Design, planning and process engineering
Part II

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Int. Biogas Planning Course, March 27th – 30th , 2012
University of Hohenheim, Stuttgart

AKADEMIE FÜR ERNEUERBARE ENERGIEN

Milestones

2011 – date Researcher, University of Applied Science and Arts, Goettingen,
Biogas Process Engineering, currently: Dynamic Percolation

2008 – date Associate Professor, Akademie für Erneuerbare Energien, Luechow,
www.akademie-ee.de
Seminars: Biomass for Energy, Facility Design, Construction, Bio-Fuels

2006 – date Senior Consultant, Krieg & Fischer Ingenieure, Goettingen,
www.kriegfischer.de
Education of engineers, waste technology

Krieg & Fischer Ingenieure GmbH

1999 – 2006 Foundation of Krieg & Fischer Ingenieure, Goettingen,
HRM, Head of Construction Division, Financial Accounting

1990 – 1998 Employed at several companies, farm-scale biogas plants in Germany,
collaboration with German Biogas Dissamination Projects, concept studies, evaluation of biogas projects in Africa and South-East-Asia,

1990 Co-founder of German Biogas Association, Freising,
www.biogas.org

Fachverband Biogas e.V.

General Outline

- Designing failures

  Substrate
  Mass balance

- Technical failures

  Construction
  Piping
  Pumps and Conveyors
  Fluid Input Device
  Mixer

Substrate I

Effluents from Animal Housekeeping:

- Feaces, urine,
- bedding material,
- waste water,
- **trash**

Municipal organic solid waste from:

- Food industry, Markets
- Kitchen, Restaurants, Catering,
- Gardening, Greenery, Parks

possibly including any kind of **trash**

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Substrate I, Parameters I-I

Effluents from Animal Housekeeping:

- Animal species, feed base
- If bedding material, what kind
- Age of Effluents (Maturity)
- TS, VS, TKN, Alkalinity, Particle size
- Kind and amount of Impurities (chains, ropes, fork-tines, stones)
- Load curve (differences in time and quantity)

Substrate I, Parameters I-II

Municipal organic solid waste:

- Pretreatment at source (Separation)
- Kind of Package
- Particle size
- Quantity of trash (metals, glas,chinaware, wires, ropes, stones)
- Load curve (differences in time and quantity)

Substrate II

Liquid food waste, e.g.:

- Spoilt juice,
- Expired beverages,
- Liquid by-products,
- Waste water with high COD

mostly only VS, no fibrous solids

Energy crops, e.g.:

- Maize,
- Beets,
- Potatoes,
- Spoilt Crops, non-food-biomass

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Substrate II, Parameters II-I

Liquid food waste:

- History of origin
- Chemical composition:
  - TN, TKN, Ammonia-N
  - Phosporus (Total)
  - Sulfate, Sulfide (Total)
  - TOC
  - Alcalinity (as CaCO3), pH-value
- Concentrations:
  - Total Solids, TDS, Volatile Solids, Ash Content
  - COD (soluble), (total), BOD (soluble)
- Quality:
  - Protein, Fat, Carbohydrates, Calories
- Load curve (differences in time and quantity)

Substrate II, Parameters II-II

Energy crops:

- Chemical composition:
  - Nitrogen (Total)
- Concentrations:
  - Total Solids, TDS, Volatile Solids, Ash Content
- Quality:
  - Protein
  - Fat
  - Carbohydrates
  - Crude Fibre,
  - Lignin, mineral fraction (e.g. sand)
  - Calories
- Particle size
- Load curve (differences in time and quantity)

Intermediate Result I

Substrates:

– Anticipatory substrate- (waste-)management
what, when, how much
quality control

– Buffer tanks as required (at first, in between, at last)

– Blend of different substrates
(in case of straight composed waste)

– Operation control

Beware of trash !

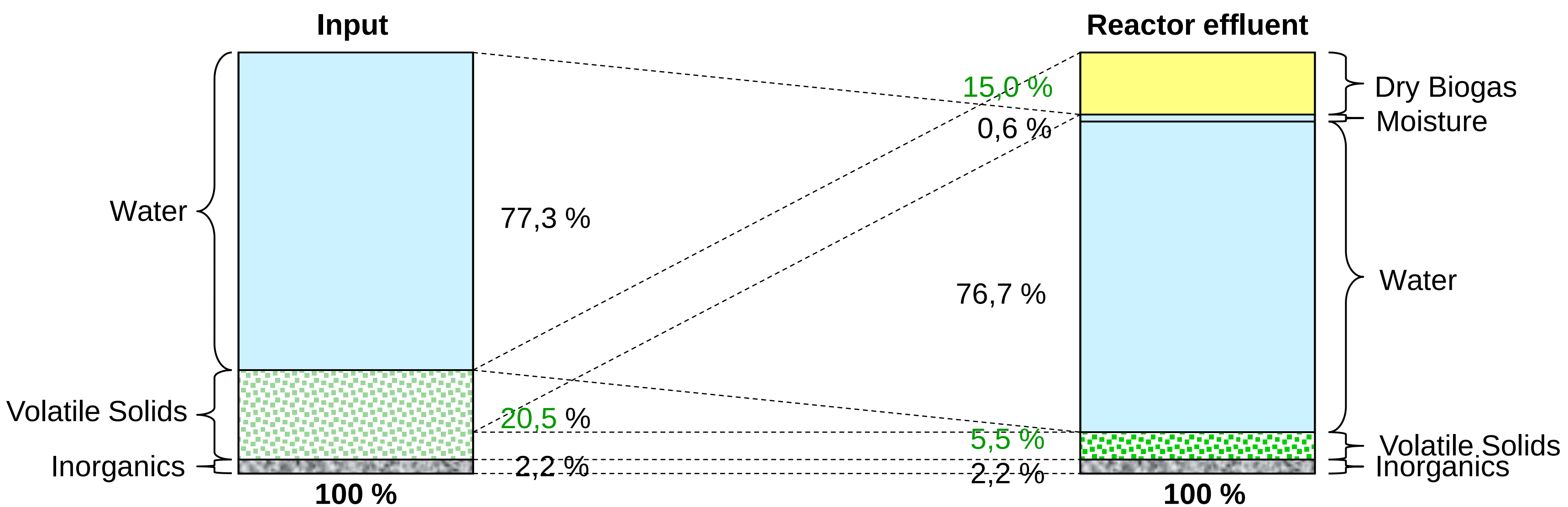
If you follow this, AD will produce biogas (energy) ongoing, as precalculated.

Dimensioning I Mass Balance I (Example)

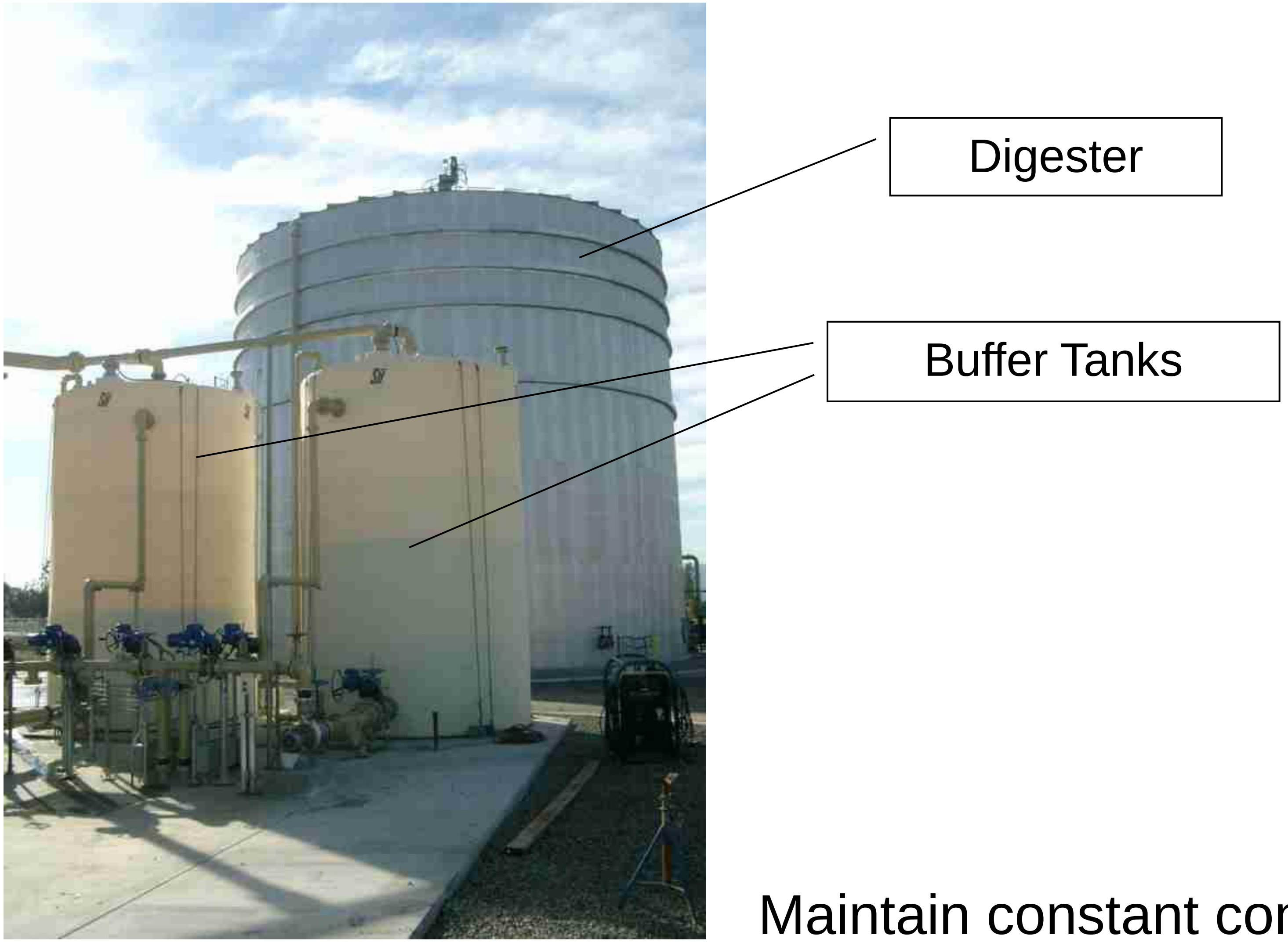
Input		Starch	Oil	Raw Potato	Sludge	Total
Input (t/a)		4.495	636	97.610	6.583	**109.324**
Input (t/d)		12,32	1,74	267,42	18,04	299,52
Total solids (%)		60,0%	100,0%	20,0%	30,0%	**22,7%**
Total solids (t/a)		2697,0	636,0	19522,0	1974,9	24829,9
Total solids (t/d)		7,4	1,7	53,5	5,4	68,0
Volatile solids (% TS)		90,0%	95,0%	90,0%	90,0%	**90,1%**
Volatile solids (t/a)		2.427	604	17.570	1.777	22.379
Volatile solids (t/d)		6,7	1,7	48,1	4,9	61
Water (t/a)		1.798	0	78.088	4.608	84.494
Water (t/d)		5	0	214	13	231
spec. Gas Production rate (m³/t VS)		600	1.000	600	700	
(dry gas, Normal conditions	1,18 kg/m³					
Biogas						
Gas production (m³/a)		1.456.380	604.200	10.541.880	1.244.187	13.846.647
Gas production (m³/d)		3.990	1.655	28.882	3.409	37.936
Gas production (t/a)		1.719	713	12.439	1.468	16.339
Gas production (t/d)		4,71	1,95	34,08	4,02	44,76
Water content:	4%	69	29	498	59	654
Wet Gas 37°C (t/a)		1.787	741	12.937	1.527	16.993
Wet Gas 37°C (t/d)		4,90	2,03	35,44	4,18	46,56

Dimensioning I Mass Balance II (Example)

Reactor effluent						
Total solids (t/a)						8.491
Total solids (t/d)						23
Volatile solids (t/a)						6.040
Volatile solids (t/d)						17
Water (t/a)						83.841
Water (t/d)						230
Output (t/a)				6 Monate:	46.166	92.331
Total solids (%)						9,2%



Dimensioning II Technical Aspects I



Maintain constant composition

Andreas Krieg MSc Associate Professor

Dimensioning II Technical Aspects II

Maintain constant feed

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Dimensioning II Technical Aspects III

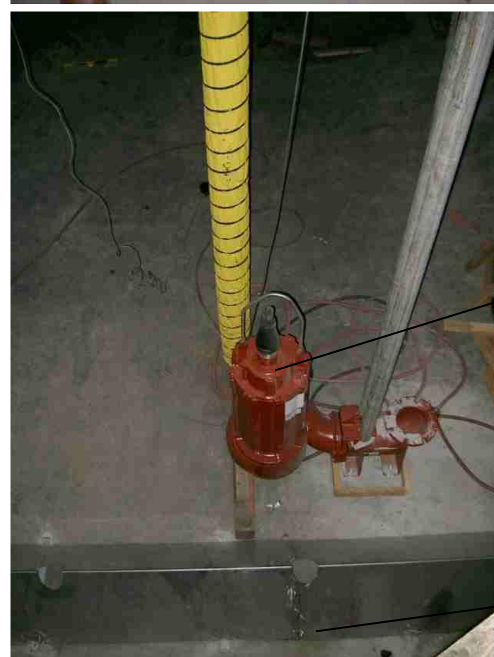
Sedimentation

Grit removal

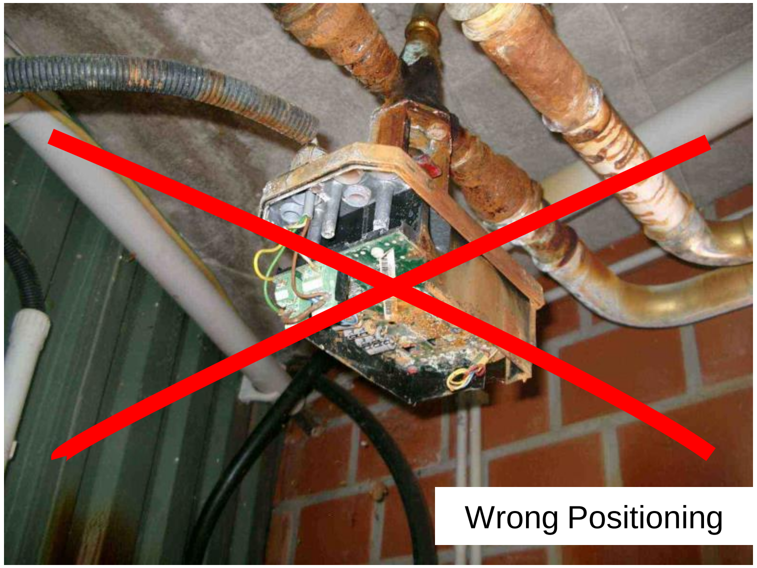
Maintain constant operation

Dimensioning III Reliable Technology (Example)

Food waste injection point



Dimensioning IV Approved Fitting and Piping


Wrong Positioning


Correct Positioning

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Dimensioning V Digester design

WHAT FOR – Decision !

- Waste water, 100 % SS, no solid matter
  - → Fixed bed reactor, fixed biomass
  - → Floating slugde, restrained biomass
  - → Completely mixed with biomass recovery

- Slurries, solid matter < 10 %
  - → Completely mixed tank
  - → Plug flow design

- Dung, Organic waste, Silage, solid matter > 20 %, fibrous matter
  - → Diluted matter (Dilution mostly via recirulation of digestate = Inoculation)
    - → completely mixed
    - → partly or intermittent mixed
    - → plug flow design
  - → Inoculated matter (normally blend of fresh and digested solids)
    - → solids stationary, circulated liquid
    - → plug flow design

Intermediate Result II

7 rules to run a digester

- Maintain constant feed rate and composition
- Avoid overfeeding and abrupt changes
- Avoid foaming
- **Don´t:** add substrate with a low pH value
  add substrate with a considerably high protein content
  overfeed the digester
  mix improper and/or inconsistent
- Choose an appropriate temperature and keep it constant
- Mix as much as necessary and as little as possible
  Keep in mind: all in - all out.
- Maintain continuous mixing

!

Construction

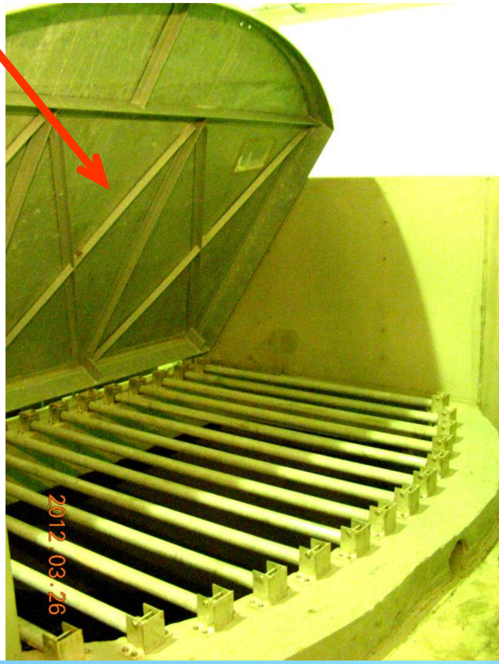
How to differentiate the tanks ?

1. By function

2. By material
   - Concrete (in situ; precast; pre-stressed)
   - Steel (glass coated steel; stainless steel)
   - Others (fiberglass)

   in particular cases: Brick, PE, Synthetic rubber

Reception Tank



Digestate and
Gas Storage

Concrete or Steel Tank ?

- Concrete:
  - \+ high compression strength
  - \+ easy installation of tank equipment (no/low static concerns)
  - +/- cheap
  - \- in situ construction: quality management

- Steel:
  - \+ high tensile strength
  - \+ easy to manufacture
  - \+ easy quality control
  - \- all static and dynamic loads on the tank defined for design in beforehand
  - \- unexpected loads (mostly underpressure) leads easily to demolition

Concrete or Steel Tank ?

- Main argument is the price – if the design is done properly
- Typical types of use
  - Concrete tanks as storage tanks or flat digester: diameter up to 32 m; height up to 8 m
  - Concrete tanks as high digester: height up to 14 m by 15 m diameter
  - Steel tanks as high digester: height up 20 m by 19 m diameter

Construction failures

Holes in the tank wall !?

- Iron mold too hot
- water in the ready-mix-concrete insufficient

Construction failures

Seal of fittings in the wall insufficient

Too large Crack Width
(e.g. inadequate reinforcement)

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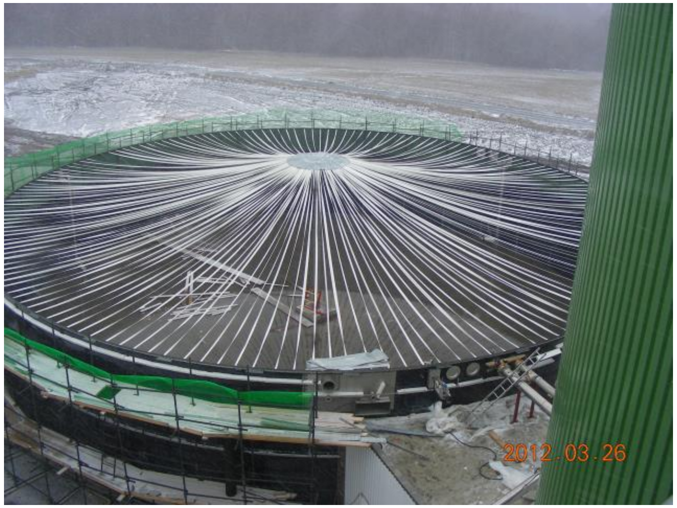
Construction failures

Unexpected loads on the wall (Importance of safety factor)

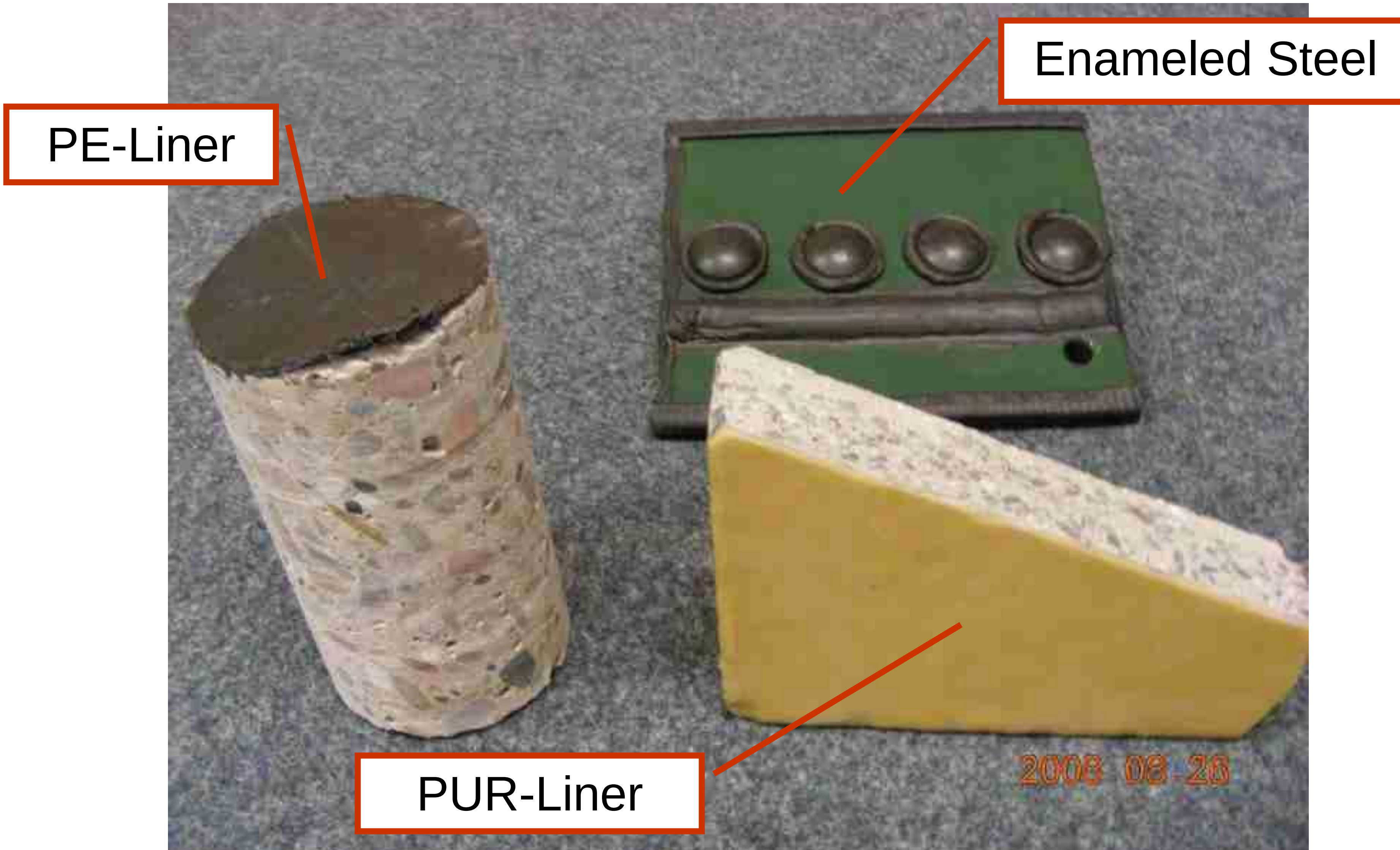


Construction failures

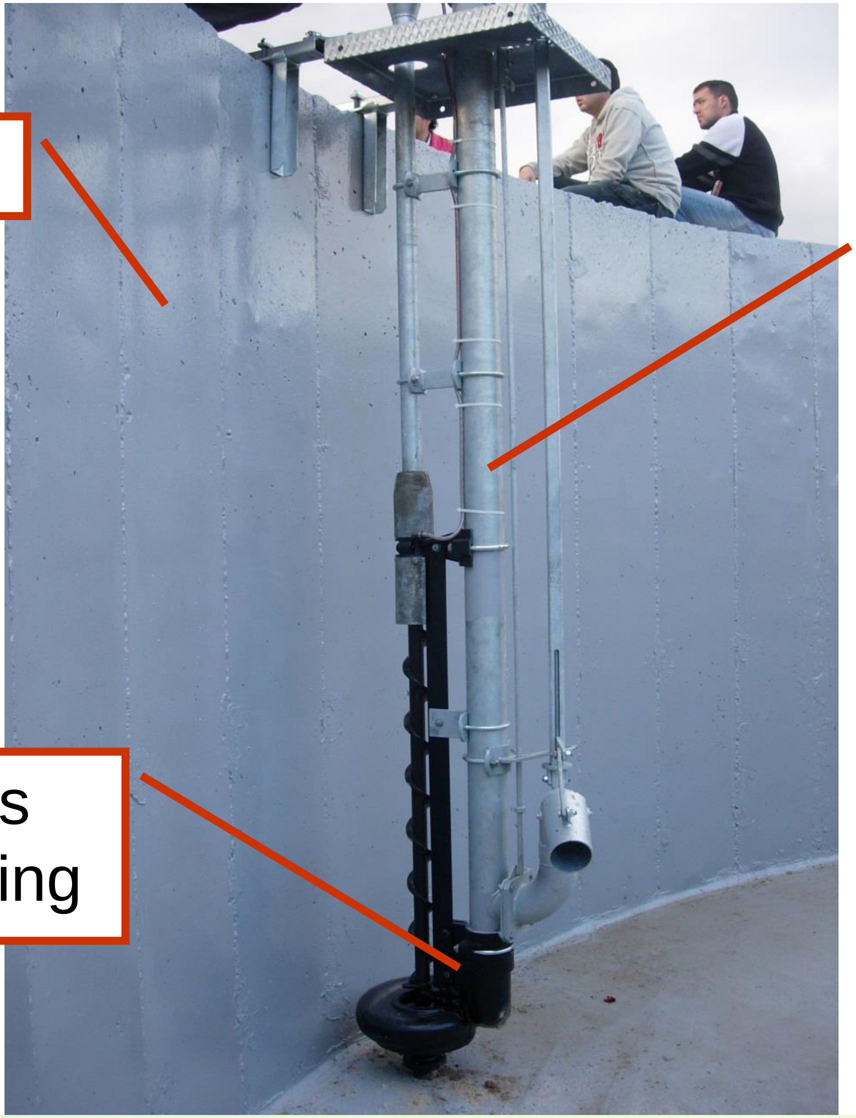
Chemical Corrosion

Construction failures

Corrosion Protection



Corrosion Protection: Concrete, Pump



Piping

	Biogas	Hot water	Substrate
Above ground	stainless steel	PP / mild steel	PVC / PE / PP mild steel
Below ground	PE	PP / mild steel (with plastic coating)	PVC / PE / PP

Piping

Pipes made of PE

(+) Medium- and UV resistant

(+) Connections defined to be unbreakable

(+) Cheap

(-) Temperatures > 60° C

(-) Easily deformed
by pressure

Major Problems of Plastic Pipes

(If application is inadequate)

Diffusion of inorganic compounds
(Example: internal heating pipe)

Demolition by hot water and high pressure

Piping

Pipes made of PVC

(+) Medium resistant

(+) Easily assembled by adhesive – bonded joint

(+) Cheap

(-) Not UV resistant

(-) Brittle at low temperatures

(-) Less aging-resistant than other materials

(-) Temperatures >60° C

Piping

Pipes made of mild steel

(+) Temperature resistant

(+) Easily assembled

(+) Very flexible installation

(+) Long life

(-) Less medium resistant than pipes made of plastic

(-) Corrosion

Piping

Pipes made of stainless steel

(+) Very long life

(+) Temperature resistant

(+) Medium resistant

(+) Thermal conductivity

(-) Expensive

(-) No installation underground (without coating!)

Piping

Under Construction pay attention to

- Mechanical damage
- Visible tank openings
- Correct assembling and tightness by manufacturer
- Frost protection

Pumps and Conveyors

Types of Pumps

- Positive-displacement pump
  - → helical rotor pump
  - → rotary lobe pump
  - → piston pump
- Centrifugal pump

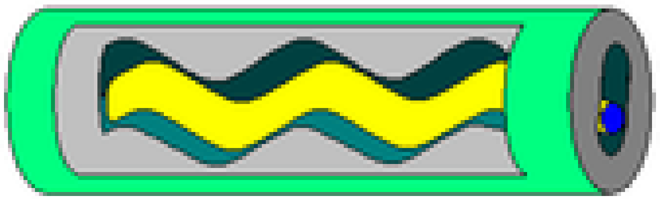
Pumps and Conveyors

Helical rotor pump / Piston pump

(+) Substrates with high dry matter contents

(+) Self – priming pump

(+) High discharge pressures (up to 24 bar)

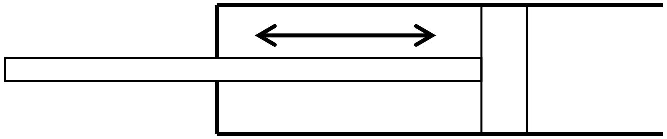


(-) Minor flow rate

(-) Long fibred materials

(-) High abrasion wear

(-) Assembly length



Pumps and Conveyors

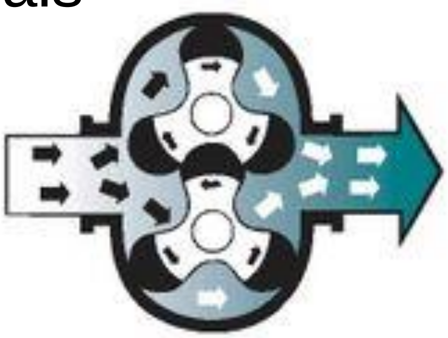
Rotary lobe pump

(+) Self-priming

(+) Bigger particles and long fibred materials

(+) Pumping capacity about 800 m^3/h

(+) Discharge pressures to 12 bar



(-) High abrasion wear

Major Problems of Positive-displacement Pumps

(If application is inadequate)

Abrasion

e.g. stones

e.g. robes and wires

Pumps and Conveyors

Centrifugal pump

(+) Good knowledge and experience

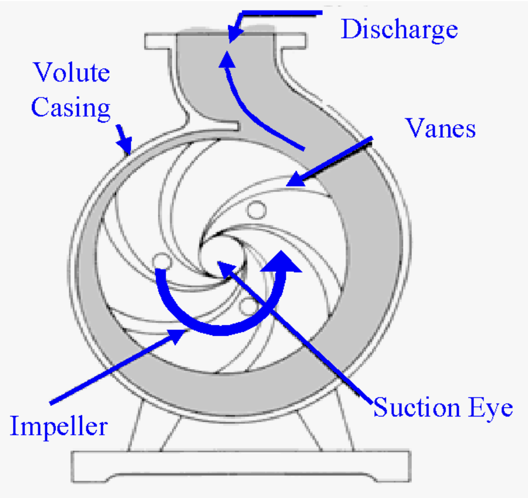
(+) Simple and tough construction

(+) High flow rates

(-) Minor total solid content

(-) Low discharge head

(-) Not self-priming



Major Problems of Centrifugal Pumps

(If applicaton is inadequate)

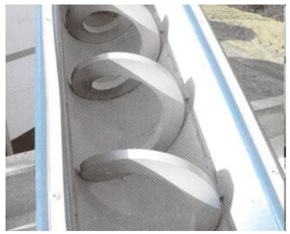
Corrosion/Abrasion

Blockage

Pumps and Conveyors

Straight input of solids:

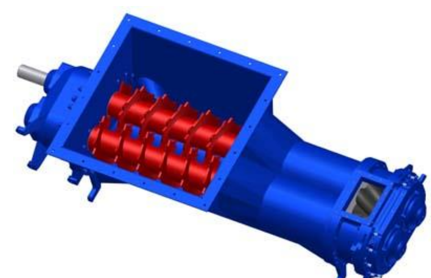
- Screw



Liquefied input of solids:

- Mixing Pit

- Fluid input device



Screw Conveyor

(+) For bulk material, chopped energy crops

(+) Low Investment

(+/-) Reliable on free flowing substrates only (e.g Corn silage)

(-) Not for greasy stuff (e.g. Dung with less straw)

(-) High abrasion

(-) Max. 12 m vertical height

Mixing Pit

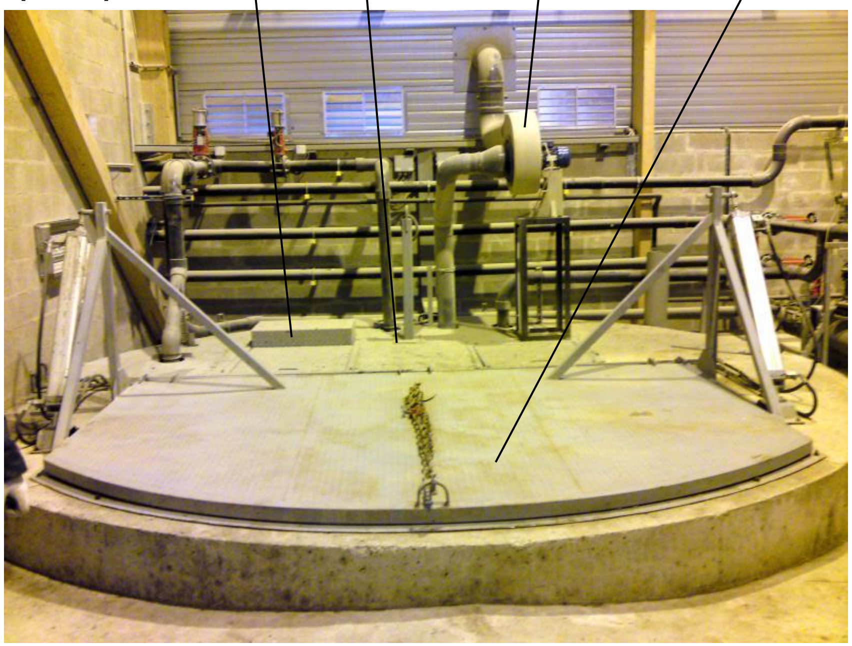
(+) For all kind of chopped solid substrates and slurries

(+) Unsusceptible at presence of contraries

(-) Dilution of solids necessary, below 12 % TS (Depending on pump design)

(-) Restricting factor is capacity of mixer

(-) Emissions during operation



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Mixing Pit

Partly back-flow

Submerged Pump

Mixer

Fluid Input Device I

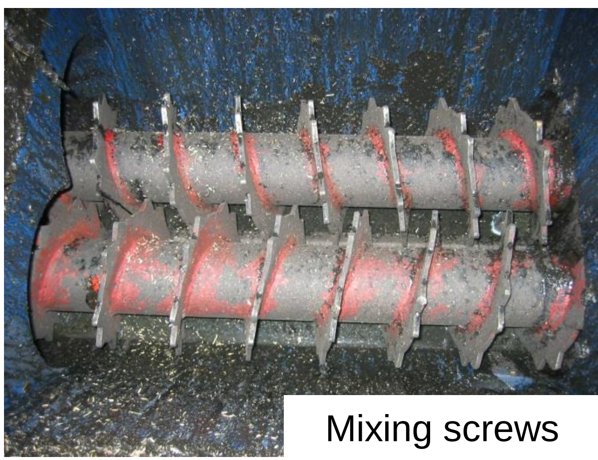
(+) For chopped energy plants or solid waste as well as slurries

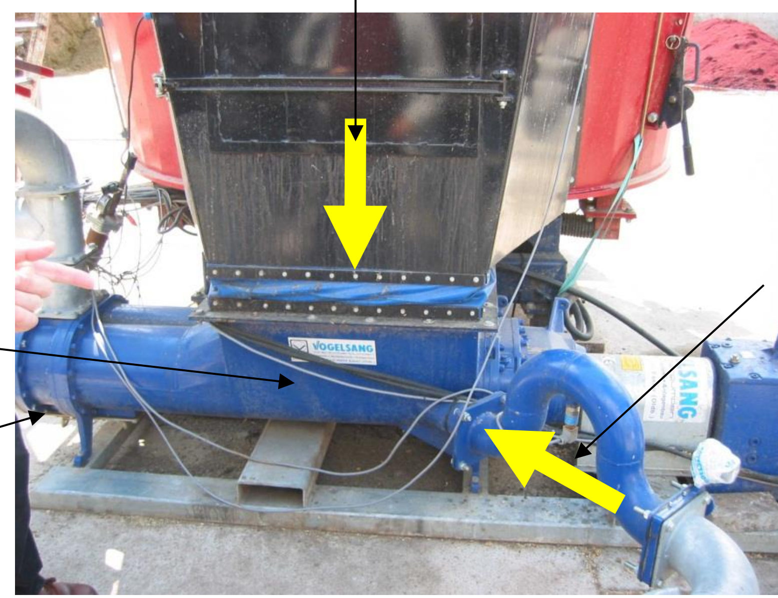
(+) Usable for any design of digesters

(-) Dilution of solids necessary, until below 15 % TS (dep. on pump design)

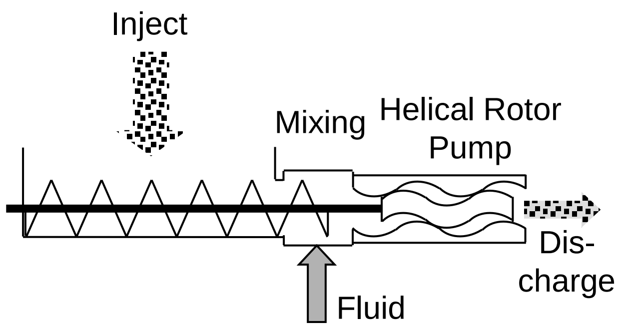
(-) Sensitive to stones and trash

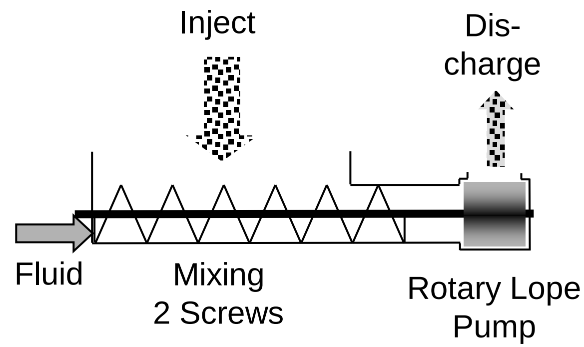
(-) High abrasion at presence of sand or the like

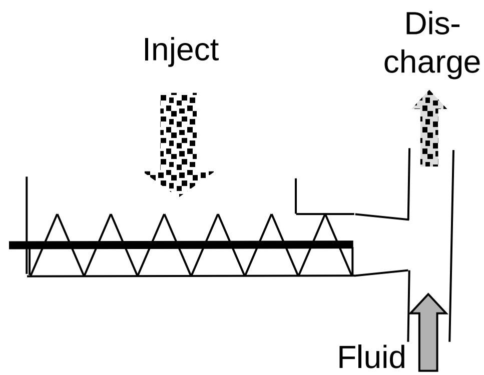




Fluid Input Device II – technical variants







(+) High pressure
(+) DM in Discharge ≤ 15 %

(+/-) Blockage, depend on Pump size

(-) Abrasion

(+) Medium pressure
(+) DM in Discharge ≤ 12 %

(+/-) Blockage, depend on Pump size

(-) Abrasion
(-) Odour in Mixing chamber

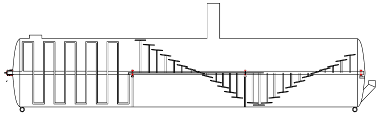
(+) No extra Pump
(+) Less risk of blockage

(+/-) Pressure ≤ 0,5 bar
(+/-) DM in Discharge ≤ 10 %
(+/-) Low Abrasion

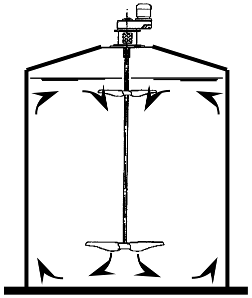
(-) Only for flat digesters
(-) Only for fibrous substrate

Type of Digester, Agitator, Mixer

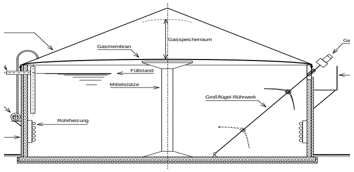
- Horizontal digester
  plug flow, vertical mixing
  bypass reduced by high viscosity



- High upright digester
  complete mixing, homogeneous
  temperature, bypass possible



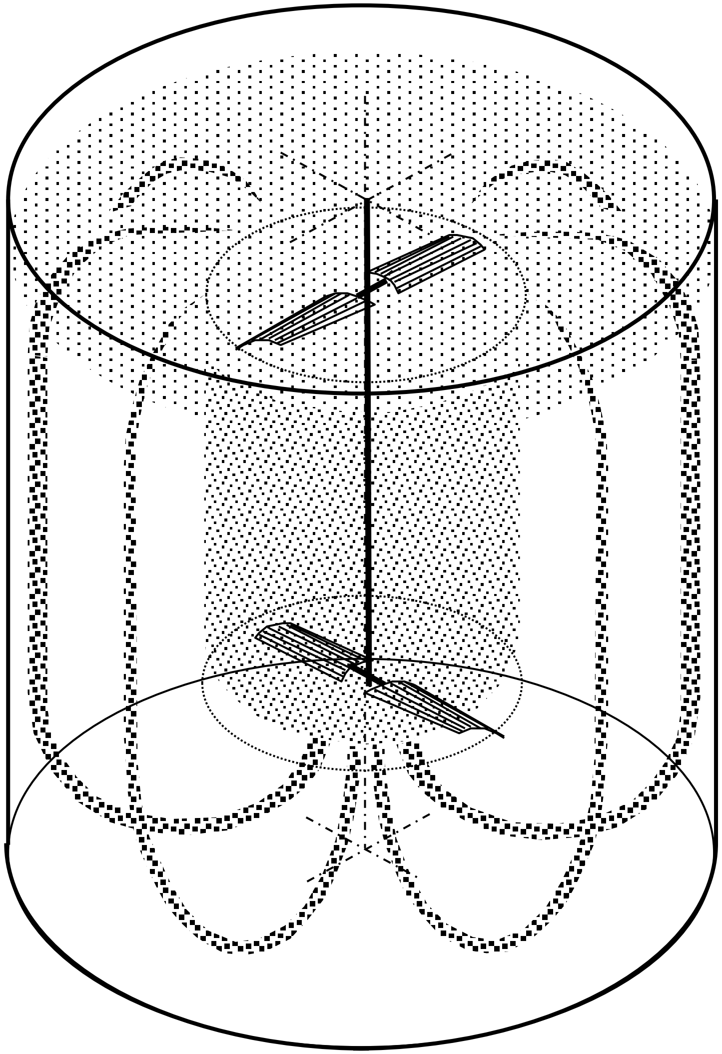
- Flat upright digester
  less mixed, zoning possible,
  bypass possible



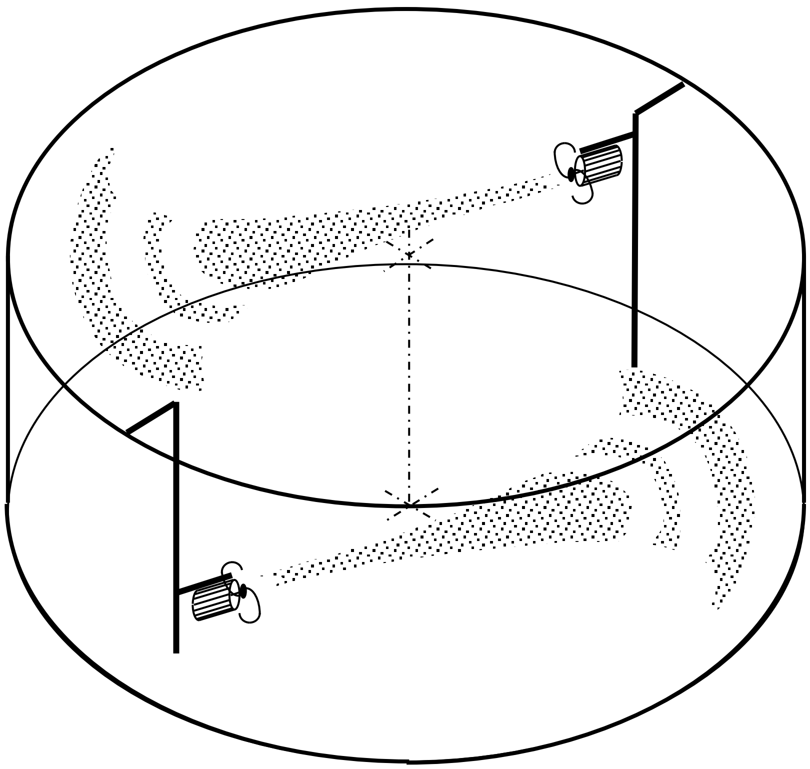
Tall Digester, Top Mounted Mixer

Operation Top Mounted Mixer

- Permanent=24 h/d
- 13-18 rds/m
- 11,5 – 30 KW
- Frequency inverter for low energy consumption



Flat Digester, Submerged Mixer



Submerged Mixer, Problem

Insufficient Mixing

Submerged Mixer, Problem

Corrosion, Abrasion

Submerged Mixer, Problem

Complex repair and maintenance regarding personal security and emissions

Nowadays submerged mixer are used like disposables

Risks of all mixed Digester:

- underpowered Mixer / Agitator
- Wrong positioned M. / A.
- Digest substrates for what Mixer is not designed
- No consideration of chances in density / release of sand / stratification of substrates during digestion

Intermediate Result III

You have to consider:

- ☞ Quality of the media (transported, mixed and stored)
  + structure, + viscosity, + abrasiveness,
  + temperature, + pressure, + pH-value, + stratification risk

- ☞ Changes in composition during AD of the media

- ☞ Quality of construction and technical equipment
  + acid protection, abrasion protection

- ☞ Dimension and Design of the equipment
  + reserve capacity, + sufficient internal cross section surface / volume, sedimentation zones

- ☞ Easy and safe maintenance and repair

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Design, planning and process engineering
Part II

Thank you for listening