet diameter required to prevent arching when the hopper is filled with the bulk solid. | AI (ft) | If AI is very small, demixing from sifting fluidization and air currents is possible. If AI is large, the solid may have difficulty discharging from the blender and a high intensity blender may be necessary to distribute the solids. |
| Rathole index is the flat conical hopper outlet required to cause cleanout of a cohesive solid. | RI (ft) | If RI is small, demixing from fluidization and sifting is possible. If RI is large, the solid will likely form lumps and air blenders will likely blow holes in the solid mass and not blend. |
| Angle of slide index is the angle (measured from the horizontal) of a flat plate that is required to cause the solids to slide along it. | ASI (degrees) | If ASI measured on a rough plate is different between various components or size fractions, we can expect angle of repose demixing. |
| Flowrate index is the rate that material will exit a 1-ft diameter conical hopper after the material has been allowed to deaerate. | FRI (lb/min) | FRI is an indirect indication of particle size. A larger FRI indicates a large particle size. A small FRI indicates a small particle size. If FRI is small (small particle size) and, if in addition, RI and AI are also small, then fluidization and air current demixing is likely. |

## TABLE 4. USING OBSERVATIONS TO EVALUATE INDICES.

| Indices | Converting observations into indices |
|---|---|
| AI | A hopper should be initially empty and then fill with solids. This will prevent excessive time effects and impose the initial pressures on the material at the outlet. If flow occurs when the hopper gate is opened or the feeder starts, then AI is less than the outlet diameter. If flow does not occur, then you can determine AI by slowly removing solids from the vicinity of the hopper outlet and remove it in layers up to a known diameter. When the arch fails, the diameter at failure is AI. |
| RI | The conical hopper should be 45" or flatter for RI to be measured from observations and material should be one to two bin diameters in depth above the hopper. If a rathole forms then RI is greater than the rathole size. As RI is likely larger than AI, it will be difficult to prod the material to open up the flow channel until failure. Consequently, the best you can do will likely be a greater than number. |
| ASI | This index is simply measured by using a rough plate (sandpaper coated) and by tilting the plate up until the solids slides down. Loosen the material first to eliminate any adhesive forces. |
| FRI | The major problem of determining FRI from observation is distinguishing between an actual bridge and a very slow flowrate. To overcome this problem you may wish to use an outlet larger than 1-ft in diameter and then use Fig. 1 to interpret FRI from the observation. If the hopper has a feeder on it the best you can do with FRI is greater than the feeder rate unless you can increase the feeder speed to where the feeder is not full. |