

# Multiple-Pass Homogenization By Continuous Recycling

In most processing systems it is desirable to prepare the finished product in a continuous, single-pass manner. This minimizes production time, and it also ensures that the product quality will be consistent from day to day. The high efficiency available with Gaulin and Rannie homogenizers is usually sufficient to permit the implementation of such a process. However, some products simply cannot be manufactured in a single pass. Such products must be homogenized for additional passes to achieve the desired product quality. An example of such a product is intravenous emulsions. These emulsions require an extremely small average particle size of  $0.3\mu\text{m}$  or less, and they can have no particles larger than  $0.6\mu\text{m}$ . This cannot be achieved in a single pass.

Having decided that multiple-pass homogenization is required, several alternative ways of achieving that goal must be considered. One method is to operate the appropriate number of homogenizers in series. This produces reliable results, but it also requires a large initial investment in equipment. Systems of this type have been efficiently producing a wide range of products for many years with minimal maintenance. A second solution to the problem involves a single homogenizer and two tanks and feed pumps. A premix would be prepared in one tank, and the first pass of homogenized product would be collected in the second tank. By means of a suitable valve arrangement, the material in the second tank will then be fed back to the homogenizer, and the two-pass material will be collected back into the first tank. This cycle is repeated, until the required number of homogenizing passes has been completed. Such a system requires a smaller investment in equipment, but there is some uncertainty that the entire product has undergone the total number of passes. On each pass there will be some product left in the feed tank, pump and pipelines, which was not homogenized during that pass. However, such effects are relatively small and are usually ignored.

A final approach to the problem involves a minimum of equipment. All that is needed is one well-agitated kettle and one homogenizer. The discharge from the homogenizer is piped back to the kettle, and the product is continuously recycled, until the required number of passes has been completed. Unfortunately, one pays a price for the mechanical simplicity of this system. First, the preferred continuous system has been changed back to a batch-type system. More importantly, one can never be sure that the entire batch of product has undergone the desired number of passes. A certain fraction of the batch will have done so, but there will be definite portions of the batch that have undergone greater and fewer numbers of passes. Despite these drawbacks, the continuous recycle-type of system is very commonly used.

For this reason a means of accurately calculating the amount of recycle time needed to complete the process must be established.

Once the volume of the batch to be processed and the capacity of the homogenizer have been determined, the correct processing time can be calculated. If one were using the two-kettle system described earlier, the following calculation would provide adequate results.

$$\text{TIME (min)} = [\text{VOLUME (gal./litres)} / \text{CAPACITY (gpm/lpm)}] \times m \text{ (number of passes)}$$

For example, four passes of a 1000 gallon/3800 litres ( batch with a 50 gpm/190 lpm homogenizer would require  $1000 \times 4/50 = 80$  minutes (or  $3800 \times 4/190 = 80$  minutes). Unfortunately, the continuous recycle system is not as easy to analyze. The problem arises because the material in the kettle is being continuously mixed with the material from the discharge of the homogenizer, which has received an additional amount of processing. If one assumes that this mixing process occurs instantaneously (a reasonable assumption for a well agitated kettle), a relatively straightforward statistical analysis yields the needed relationship. The details of this analysis can be found in Volume 42 of the Journal of Dairy Science (pp. 20-27, 1959). The final equation is repeated below.

$$f = \frac{m^P e^{-m}}{P!}$$

Where: P = required number of passes  
f = fraction of total volume which has received P passes  
m = number to be used in the previous time calculation  
e = the base for the natural logarithm (a constant equal to approximately 2.718)  
! = the symbol for the factorial function

The above equation is difficult to solve directly for m, but a graphical representation leads to a family of simple curves. These curves are shown on the attached graph for six values of f.

The proper way to use the curves is best explained by a practical example. Suppose that one must process a 1000 gallon (3800 litres) batch of product with a homogenizer which has a capacity of 50 gpm (190 lpm). Furthermore, assume that we wish to be certain that 99% of the batch has undergone the needed four passes. Using the f = 0.99 curve and the value of 4 for P, one easily determines that m = 11.6. The dotted lines on the graph illustrate this example. Finally, our previously shown calculation procedure yields the needed recycle time.

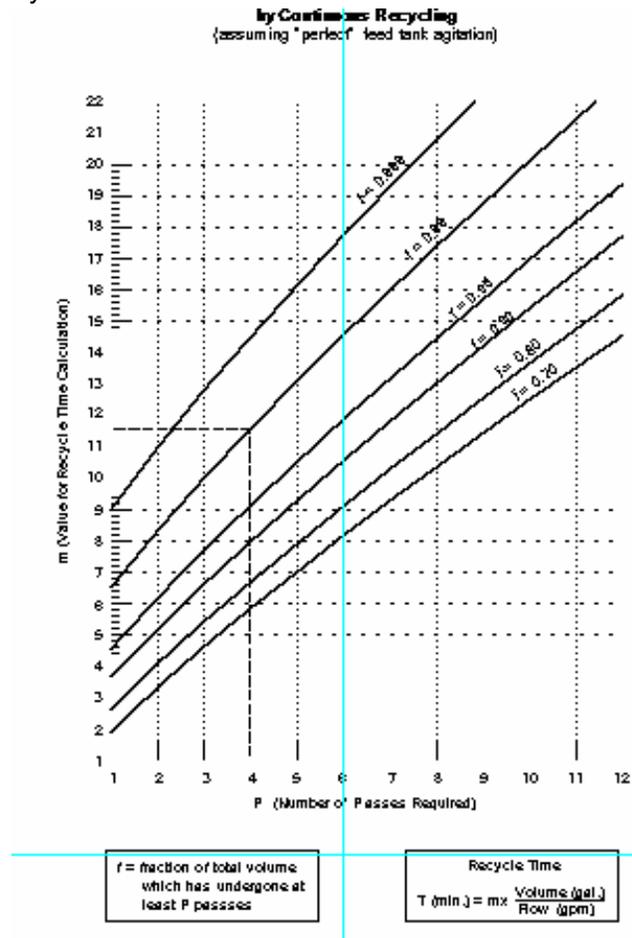
$$\text{Time} = \frac{1000 (3800)}{50 (190)} \times 11.6 = 232 \text{ minutes}$$

Thus, after 232 minutes of continuous recycling, 99% of the batch will have undergone at least four passes.

One final comment needs to be made concerning the statistical nature of the continuous recycle process. A more detailed analysis of the above situation reveals that a small portion of the batch will

have received as many as 24 passes, but most of the batch will have received a minimum of four passes. In order to guarantee that only 1% of the product receives less than the needed four passes, it is inevitable that much of the product will receive more passes than necessary. This is the reason for the very long recycle time. If this factor is ignored and the simple calculation used for the two-kettle system is mistakenly used, the 80-minute recycle time would leave 41.5% of the total volume with fewer than four passes (7.3% with 1 pass, 14.7% with 2 passes and 19.5% with 3 passes). Obviously, this would be disastrous. The compromise one must make is now clear. A balance must be achieved between the amount of insufficiently homogenized material that can be tolerated and the amount of recycle time that is practical.

At this point it is interesting to compare the time needed to process our 1000 gallon batch with each of the three multi-pass systems. Four homogenizers in series would require only 20 minutes. The one homogenizer and two-kettle system requires 80 minutes. The continuous recycle system required 232 minutes to reach a 99% certainty level. An important decision must be made during the system design process. Should one purchase the equipment necessary to minimize equipment purchases and settle for a production time that is more than ten times greater? Whatever the choice, the situation must be correctly analyzed.



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