Cleveland Eastern Mixers
DIVISION OF
EMI INC. TECHNOLOGY GROUP

TP-102

MIXING PROCESS CLASSIFICATIONS

BLENDING OF MISCIBLE LIQUIDS

Blending of miscible liquids is a simple physical mixing consisting of combining two or more materials until the particles, portions, or drops of each of the components are disseminated within each other satisfactorily. The degree of mixing or intimacy of the particles is a matter of subjective judgement as to what is necessary. Specific data required include:

- The relative proportions of the liquids to be blended.
- The time available to obtain the final blend.

The evaluation of the time available is quite important as it has a considerable effect on mixer horsepower. Input horsepower is selected to give a certain number of batch turnovers in a given time period. By extending the time period, input horsepower can be decreased, or conversely increasing the input horsepower will decrease the blend time.

The number of batch turnovers required to achieve a satisfactory blend is extremely variable. For example, 12 turnovers should give blending of readily miscible liquids of similar viscosity and density such as alcohol and water. However, as many as 36 turnovers may be required for readily miscible liquids of widely different viscosities such as glucose and water.

SOLIDS SUSPENSION

Solids suspension is also a simple physical mixing job involving suspending insoluble solids in a liquid. Specific data required include:

- Percentages of solids, particle sizes, and setting velocities in feet per second.
- Ease of wetting of the solids (See also Dispersion).
- Type of suspension required either (a) uniform suspension of all particles, or (b) off-bottom suspension of all solids.

Type of suspension is extremely important in mixer selection as illustrated in the following example:

Assume a vessel with working volume of 3,000 gallons containing light liquid with 20% insoluble solids, of which 1/3 are 10 mesh, 1/3 are 40 mesh, and 1/3 are 200 mesh. Settling velocities of the largest 1/3 is 10 ft. per minute. Horsepower required for various types of suspension is:

- Uniform Suspension 7 1/2 HP
- Off-bottom Suspension 3 HP

DISPERSION

Dispersion is usually defined as the mixing of two or more non-miscible liquids, or solids and liquids, into a pseudo-homogeneous mass that is more or less stable as measured by its life before noticeable separation occurs. This can cover a wide range of product types from slurries to heavy dispersions such as pigment pastes, caulking compounds, etc. Power input per unit volume can vary widely. Conventional propellers or turbines at typical propeller and turbine speeds are adequate in some applications. In others, higher speed impellers introducing higher shear and greater intensity of agitation are desirable to satisfy the dispersing problem in a reasonable time period. Some dispersing applications can be routine, others may require experimental data to determine the best type of mixer.

Additional data required include:

- Type of dispersion (liquid-liquid, solid in liquid, gas in liquid).
- Relative amounts of each phase.
- Viscosity of final product, if known, together with details on temporary or interim viscosity conditions that are more extreme than initial or final conditions.
- Rate of addition of one component into another, and in which order.
- If solids are present, some expression as to ease or difficulty of wetting. Some materials that are of a light fluffy nature tend to float on the surface of a liquid, whereas others may tend to form agglomerates that resist complete wetting. Both conditions require greater intensity of agitation to complete the dispersion.
- Time available to create the dispersion. Where the solids content is low, solids easily wettable, and agglomerates do not form, the application and horsepower requirements are similar to solids suspension. A change in time available has very little effect on horsepower levels since the material is usually dispersed as rapidly as it is added. In more difficult applications horsepower levels and available time usually have a definite relationship due to the need not only for high shear but for adequate turnover.

- Fineness of dispersion required to be produced by the mixer. This applies to solids in liquids dispersions and is usually designated as micron size of particles. Some dispersions are considered complete when merely smooth in appearance; others may require reduction of agglomerates to certain maximum micron size. Agglomerates formed after initial entrainment of solids may be reduced rather easily up to a point, after which further reduction becomes exceedingly slow with conventional horsepower levels. Under this condition, if time is critical, a special high horsepower, high shear, high turnover mixer will be required. If subsequent processing (or particle reduction in other types of equipment, such as roller, sand or colloid mills, is planned, this should be stated since it will simplify the dispersing job required of the mixer.

DISSOLVING

Dissolving generally refers to the dissolving of a solid in a liquid. Here the requirement is to provide a good flow rate of liquid past the surface of the solids. In general, for readily soluble crystalline materials the type of agitation that provides initial wetting and suspension of all solids will satisfy the application. In those cases where solids are difficult to dissolve or where faster dissolving is desired, higher horsepower levels are required.

A different type of dissolving problem is encountered when the solids are non-crystalline materials such as natural and synthetic rubbers, solid resins and other commercial polymers. These materials first soften and become quite sticky. These particles tend to agglomerate into larger masses or to adhere to the vessel walls. The solution increases in viscosity as dissolving proceeds, with final viscosities becoming extremely high in solutions having high solids content. Dissolving applications of this type must consider the viscosity factor as an inherent part of the dissolving problem. Input power levels may run to 100 HP or more per 1000 gallons, with high shear being desirable. Where long dissolving times can be tolerated, lower horsepower levels can be used. Actual times will depend upon the material involved, the temperature and particle size.

An easy dissolving application is salt solution make-up, as in preparing a 20% sodium chloride brine in a 2000 gallon tank at temperature of 150° F. This will require one horsepower. On the other hand, dissolving 1% carboxy-methyl-cellulose in 2000 gallons of water where final viscosities could run as high as 7500 cps. will require 1/2 to 10 HP. Starch cookers using turbine mixers are a good example of dispersing and dissolving. At a point in the cooking cycle the starch is changed from a slurry to a viscous solution and passes a peak viscosity before it is finally diluted. The mixer must be sized for the viscosity at the peak.

For example, for a 1000 gallon starch batch at 12,000 cps. peak viscosity, 3 HP would be satisfactory. At 80,000 cps. peak viscosity, 7 1/2 HP will be necessary.

Another example is dissolving of crumb rubber in organic solvent. Final viscosities can easily reach 500,000 cps., 1,000,000 cps., or higher depending upon solids content. Dissolving can be accomplished slowly over several hours time at moderate horsepower inputs with large diameter low speed impellers. Power levels in the range of 25 HP per 1000 gallons are typical. Dissolving time can be reduced by up to 80% by sharply increasing power input and providing high shear in addition to high fluid turnover. Power levels in this instance will be in the range of 200 HP per 1000 gallons.

Data to be provided in dissolving applications should include:

- Percent of solids in solution.
- Physical characteristics of initial products, interim
- changes, and the final product.
- Temperature.
- Solubility.
- Permissible dissolving time.

CRYSTALLIZATION

Crystallization is the reverse of dissolving and is accomplished either by cooling a saturated solution to deposit out crystals, or by heating a solution to drive off the solvent. The agitator selection usually resolves itself into (1) a heat transfer application necessitating good flow of the solution past the heat transfer surfaces and (2) satisfactory handling of the crystals being formed.

The problem of handling crystals usually dictates the choice of an impeller system. Some crystals are sensitive to fracture and must be agitated gently. Other crystals may tend to form on cooling surfaces and must be actually scraped off by the impeller. Some crystallizers in continuous flow may be designed to concentrate crystals at the bottom of the vessel for draw-off. Other applications may require that the crystals be maintained uniformly in suspension. In other crystallizers, the solids may deposit out to the extent that the fluidity is impeded because of the high percentage of solids in suspension.

In general, crystallizers fall into three basic types. The first is a conventional vessel with either jacket or internal coils or both. The impeller is usually a low speed type to provide good volumetric flow rates at moderate to low velocity. This type is useful for friable, easily damaged crystals, or where solids content builds up to a high level.

The second is a conventional vessel fitted with a draft tube in addition to a jacket or coils. The draft tube provides positive flow control that prevents short circuiting of the desired flow pattern. Usually higher speed impellers such as propellers are used. This type is useful where crystal size is not important or not affected by the higher shear type impeller.

A third type is a vessel used with pusher type impellers such as helical ribbons or gates running in close proximity or actually scraping the vessel wall or heat exchange surfaces to continuously remove the crystals from these surfaces as they are formed.

Additional data required for crystallization agitation requirements are as follows:

- General description of the process with particular emphasis upon progressive changes in crystals and slurry characteristics as crystallization proceeds.
- Sensitivity of crystals.
- Temperature and pressure of system.
- Description of heat transfer surfaces.
- Nature of crystals, whether they should be maintained in suspension, or permitted to settle.
- Specific gravities of crystals and of liquor, particle size of crystal, settling velocities.
- Crystal formation rates and method of forming; i.e., do they form as slurry or do they deposit out on heat transfer surfaces.

A typical example is as follows:

> A 15,000 gallon crystallizer is equipped with a central draft tube and used for forming solids at 25% maximum by weight, settling velocity up to 5 ft. per minute, with crystals being continually drawn-off at the tank bottom. Here motion only of the solids is desired, since a higher solids concentration at the draw-off point is necessary. A 10 HP axial flow impeller to provide motion only of solids would be suitable.
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> However, if uniformity of crystals in suspension is desired for other reasons, 15 HP would be required.

HEAT TRANSFER

Heat transfer applications involve either heating, or cooling, or merely maintaining a uniform temperature. The latter is the easiest application, with heating next, and cooling usually the most difficult. In processing, heat is transferred by conduction from the wall of the vessel or surface of the internal heating elements to the contents of the vessel. As the contents are agitated, heat is carried throughout the mass by convection. Mixing thus speeds up conduction from heat transfer surfaces, and helps promote heat transfer by forced convection.

Heating and cooling applications are best handled by providing an adequate flow of fluid past the heat transfer surfaces, with proper measures taken to insure good top to bottom turnover of the tank contents. This flow pattern will provide good exchange of fluid between the center of the tank and tank wall resulting in reasonably uniform temperature of tank contents.

Heat transfer applications may be considered similar to blending. Consequently, for low viscosity liquids, conventional propeller and turbine mixers are generally used. One qualification on horsepower levels for low viscosity applications is that, unlike blending, a point can be reached where an increase in input horsepower does not have any pronounced effect. For higher viscosity liquids, larger diameter lower speed impellers are usually necessary to obtain the desired flow pattern, with accompanying increases in horsepower similar to that required in higher viscosity liquid blending.

Complete data on all the contributing factors in a heat transfer agitator application are often difficult to obtain. As much data as are available should be furnished and should include the following:

- Tank dimensions and details of tank jacket and/or coils.
- Whether heating or cooling or merely maintaining an existing temperature is required. Time available for heating or cooling.
- Are solids present that must be handled as solids suspension problem. If so, give details as in solid suspension applications.
- Viscosity of fluids at the temperatures to be encountered.
- Details on heating or cooling media, temperature of batch at start and at end of cycle.
- Specific heats and conductivity of tank contents.
- Is the process material susceptible to decomposition at the temperature of the heating medium; or can it solidify at the temperature of the cooling medium.

CHEMICAL REACTION

Reactor agitators are usually treated as one or more of the other types of agitator applications such as blending, dissolving, solids suspensions, heat transfer, extraction, or gas dispersion, depending upon which of these promote the reaction. Complete data as requested under the specific applicable operation should be furnished.

Some chemical reaction applications are difficult to classify from that standpoint of the type of mixing operation. For example, the reaction of a gas with a liquid promoted by a solid catalyst in suspension usually involves gas dispersion, solids suspension, and heat transfer. Applications of this type are usually evaluated in pilot plant equipment, and pilot plant mixing data should be made available to the mixer vendor. These data should include (1) input horsepower per unit volume (2) the geometrical relationship of the pilot vessel and mixer and (3) the peripheral speed of the mixer.

EXTRACTION

In mixing applications, this is defined as the separation of one or more components of a mixture by the use of a solvent liquid. At least one of the components must be immiscible with or only partly soluble in the extractive liquid so that at least two phases are formed during and following the extraction process. Extraction operations are commonly broken down into the following:

- Liquid-liquid extraction, in which the mixture treated is a liquid and the two phases formed are both liquids.
- Leaching, in which one or more components of a solid mixture are removed by liquid treatment.
- Washing, which is similar to leaching except that the solids removed are usually present only on the solid surface rather than throughout the solid phase.

- Precipitive extraction, in which a homogeneous liquid system of two or more components is caused to split into two phases by addition of a third component.

In all these systems, agitation is used to improve extraction rates by increasing contact areas and mass transfer coefficients. High shear and high turnover are generally provided to disperse the phases in liquid-liquid extraction and in leaching with horsepower levels similar to dispersion. However, washing and precipitive extraction usually require only mild agitation similar to blending.

Extraction can be carried on in a single stage vessel, or in a series of vessels. The continuous countercurrent extraction column has become of interest in recent years because it can handle fairly high flow rates through relatively small mixing areas with a speed-up in process flow rates.

Extraction processing requirements are so varied depending on the operation to be conducted that it is impractical to attempt to tabulate specific data required. Usually it is best to try to classify it under one of the other operations such as solids suspension or dispersion.

GAS DISPERSION

Gas dispersion refers to any operation in which an incoming gas is intimately distributed throughout a liquid mass, usually with resultant chemical reaction. The following features are desired in setting up equipment for this operation:

- Radial type turbines are preferred to give a combination of shear and radial discharge pattern.
- A sparger ring for gas introduction below the bottom impeller is preferred over an injection tube.
- Tanks should be tall and narrow in configuration to provide the greatest residence time for the gas, and should be fully baffled.
- Multiple impellers are recommended.

Impeller systems are designed for relatively high fluid discharge velocities in order to disperse the gas into fine bubbles throughout the liquid. This will retain the gas in the liquid as long as possible and provide greater contact surface between the gas and liquid phases. The liquid in the vessel will expand by the volume of gas entrained and it is therefore necessary that adequate expansion space be provided above the normal ungassed liquid level. Under conditions of high gas input and/or low tank pressure the batch may expand considerably resulting in a reduced batch specific gravity. In order to use the maximum horsepower capability of the mixer during the gassing period (when it is needed), two-speed motors are sometimes used to permit operation of the agitator at reduced speed when that batch is in an ungassed and denser condition. The impeller is then sized on the basis of fully loading the mixer when the batch is in a gassed and lower density condition.

The following generalizations can be made regarding gas dispersions:

- Increasing the gas input increases the horsepower requirement to obtain equal gas dispersions.
- Increasing the vessel operating pressure tends to decrease the horsepower required for identical gas rates.
- Increasing the operating temperature increases reaction rates, but also increases gas volume by vapor expansion, thereby increasing the horsepower requirement necessary to produce equivalent gas dispersion at lower temperatures. The increased reaction rate may offset the need of equal gas dispersion with its higher horsepower requirement.
- The gas dispersion required is a function of the mass transfer rate. A given time cycle can be attained by a high mass transfer rate with relatively small surface area contact (large bubbles) or by a slower mass transfer rate and a high surface area contact (small bubbles). The horsepower requirement is determined by the gas bubble size needed to give the desired performance. Horsepower increases with increasing surface area requirements.

Apart from the above factors influencing horsepower inputs is the relative dissolving rate or reaction rate between gas and liquid. Some gases absorb or react rapidly—particularly in the initial stages of the reaction. Others are considerably slower to react. The slower reacting applications require a finer gas dispersion and therefore greater horsepower input.

Data relating to gas dispersion are as follows:

- Tank details, including all dimensions.
- General description of process with indication of reaction rates, if available.
- Batch size.
- Tank operating pressure and temperature.
- Volume of gas input in SCFM.

The following examples indicate how reaction rate can affect horsepower input levels

> Vegetable oil hydrogenation goes easily but halogenation of an organic in a Friedl-Crafts reaction can be quite difficult. A vegetable oil hydrogenator might require about 1 HP/1000 gallons, whereas a halogenator might be in a range as high as 10 HP/1000 gallons.