# DIGESTER MIXING SYSTEMS

## CAN YOU PROPERLY MIX WITH TOO LITTLE POWER?

*by*

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Although some natural mixing occurs in an anaerobic digester because of rising sludge gas bubbles and the thermal convection currents caused by the addition of heat, these levels of mixing are not adequate to ensure stable digestion process performance at high loading rates.

It is therefore necessary that a mixing system be installed to create a homogeneous environment throughout the reactor, so that the digester volume can be fully utilized. Such mixing will lessen temperature stratification, reduce grit settling, and control the formation of a surface scum layer. Further, a proper level of mixing promotes contact between raw sludge and active biomass, and evenly distributes metabolic waste products during the digestion process.

What constitutes "adequate mixing" is indeed a difficult question to answer, and forms the basis of competitive promotions by various equipment suppliers, offering distinctively different types of mixing apparatus. The competitive promotion in many cases centers upon claims that their system "is so much more efficient that you can use less power to adequately mix the digester." Such claims are dangerous, and in many cases this has led to installations with inadequate mixing regimes, solely due to too little power applied, not necessarily the type of mixing apparatus.

This document, therefore, examines the question of the wisdom of allowing any type of mixing apparatus to be applied with less applied power than is recommended by various researchers.

## WHAT IS "ADEQUATE MIXING?"

Again, this question is subject to many interpretations, subject to one's own perspective. Perhaps the simplest and most direct definition[1] concentrates upon the main objective of applied mixing, namely that the uniformity of solids concentrations within the digester will be such that any sample taken from any point will not vary by more than 10% from the average of all samples taken, except for deposits on the tank bottom (containing course sand) and floating scum (containing low density material).
A number of different criteria for evaluating or specifying mixing performance have been used and is the subject of some controversy. The remainder of this paper discusses and compares those criteria.

## TURNOVER RATE

One method of quantifying mixing performance that has been traditionally used by Walker Process Equipment is based upon turnover rate, and simply the volume of the digester divided by the pumping capacity of the confined gas injection system (GasLifter), expressed in minutes. For example, a 20 minute turnover constitutes a pumping capacity equal to 1/20th of the total digester volume, per minute. It is important to note that only systems that actually move sludge through eductor tubes, or pipes, can directly exhibit turnover rates. So-called "unconfined" mixers cannot properly define their rate of pumping.

It should also be stressed that only "primary" pumping capacities be used for this criteria, and **not** induced movement of sludge, which is the **effect** of the primary pumping capacity. We have seen many times a competitive promotion that has used this ploy to justify lesser power input.

Walker Process Equipment standards have traditionally been based on turnover rates, recommending 20 minute turnover for thickened sludges, and 30 minute turnover for non-thickened sludges. The pumping capacity is based, experimentally, on an eductor tube pumping rate of 75 GPM/CFM released at 12 ft. submergence.

Operational experience has shown that the Walker GasLifter at 20 minute turnover can be run on an intermittent basis; however it is important that while mixing and/or adding raw sludge that the intensity indicated above be available.

## "G" VALUE

Cooper and Tekippe[2] have presented a theory of determining proper mixing levels on the basis of Root-Mean-Square Velocity Gradients, or "G" value. These levels were determined to range between 50 $sec^{-1}$ and 85 $sec^{-1}$.

G values are expressed[3] mathematically as:

$$G = \left(\frac{W}{\mu}\right)^{1/2} = \left(\frac{E/V}{\mu}\right)^{1/2}$$

Where:

$G$ = Root-Mean-Square Velocity Gradient, $sec^{-1}$
$W$ = Power Dissipated per unit volume, lb/sq ft/sec
$E$ = Rate of Work on energy transfer (power), ft-lb/sec
$V$ = Volume of Reactor, cu ft
$\mu$ = Absolute viscosity of liquid, lb-sec/sq ft

For a gas mixing (gas injection) system, the rate of work imposed upon the system can be calculated as follows:

$$E = 2.40\ P_1\ (Q)\ \ln(P_2/P_1)$$

Where:

$Q$ = Gas flow, inlet CFM
$P_1$ = absolute pressure at the liquid surface, psi

$P_2$ = absolute pressure at the depth of gas injection, psi

and, since 1 HP = 550 ft-lb/sec,

$$HP = 0.00436\ P_1\ (Q)\ \ln(P_2/P_1)$$

Similarly, for mechanical systems:

$$E = \text{HP applied X 550 ft-lb/sec}$$

Care must be taken to fairly evaluate a mechanical system; just as the power applied in a gas injection system, as shown above, is based on the gas volume and pressure at the gas release point rather than the compressor horsepower, so also does the mechanical system demand that the evaluation be based on the power induced at the impeller, nozzle, etc., not the motor HP, since line losses within the piping system, gearbox inefficiencies, etc. are not useful work.

## POWER PER UNIT VOLUME

The US EPA has advanced the theory[4] that proper digester mixing requires a power input of 0.20 - 0.30 HP/1000 cu ft of digester volume. In actuality, as shown in the previous discussion, "G" values also consider power per unit volume, with the additional inclusion of viscosity.

## COMPARISON OF THESE THREE METHODS

If we are to make any comparison of the three theories of mixing just presented, a viscosity must be assumed to calculate "G" values. Some manufacturers have promoted the idea that gas mixing systems should be based on viscosities of 300, and even 600 centipoises. However, Cooper and Tekippe[2] report that such values are "apparent" viscosities, those which might be measured with a viscometer in a low shear stress range, whereas the actual "absolute" viscosity is much lower in comparison. This can best be explained as the difference between measuring viscosity of a homogeneous fluid, such as oil, and that of a suspension, such as sludge. The solids in suspension create a non-Newtonian fluid which has a viscosity which varies with the shear rate in a non-linear fashion.

Their conclusion was, that since an absolute viscosity cannot be used for digester sludge, the viscosity of 95 deg water was to be used: 0.73 centipoise, equivalent to $0.1525 \times 10^{-4}$ lb-sec/sq ft.

Now the comparison can be made, first to compare the Walker Process Equipment turnover rate recommendations with "G" values and power per unit volume:

| Turnover | "G" Value | HP/1000 cu ft |
|---|---|---|

| | | |
|---|---|---|
| 20 min | 60.2 | 0.1005 |
| 30 min | 49.15 | 0.067 |

At the Velocity Gradient values indicated by Cooper and Tekippe, the corresponding values of HP/1000 cu ft are:

| "G" Value | HP/1000 cu ft |
|---|---|
| 50 | 0.0693 |
| 85 | 0.2000 |

Given the ranges of the three parameters referenced, the "G" values as recommended by Cooper and Tekippe strike the middle ground. The traditional turnover rates recommended by Walker Process Equipment match the minimum figures they have given, and only the high end of their range, a "G" value of 85, meets the minimum range given by US EPA. That being the case, what can be
said for a supplier who claims that he has a system that can produce adequate digester mixing with far less power? Are we to believe that claim?

Some researchers[5] have even suggested that a value of 0.30 HP/1000 cu ft to be too little to effect complete digester mixing. We do not agree with this position, since it can be construed as a diminishing returns phenomenon; better performance, perhaps, but with a high price to pay for little added return. However, it does underscore the wide range of opinions that exist on the subject.

## CONCLUSION

The traditional turnover rate method used successfully by Walker Process Equipment for many years compares favorably with the recommendations of Cooper and Tekippe, and actually falls below the power input values set forth by the US EPA. How can a supplier claim adequate digester mixing with less power than these values? One should beware of such claims!

They can probably point to installations where the digester is performing properly with this lesser power consumption, but the unknown factor is how much better the operation might perform with greater power input.

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