

## Pumping and Stirring of Anaerobic Straw and Liquid Animal Manure Substrate.

### **Introduction.**

A recent publication 02.12.2013 on agitators in biogas digesters by Andreas Lemmer et. all. (<http://www.mdpi.com/1996-1073/6/12/6255>) found little information on hand about the optimal choice of agitators and their setup in digesters, mixing intervals and the time required for optimal homogenization. By the end of 2012, approximately 7589 biogas plants (BGP) with an installed electrical capacity of 3179 MW have been in operation in Germany. Taking into account that approximately 8% of the produced electricity is used for BGP operation and 50% of this energy is used for agitation, calculations show that 1 billion kW h/a are used for agitation in German biogas stations.

Information on pneumatically agitated reactors is scarce. Airlift bioreactors and bubble columns are the two main types. Airlift bioreactors have superior performance. They all consist of a gas-sparged riser and an un-sparged downcomer. The difference in bulk density powers the circulation. Compared to conventional stirred fermenters, airlift devices require less power and are more mechanically robust.

Pressurized gas mixing mimics the air-lift pump. It provides above all a good axial flow with less wear and stress at a low investment cost, but compressors are energy consuming.

Headspace may also be introduced by a venturi effect created by a substrate circulation pump. Combigas near Tarm have successfully used this principle as

the only one for a year, but we have not yet found studies confirming its superiority or how to operate it optimally.



### **Pumping.**

A chopper non-clog pump like Flygt N-pumps provides trouble-free pumping with slurry containing fibrous agglomerates and



coarse components like bones from mink slurry. A YouTube video explains its function - <http://www.youtube.com/watch?v=yQLgFJ3T51Q>

A chopper pump can probably make a macerator redundant.

Eccentric screw pumps like Mohno pump are vulnerable and have a maintenance issue.

An important application for the chopper pump is for recycling substrate over the mix-tank. The mix tank receives – in the ESØ case - a steady feed of 33 t per hour of fresh slurry and straw briquettes in a ratio of straw to slurry of 1:10.

The straw briquettes will disperse within minutes and begin absorbing water. To maintain pumpability, substrate from primary reactors is cycled over the mix-tank continuously replacing the fresh feed. In the reactors equilibrium will be reached and straw will so to speak be saturated with moisture. Recycling substrate will bring down the ratio of straw to liquid in the mix-tank. The optimum ratio of fresh briquettes to fluid can be determined by testing, but as a starting point, a ratio 1:30 is supposed sufficient, requiring the recycling of 66 tons of substrate per hour ~ pumping a total of 100 t per hour.

By decanting the substrate and use the liquid phase recycling may improve, but there is probably no need for such precaution.

## **Agitation.**

### **Stirring as a precipitate counteract.**

There is a long tradition for using agitated anaerobic reactors. Ekato has successfully applied paddle types. Linko Gas a.m.b.a. has recently replaced side wall stirrers with a central paddle type agitator just in order to keep sand in suspension and avoiding a buildup of sand at the bottom. It requires emptying the tank completely every two years.

The largest source of sand is energy crops, which are not used in our process. During briquetting straw sand is removed in a sand trap making the briquettes low in sand. Slurry may contain sand, especially when using sand in cubicles. Such slurry has to be rejected or decanting applied. Foreign elements and to some extent also sand may be settled in the fresh slurry tank and removed at intervals.

Offal is known to settle and build up, but isn't used in our process.

A central paddle agitator may only require 15 kW, but it is difficult to transfer the torque to the reactor walls with planned reactor design.

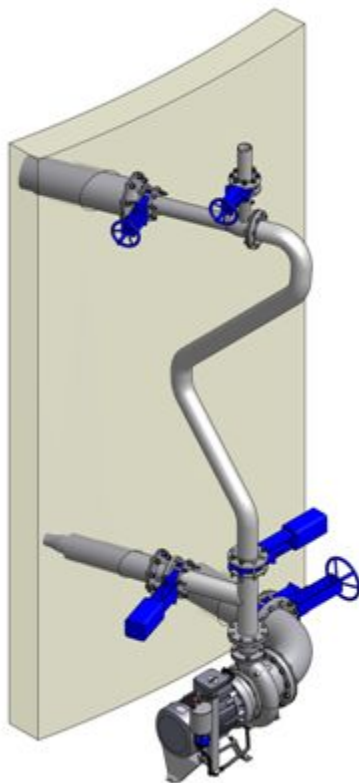


### **Stirring to counteract floating layer**

Straw and deep litter is known to form floating layers requiring agitation to cope with. The straw nodes tend to settle and form layers at the bottom. Briquetting, however, “break” both nodes and internodes of the straw keeping all parts suspended.

### **Interval stirring to save energy**

To save energy most fermenters are agitated at intervals only nowadays. The most recent fermenter put in operation last year is the EUDP-supported plant owned by Combigas. This plant is operated with interval stirring and with pumps only – with no stirrer otherwise. Twenty minutes stirring per hour.



### **Bubble Stirring**

Landia has supplied its GasMix system to Combigas. A video on YouTube explains the operation - <http://www.youtube.com/watch?v=42G8fU109Tw&feature=youtu.be>

The chopper pump draws sludge from the digester and pumps it through the aspirating venturi chamber.

Biogas is aspirated from the top of the digester, mixed with the sludge and injected into the tank.

Powerful mixing performance is ensured in all areas of the tank by one or more top gas/sludge ejector type nozzles and the bottom mixing nozzle.

The same GasMix system is used for mixing at the primary reactor at Foulum. They use a center agitator as well.

By stirring at intervals the amount of gas increases when the agitators are started. Analysis of the gas composition shows carbon dioxide as the cause – not the methane. Stirring releases carbon dioxide, thereby preventing acidification of the substrate. Carbon dioxide build up is more likely a problem in rich starchy feeds and of less importance in lean cellulosic feeds.

Bubbling of the substrate by headspace is useful for releasing carbon dioxide. Same effect may be obtained by spraying substrate on the top or into a tall unpressurized gas-filled chamber (a scrubber).



### **Stirring necessary**

At ComBigas bubble pumping (GasMix) provides sufficient stirring and one third of the time is enough. For a 2,500 m<sup>3</sup> reactor two pumps one with 18.5 kW and one with 30 kW motor are sufficient. The feed at Combigas contains plenty energy crops, bedding, straw and slurry of course.

Straw and manure form a stable suspension that does not require agitation to prevent settling or floating layer.

Released gas that bubbles up through the substrate, and the daily replacement of the substrate provides some minimal agitation. For the sake of mixing and effective inoculation of fresh feed there is no need for more mixing than takes place in the mix tank. Further agitation to maintain the suspension in the reactor is hardly necessary, but may be needed to keep carbon dioxide in control.

Supply of headspace and more out-and intakes for the recycling of substrate in the reactors should be prepared.

### **Testing**

The primary reactor at Foulum has - as it is - the necessary equipment for the verification of stirring need assumptions, preferably as long as the current straw manure feeding is in progress.

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Patent application 28.09.2012 GAS MIX INSTALLATION AND METHOD

Pub. No.: WO/2013/044926

[http://patentscope.wipo.int/search/en/detail.jsf?docId=WO2013044926&recNum=9&docAn=DK2012050364&queryString=\(FP/biogas\)%20&maxRec=539](http://patentscope.wipo.int/search/en/detail.jsf?docId=WO2013044926&recNum=9&docAn=DK2012050364&queryString=(FP/biogas)%20&maxRec=539)

<http://www.google.com/patents/WO2013044926A1?cl=en>