

**SB Engineering  
SB 250 Slurry separator**

**Verification Report**





#### **Document information**

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## **2 INTRODUCTION**

Environmental technology verification (ETV) is an independent (third party) assessment of the performance of a technology or a product for a specified application, under defined conditions and quality assurance.

This document is the verification report resulting from the test and verification of a specific slurry separator, SB 250.

### **2.1 Name of product**

The product for verification was SB 250 slurry separator.

### **2.2 Name and contact of vendor**

SB 250 slurry separator is developed and produced by SB Engineering Aps, Bjerregaardsvej 10, DK-9620 Aalestrup, Denmark. Contact person is Søren Brams. Phone: +45 9864 3178. E-mail: [mail@sbrams.dk](mailto:mail@sbrams.dk).

SB 250 is also marketed by AL-2 Agro, Kroegebaekvej 25, DK-6682 Hovborg, Denmark. Contact person is Preben Nissen. Phone: +45 3169 6501. E-mail: [pbn@al-2.dk](mailto:pbn@al-2.dk).

### **2.3 Name of verification centre and verification responsible**

Verification centre: DANETV, Test Centre AgroTech, Udkaersvej 15, DK-8200 Aarhus N, Denmark.

Verification responsible: Thorkild Q Frandsen. Phone: +45 8743 8468. E-mail: [tqf@agrotech.dk](mailto:tqf@agrotech.dk).

### **2.4 Verification and test organization**

The verification was conducted by Danish Centre for Verification of Climate and Environmental Technologies, DANETV, which performs independent tests of technologies and products for reduction of climate changes and pollution.

The verification was planned and conducted to satisfy the requirements of the ETV scheme currently being established by the European Union (EU ETV).

An internal and an external technical expert have provided independent review of the planning, conducting and reporting of the verification and tests.

An overview of the organisation associated with test and verification is given in figure 1.

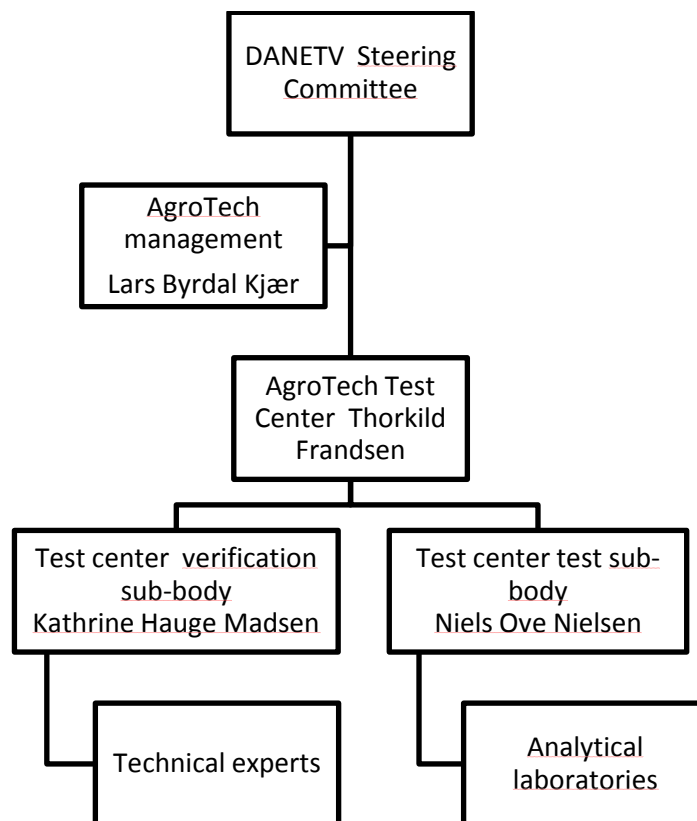


Figure 1. Organisation of test and verification

## 2.5 Technical experts

The technical experts assigned to this verification and responsible for review of the verification plan and report documents include:

Internal expert: Bjørn Hjortshøj Andersen, AgroTech, Udkaersvej 15, DK-8200 Aarhus N, phone: +45 8743 8420, e-mail: [bha@agrotech.dk](mailto:bha@agrotech.dk).

External expert: Maibritt Hjorth, Aarhus University, Faculty of Agricultural Sciences. E-mail: [Maibritt.Hjorth@agrsci.dk](mailto:Maibritt.Hjorth@agrsci.dk). Phone: +45 8999 1932.

## 2.6 Verification process

Verification and tests was conducted in two separate steps, as required by the EU ETV. The steps in the verification are shown in Figure 2.

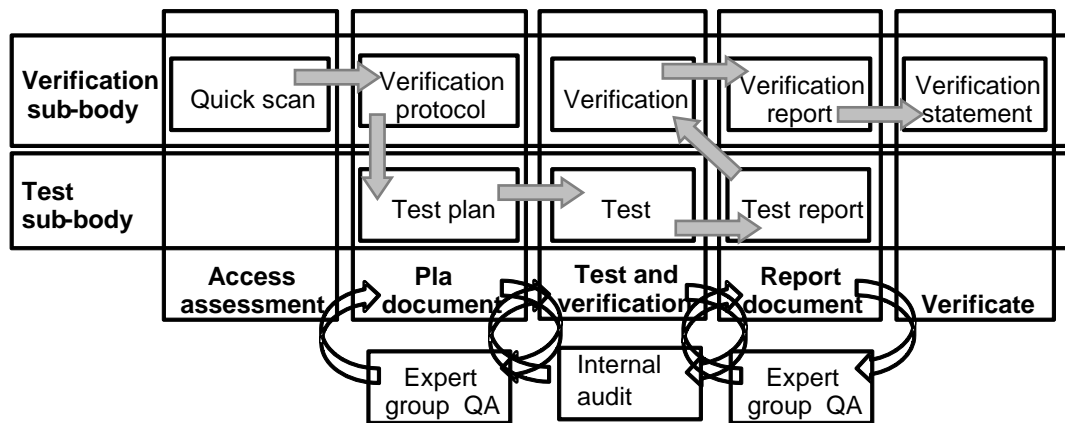


Figure 2. Verification steps.

The verification process is described in the AgroTech Test Centre Quality Manual [2].

This verification protocol, the test plan and the AgroTech Test Centre Quality Manual shall be seen as one consolidated verification description.

### 3 DESCRIPTION OF THE TECHNOLOGY

Slurry separation technologies divide slurry (liquid livestock manure) into one (or more) solid fraction(s) and one (or more) liquid fraction(s). The solid fraction is characterized by high dry matter content and a higher concentration of phosphorous and organic nitrogen compared to the un-treated slurry.

Separation of slurry can be done using a wide range of techniques. For instance, screw presses, mechanical screen separators, sedimentation techniques, decanter centrifuges, chemical treatment and reverse osmosis.

In most cases these techniques function as end-of-pipe systems meaning that the slurry from all animal houses on the farm is gathered in a collection slurry tank and then led into the separator. However, separation can also be achieved using special designed floors in the animal houses so that the urine and the excrements are separated immediately after leaving the animals (in this context referred to as in house slurry separation).

This verification protocol is intended for end-of-pipe separation systems only.

### 4 DESCRIPTION OF THE PRODUCT

SB 250 is a slurry separator of the screw press type. This separator is functioning mechanically and no additives are used in the process. The SB 250 separator used for the test is installed in a container at a commercial farm. However, SB 250 can also be delivered as a mobile unit if the separator is intended for use at more farms.

Slurry is led to the screw press from a small slurry collection tank or directly from the slurry channel in the animal house.

The slurry is transported into a cylindrical screen with a screw. The diameter of the openings in the screen of the separator tested is 250  $\mu\text{m}$  (this is reflected in the name of the model, SB 250). However, the screen can easily be replaced with screens with other diameters. Normally screens with selected diameters within the range of 250  $\mu\text{m}$  and 1000  $\mu\text{m}$  are used when slurry is separated.

The liquid passes through the screen and is collected in a container surrounding the screen. To remove even more liquid the solid fraction is pressed against a plate at the end of the axle. The solid fraction drops out from the opening between the plate and the opening of the cylindrical mesh. Figure 3 is a schematic illustration of a typical screw press [1].

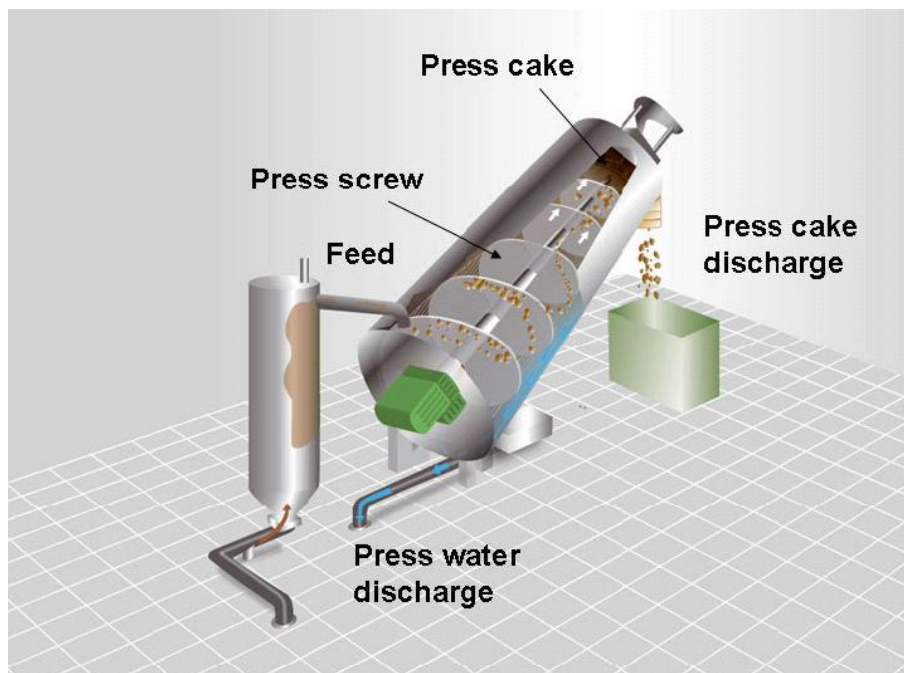


Figure 3. A typical screw press [1].

From the screw press the solid fraction is transported to a closed container. On the test site the container has a capacity of approximately 8 tonnes. When the container is full it is transported to an anaerobic digestion plant where the solid fraction is used as substrate for biogas production.

The liquid fraction is pumped from the separator to a big storage slurry tank with a cover. Here the liquid fraction is stored and later applied to land as liquid manure. In figure 4 the SB 250 separator installed in a container is shown.

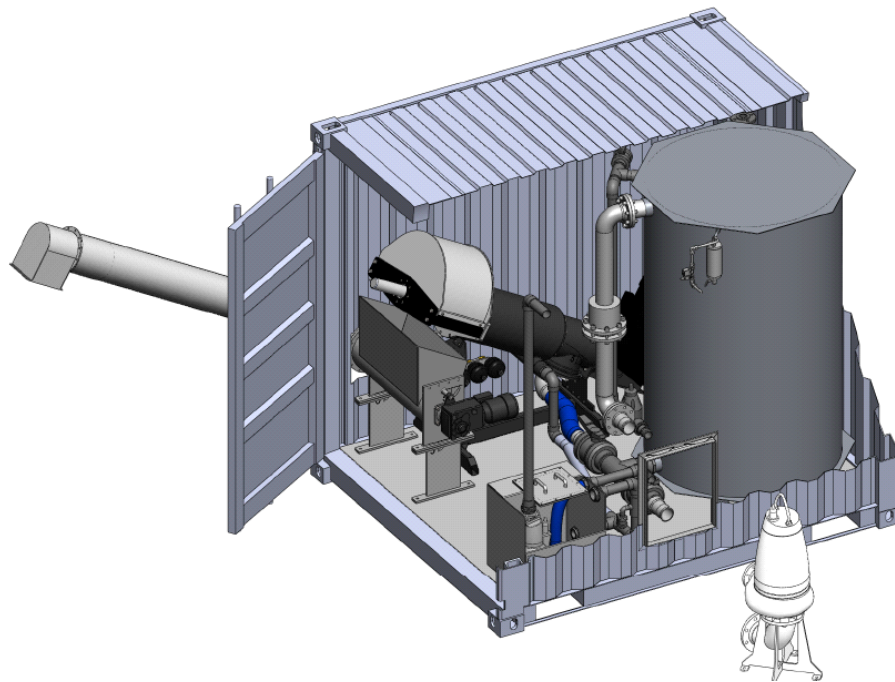


Figure 4. SB 250 installed in a container.

## 5 APPLICATION AND PERFORMANCE PARAMETERS

The intended application of the SB 250 is defined in terms of the matrix, the target and the effect of the slurry separator.

The matrix is the type of material that the product is intended for. Targets are the measurable properties that are affected by the product for verification (SB 250). The effects describe how the targets are affected by the product (SB 250).

A detailed description of the application is given in Appendix 3 – Application and performance parameter definitions.

### 5.1 Matrix

The SB 250 separator was verified for separation of regularly mixed cattle slurry representing prevalent combinations of cattle housing systems, management systems and feeding strategies in Denmark, Germany, the Netherlands and other countries with similar cattle production systems. Normally the dry matter content of such cattle slurry is between 6,5 and 10 % TS.

### 5.2 Targets

In the case of SB 250 the targets of the application are:

- Concentrations of total solids (TS) and volatile solids (VS) in input slurry, liquid output fraction and solid output fraction.

- Concentrations of total-nitrogen, ammonium-nitrogen, phosphorous (P) and potassium (K) in input slurry, liquid output fraction and solid output fraction.
- Weight of input slurry, liquid output fraction and solid output fraction.
- Methane yield of solid fraction resulting from separation of cattle slurry.

### 5.3 Effects

In the case of SB 250 the effects were:

- Increased concentrations of total solids (TS) and volatile solids (VS) in solid fraction compared to input slurry.
- Increased concentrations of total-nitrogen and phosphorous (P) in solid fraction compared to input slurry.
- Increased methane yield of solid fraction per unit of weight compared to slurry.

Based on the weights of input slurry, liquid fraction and solid fraction and the measured concentrations of TS, VS and nutrients in the input and output fractions mass balances and separation efficiencies were calculated.

### 5.4 Performance parameters for verification

The performance parameters provide the relevant information on the performance of the technology product. In the case of the SB 250 separator the performance parameters were:

- Separation efficiency with respect to total solids (TS), volatile solids (VS), total nitrogen (N), phosphorous (P) and potassium (K).
- Concentration of total solids (TS) in liquid output fraction after separation (%)
- Methane yield of the solid output fraction (Nm<sup>3</sup>/ton of solid fraction)

In this verification the *recovery factor* expresses the proportion of a given component in the input slurry that end up in a specific output stream. The recovery factor is expressed as a percent.

Here the recovery factor is calculated this way:

$$RF_i^{S,L} = \frac{(M^{S,L} \times C_i^{S,L})}{(M^{input} \times C_i^{input})} \times 100$$

Where:

$RF_i^S$  = Percent of component *i* in input slurry recovered in solid fraction.

$SE_i^L$  = Percent of component *i* in input slurry recovered in liquid fraction.

$M^{input,S,L}$  = Mass of input slurry (input), solid (S) and liquid (L) output fractions respectively.

$C_i^{input,S,L}$  = Concentration of component *i* in input slurry (input), solid (S) and liquid (L) output fractions respectively.

In this verification *separation efficiency* is defined as the recovery factor for the solid fraction. Thus, separation efficiency is a measure of the proportion of a given component in the input slurry that ends up in the solid fraction (expressed as a percent).

The claims put forward by the manufacturer, SB Engineering, are:

Table 1. Performance claims for this application of SB 250 by the manufacturer, SB Engineering.

Performance parameter	Claim
Total nitrogen separation efficiency	Min. 18 %
Total phosphorous separation efficiency	Min. 30%
Total solids separation efficiency	Min. 40 %
Volatile solids separation efficiency	Min. 50 %
Total solids concentration in liquid fraction	Max. 5 %
Methane yield of the solid fraction	Min. 45 Nm <sup>3</sup> CH <sub>4</sub> / ton solid fraction

In order to verify the performance claimed by the manufacturer a number of parameters had to be measured during the test. In table 2 below the primary measurement parameters are presented. For each parameter it is noted how many samples that were taken, where the samples were taken and the measuring method used.

Table 2. Primary measurement parameters.

Parameter [Unit]	Numbers of samples	Measured in	Measuring method
Total solids, TS [Kg/ton]	1 per day from each stream in 5 batches.	Slurry, liquid and solid output fraction	EØF 103°C
Total volatile solids, VS [Kg/ton]	1 per day from each stream in 5 batches.	Slurry, liquid and solid output fraction	DS 204
Total nitrogen [kg/ton]	1 per day from each stream in 5 batches.	Slurry, liquid and solid output fraction	Kjeldahl/Dumas
Ammonium nitrogen [kg/ton]	1 per day from each stream in 5 batches.	Slurry, liquid and solid output fraction	71/393/EØF
Mass flow [tons/hour)	1 per day from each stream in 5 batches.	Slurry, liquid and solid output fraction	Flowmeter
Total phosphorus [kg/ton]	1 per day from each stream in 5 batches.	Slurry, liquid and solid output fraction	ICP/OES DS1885,1998
Total potassium [kg/ton]	1 per day from each stream in 5 batches.	Slurry, liquid and solid output fraction	ICP/OES DS11885,1998
pH [pH units]	1 per day from each stream in 5 batches.	Slurry, liquid and solid output fraction	Radiometer, GLP
Methane yield [Nm <sup>3</sup> /ton]	1 pooled sample consisting of sub-samples representing 5 batches. Methane yield test based on 6 replicates.	Solid fraction	Adapted version of ISO11734

## 5.5 Additional parameters

Additional parameters are effects of the product that were evaluated as part of the verification but are considered secondary compared to the primary performance parameters.

### **5.5.1 Operational parameters**

In the case of SB 250 electricity consumption (kWh/tons input slurry separated) was judged to be a relevant additional parameter.

During the planning of the test of SB 250 the test organisation assessed whether it was relevant to measure the emission of ammonia and hydrogen sulphide from the separator in operation. Depending on the design and the function there might be such emissions from certain separators.

In the case of SB 250, it was judged by the test organisation that these emissions are minimal and do not constitute any risk to occupational health or to environment and therefore it was decided not to include these parameters as part of the verification.

### **5.5.2 Occupational health and safety**

In general, slurry separators as all industrial machinery and equipment – must comply with the Machinery Directive (Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast)). They must be designed and constructed in such a way that they can be used, adjusted and maintained throughout all phases of their life without putting persons at risk.

In detail the installations must satisfy the essential safety requirements contained in Annex I of the Directive, a correct conformity assessment must be carried out and a “Declaration of Conformity” must be given.

It is the responsibility of the manufacturer, importer or end supplier of the equipment to ensure that equipment supplied is in conformity with the Directive. In addition, Council Directive 89/655/EEC of 30 November 1989 concerns the minimum safety and health requirements for the use of work equipment by workers at work (amended 2007/30/EC) and places obligations on businesses and employers to take into account potential dangers to operators and other persons using or affected by machines and equipment.

In general terms, the directive requires that all equipment provided for use at work is: Suitable for the intended use; safe for use, maintained in a safe condition and, in certain circumstances, inspected to ensure this remains the case; used only by people who have received adequate information, instruction and training; and accompanied by suitable safety measures, e.g. protective devices, markings, warnings.

In addition, ISO 12100-2:2003 (Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles) defines technical principles to help designers in achieving safety in the design of machinery.

The safety instructions must be documented for example in a safety data sheet and must be observed carefully.

Before the beginning of any work, the installation must always be shut down. In addition, good ventilation and appropriate protective equipment, such as acid resistant protective clothing, eye protection, etc. may be required. Moreover, one must make sure that protective installations, such as eye wash and shower units, are available and work properly.

### 5.5.3 **Animal health and welfare**

Since the SB 250 is an end-of-pipe separator installed outside the animal house it was judged by the test organisation that the operation of the separator will not have any influence on animal welfare. Consequently, animal health and welfare were not evaluated as part of this verification.

### 5.5.4 **User manual**

An evaluation of the user manual for the SB 250 separator was not undertaken as part of this verification task.

## 6 **EXISTING DATA**

No third party test has yet been done for SB 250 on cattle slurry. However, the manufacturer (SB Engineering) has carried out some tests during the final development phase of SB 250.

### 6.1 **Summary of existing data**

Two full scale tests of SB 250 on cattle slurry have been performed by SB Engineering:

- Bramming: Test on a commercial cattle farm.
  - One batch using acidified slurry from a cattle house where the Infarm A/S slurry acidification system is installed.
  - One batch using slurry which was not acidified.
- Aalestrup: Test on a commercial cattle farm.
  - 4 batches using cattle slurry, which was not acidified.

In both tests focus was to determine the separation efficiency with respect to total nitrogen. In the table below the results are summarized.

*Table 3. Summary of existing data from previous tests of SB 250 on cattle slurry.*

Test location	Slurry type	Number of batches	Total nitrogen separation efficiency
Bramming	Acidified cattle slurry	1	19 %
Bramming	Non-acidified cattle slurry	1	27 %
Aalestrup	Non-acidified cattle slurry	4	19 %

### 6.2 **Quality of existing data**

Data and results from previous tests are based on test protocols that differ significantly from the present DANETV verification protocol. For instance, the tests have not been undertaken by a third party but by the manufacturer. Consequently, the existing data do not qualify for the verification of the SB 250 separator.

### **6.3 Accepted existing data**

No data from previous tests have been included in this verification of the SB 250 slurry separator.

## **7 TEST PLAN REQUIREMENTS**

Based on the application and performance parameter identification above the requirements for the test design have been set. A detailed test plan was prepared by the test organisation based upon the specification of the test requirements presented below.

### **7.1 Test design**

The test should be designed so that mass balances of total solids, volatile solids, total nitrogen, ammonium nitrogen, phosphorous and potassium could be calculated.

This was done by following the separator in batches with a fixed start time and end time. For each batch the weight of input slurry, liquid output fraction and solid output fraction was determined as part of the test. In addition, during the batch representative sampling of input slurry, liquid output fraction and solid output fraction was done to determine concentrations of solids and nutrients.

#### **7.1.1 Requirements for the test site**

The test should be carried out at a commercial farm or at a test farm. The test should be carried out under normal conditions that reflect how the separator will be used by a farmer at farm level. The test site proposed by the test unit should be approved by the verification responsible.

#### **7.1.2 Sampling strategy**

The test should consist of minimum 5 batches. Each batch should last at least 2 hours and the minimum amount of slurry to be treated in one batch was 10 tons. The test could be performed throughout the year.

The performance of a slurry separator should be determined by sampling, measuring and analyzing the input and output flows. The sampling and measurements had to be carried out while the system was in normal operation (without any disturbances or malfunctions).

During the period of sampling and measuring a logbook had to be used. All matters concerning the sampling and measurements had to be recorded in the logbook. It means that all relevant information including functional problems that occurred had to be recorded in the logbook.

The test staff should strive to take samples that were representative of the flow at that moment. This means that the sample should have the same composition as the sampled flow. The test plan should describe the sampling method and equipment used.

In addition, the mass flow to and from the separator (measured in tons or cubic metres) had to be determined.

The test plan should describe the methods used for measuring mass flow.

## 7.2 Reference analysis

All measurements and analytical methods had to be documented satisfactory.

### 7.2.1 Mass balances and separation efficiencies

If it is assumed that no losses would occur during the separation process the mass of each parameter led into the SB 250 should equal the mass of that parameter leaving the separator as part of either the solid output or liquid output.

To evaluate the validity of the mass balance calculations should be made demonstrating to what extent the mass led into the separator was recovered in the solid and liquid output fractions (expressed as a percent).

$$R_i = \frac{M_i^I - (M_i^L + M_i^S)}{M_i^I} \times 100$$

Where:

$R_i$  = Percent of component  $i$  not recovered in liquid or solid output fraction

$M_i^{I,L,S}$  = Mass of component  $i$  in input slurry (I), liquid (L) or solid output fraction (S)

In each batch for every parameter:

- $R_i$  (per batch) has to be less than +/- 25%

In cases where  $R_i$  (per batch) was larger than +/- 25% the result had to be omitted from the calculation of separation efficiency. If possible the batch should be repeated.

All batches together for every parameter:

- $R_i$  (all batches) had to be less than +/- 15%.

In cases where  $R_i$  (all batches) was larger than +/- 15% the result had to be omitted from the calculation of separation efficiency. If possible the test should be repeated. If it was not possible to repeat the whole test the test responsible should assess whether some of the samples should be re-analyzed.

### 7.2.2 Methane yields

In order to control the quality of the inoculum used for measurement of methane yield a reference material (e.g. cellulose powder) should be tested parallel with the batches of solid fraction material. In addition, blank tests should be performed in order to determine the methane yield originating from the inoculum.

The reference analysis for measurement of methane yield should be described as part of the test plan.

### 7.3 Data management

Data storage, transfer and control had to be done in accordance with the requirements described in the AgroTech Test Centre Quality Manual. Similarly, filing and archiving requirements should be described in the AgroTech Test Centre Quality Manual.

### 7.4 Quality assurance

The test plan and test report had to be reviewed by an internal and an external expert.

The quality assurance of the tests should include control of the test system and control of the data quality and integrity.

### 7.5 Test report

The test report should be based on the template included in the AgroTech Test Centre Quality Manual.

## 8 EVALUATION

### 8.1 Calculation of performance parameters

For each individual batch and for all batches together mass balances and separation efficiencies with respect to nutrients and solids have been calculated. The calculations are based on the measured concentrations of the nutrients and solids and the masses of input slurry and the two output fractions.

The measured concentrations of solids and nutrients are presented in table 4 and table 5 below. Data from all batches are presented in the test report, which is attached as Appendix 4 to this verification report.

Table 4. Average content of total solids, ashes, volatile solid and pH over 5 batches.

Fraction	Total solids (%)	Ash content (%)	Volatile Solids* (%)	pH (pH units)
Input slurry	7,88	1,60	6,28	6,85
Liquid output fraction	4,95	1,50	3,45	6,86
Solid output fraction	22,39	2,06	20,33	7,58

\*Note: Values for volatile solids are not measured but calculated as the difference between total solids and ash content.

Table 5. Average concentrations of nutrients over 5 batches.

Fraction	Total Nitrogen (Kg/ton)	Ammonium Nitrogen (Kg/ton)	Organic Nitrogen* (Kg/ton)	Total phosphorous (Kg/ton)	Total potassium (Kg/ton)
Input slurry	3,70	1,72	1,98	0,50	3,30
Liquid output fraction	3,48	1,73	1,75	0,47	3,40
Solid output fraction	4,59	1,45	3,14	0,65	3,08

\*Note: Values for organic nitrogen are not measured but calculated as the difference between total-N and ammonium-N.

During the test the weight of the liquid output fraction and solid output fraction have been measured. The weight of the input slurry has been calculated this way:

$$M^{\text{input}} = M^{\text{L}} + M^{\text{S}}$$

Where:

$M^{\text{input}}$  = Mass of input slurry

$M^{\text{L}}$  = Mass of liquid output fraction

$M^{\text{S}}$  = Mass of solid output fraction

In converting the measured volume of liquid output fraction to mass, the density of the treated biomass is approximated to 1 ton/m<sup>3</sup>.

The verified recovery factors as defined in section 5.4 above are presented in table 6 and table 7.

Table 6. Recovery factors\* for total solids and volatile solids.

Batch no. 1 - 5	Fraction	Total solids %	Volatile Solids %	Treated input slurry %
Average	Solid output	50	56	18
	Liquid output	50	44	82
	Control	100	100	100

\*Note: Values are adjusted to make masses of the solids sum up to 100 %

Table 7. Recovery factors\* for nutrients.

Batch no. 1 - 5	Fraction	Total nitrogen %	Ammonium nitrogen %	Organic nitrogen %	Total phosphorous %	Total potassium %
Average	Solid output	22	16	28	23	17
	Liquid output	78	84	72	77	83
	Control	100	100	100	100	100

\*Note: Values are adjusted to make masses of the nutrients sum up to 100 %

It is seen from table 6 and table 7 that no concentration of ammonium nitrogen and potassium takes place in the solid fraction as a result of the separation. The share of these nutrients from the input slurry that is recovered in the solid fraction (16 % and 17 % respectively) corresponds to the share of solid fraction relative to the amount of input slurry (18 %).

For total nitrogen and phosphorous the SB 250 separator leads to slightly higher concentrations in the solid fraction than in the input slurry and as a result the removal efficiency for these nutrients is moderate.

Highest removal efficiencies of the SB 250 separator are found for total solids and volatile solids. The solid fraction that constitutes 18 % of the input slurry amount contains 50 % of the total solids of the input slurry and 56 % of the volatile solids of the input slurry.

The methane yield test was undertaken as a batch test at 48 ° Celcius using inoculum from Baanlev Biogas Plant. The test period of the methane yield test was 90 days. The results of the methane yield test are presented in table 8.

Table 8. Methane yields (90 days) of solid fraction from separation of cattle slurry using SB 250.

Sample	TS [%]	VS [%]	VS/TS [%]	Methane yield [Nm <sup>3</sup> CH <sub>4</sub> /ton VS]	Methane yield [Nm <sup>3</sup> /ton solid fraction]
Average	22,07	20,10	91	263	52,8

In figure 5 the results of the methane yield test are presented in a graph showing the accumulated methane production as a function of time.

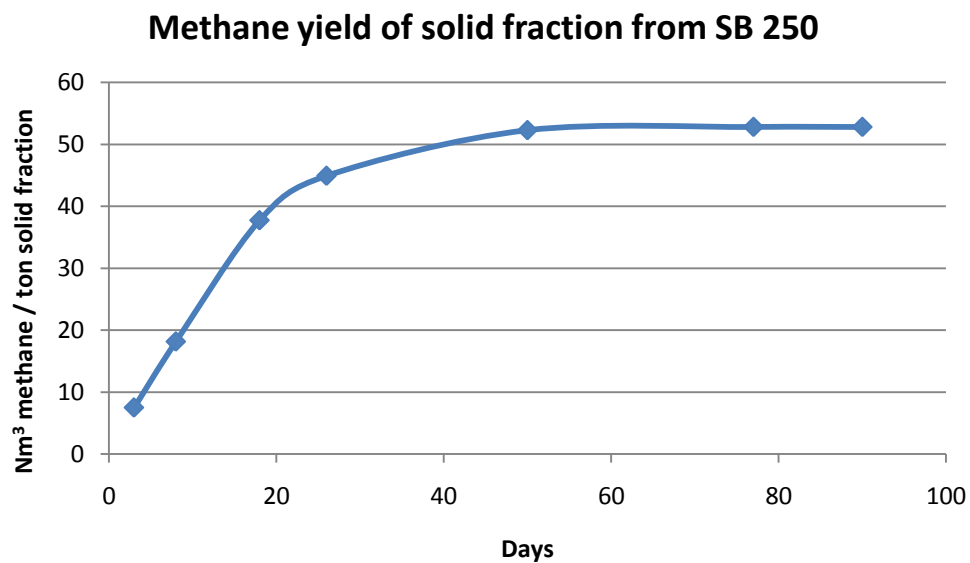


Figure 5. Accumulated methane yield per ton solid fraction (fresh weight) at 48° C.

It is seen in figure 5 that from day 50 there was almost no more methane production. The curve for accumulated methane production has reached the plateau around 52 – 53 Nm<sup>3</sup> methane pr. ton solid fraction.

## 8.2 Performance parameter summary

In table 9 the verified performance is compared with the performance claimed by the technology producer.

Table 9. Evaluation of performance parameters.

Performance parameter	Claimed performance	Verified performance
Total nitrogen separation efficiency	Min. 18 %	22 %
Total phosphorous separation efficiency	Min. 30%	23 %
Total solids separation efficiency	Min. 40 %	50 %
Volatile solids separation efficiency	Min. 50 %	56 %
Total solids concentration in liquid fraction	Max. 5 %	4,95 %
Methane yield of the solid fraction (Nm <sup>3</sup> CH <sub>4</sub> / ton solid fraction)	Min. 45	53

On the basis of this test all claims have been confirmed except the claim for separation efficiency for total phosphorous.

Higher separation efficiencies on dairy cow slurry have been recorded for other types of separators like for instance decanter centrifuges or separation systems based on chemical treatment [6], [7]. However, these types of separators are more costly both with respect to the initial investment and the operational costs. Thus, despite relative low separation efficiencies on cow slurry SB 250 will still be a relevant slurry separator for many dairy cow farmers.

### 8.3 Evaluation of test quality

#### 8.3.1 Control data

The  $R_i$  (per batch) values and  $R_i$  (all batches) values are presented in table 10 below (see definition of  $R_i$  values in section 7.2.1).

Table 10. Percent of components not recovered in liquid or solid output fraction ( $R_i$  values).

Batch no.	Total Nitrogen	Ammonium-Nitrogen	Organic Nitrogen	Total phosphorous	Total potassium	Total solids	Volatile Solids
1	1,37%	8,02%	-4,73%	4,58%	1,01%	-0,96	-1,42
2	1,57%	1,19%	1,89%	0,01%	-4,69%	0,36	0,19
3	0,18%	3,59%	-2,75%	-0,93%	-0,87%	-4,40	-5,44
4	0,50%	-0,06%	1,00%	1,58%	1,72%	-3,60	-4,01
5	-0,09%	0,07%	-0,23%	-8,40%	-3,84%	-3,35	-4,26
1-5	0,71%	2,56%	-0,97%	-0,63%	-1,33%	-2,39	-2,99

It is seen that the analytical performance requirements have been met:

- $R_i$  (per batch): No values greater than +/- 25%
- $R_i$  (all batches): No values greater than +/- 15%
- 

Consequently, no analytical results from the samples have been omitted in the calculation of the separation efficiencies.

The methane yield test had to be repeated because the test on reference material (Avicel, cellulose material) did not meet the analytical performance requirements during the first test. When the test was carried out the second time the methane yields on the reference material were within the accepted range (See methane yields of reference material in Test report, Appendix 4).

#### 8.3.2 Audits

No external or internal audits were undertaken for this specific verification task.

### 8.3.3 Deviations

According to the test plan Marie Louise Nielsen was responsible for the test and responsible for part of the sampling and measurement activities. However, since Marie Louise Nielsen moved to a new job during the test period, Hans Jørgen Tellerup has taken over the responsibility for the test. This delayed the analysing and reporting phase of the test.

As mentioned in section 8.3.1 the methane yield test had to be repeated because the test on reference material (Avicel, cellulose material) did not meet the analytical performance requirements during the first test. As a consequence the test was delayed and the original time schedule could not be followed.

Due to time constraints external review (by Maibritt Hjorth) was performed for the test report only and not for the verification report.

## 8.4 Additional parameter summary

### 8.4.1 User manual

The user manual for SB 250 separator was not evaluated as part of this verification.

### 8.4.2 Occupational health and wastes

Issues related to occupational health, safety and wastes were not evaluated as part of this verification.

## 8.5 Operational parameters

In table 10 the measured capacity of the SB 250 separator and the results of the electricity consumption measurements are presented.

Table 10. Capacity and electricity consumption.

Batch no.	Capacity Tons of input slurry treated per hour	Electricity consumption kWh / ton input slurry
1	6,65	0,83
2	6,34	0,83
3	5,33	0,89
4	6,56	0,71
5	6,73	0,74
<b>Average</b>	<b>6,3</b>	<b>0,80</b>

## 8.6 Recommendations for verification statement

It is recommended to issue a verification statement based on the verified performance described in section 8.1, 8.2, 8.3 and 8.5.

In a publication of Hjorth et al (2009) [1] results from different studies of dairy cow slurry composition are analysed and presented. In table 11 the mean values for the content of total solids and some nutrients are compared to the contents of the dairy cow slurry from the farm where the SB 250 was tested.

Table 11. Contents of total solids and nutrients in “normal” cow slurry compared to the slurry used in test.

Component	Mean values [1] (standard deviation)	Contents in cow slurry used in test
Total solids (%)	8,2 (24)	7,9
Total nitrogen (kg/ton)	3,7 (1,7)	3,7
Total phosphorous (kg/ton)	1,0 (0,2)	0,5
Total potassium (kg/ton)	4,3 (1,8)	3,3

In table 11 it is seen that the content of total solids and total nitrogen in the cow slurry used in test are close to the contents of normal cow slurry. Thus, it is judged that the cow slurry used in test is representative for normal cow slurry with respect to contents of total solids and total nitrogen.

For total potassium and especially for total phosphorous the contents in the cow slurry used in test are lower than the contents of these nutrients in a normal cow slurry. This could lead to underestimation of the separation efficiency with respect to phosphorous and potassium.

## 8.7 Liability exclusion

DANETV verifications are based on test and evaluation of technology performance under specific, predetermined operational conditions and parameters and the appropriate quality assurance procedures. AgroTech makes no expressed or implied warranties as to the performance of the technology and do not certify that the technology will always operate as verified. The end user is solely responsible for complying with any applicable regulatory requirements.

## 9 VERIFICATION SCHEDULE

The verification was planned and carried out in 2009-2010. The overall schedule is presented in table 12.

Table 12. Schedule for verification of SB 250 separator.

Task	Timing
Quick scan and contract negotiation	May – June 2009
Verification protocol and test plan	July – August 2009
Test	August – November 2009
Test reporting	January 2010
Verification report	February 2010
Report document review	March 2010
Verification statement	April 2010

## 10 QUALITY ASSURANCE

The quality assurance of the verification is described in table below and in figure 2. The quality assurance of the test is described in the test plan.

*Table 13. Quality assurance plan for the verification of SB 250 slurry separator.*

<b>Task</b>	<b>AgroTech</b>	<b>Technical experts</b>
Plan document including verification protocol and test plan	Bjørn Hjortshøj Andersen	Maibritt Hjorth, Aarhus University, Faculty of Agricultural Sciences.
Report document including test report and verification reports	Bjørn Hjortshøj Andersen	Maibritt Hjorth, Aarhus University, Faculty of Agricultural Sciences.

No test system audit was planned for this specific verification task.



## ***A P P E N D I X 1***

### ***Terms and definitions used in the verification protocol***

Word	DANETV
Analytical laboratory	Independent analytical laboratory used to analyse test samples
Application	The use of a product specified with respect to matrix, target, effect and limitations
DANETV	Danish center for verification of environmental technologies
(DANETV) test center	Preliminary name for the verification bodies in DANETV with a verification and a test sub-body
Effect	The way the target is affected
(Environmental) product	Ready to market or prototype stage product, process, system or service based upon an environmental technology
Environmental technology	The practical application of knowledge in the environmental area
Evaluation	Evaluation of test data for a technology product for performance and data quality
Experts	Independent persons qualified on a technology in verification
Matrix	The type of material that the product is intended for
Method	Generic document that provides rules, guidelines or characteristics for tests or analysis
Liquid fraction	Liquid or thin fraction derived from the separation of slurry.
Performance claim	The effects foreseen by the vendor on the target (s) in the matrix of intended use
Performance parameters	Parameters that can be documented quantitatively in tests and that provide the relevant information on the performance of an environmental technology product
Procedure	Detailed description of the use of a standard or a method within one body
Producer	The party producing the product
Recovery factor	Expresses the proportion of a given component in the input slurry that end up in a specific output stream. The recovery factor is expressed as a percent.
Separation efficiency	In this verification separation efficiency is defined as the recovery factor for the solid fraction. Thus separation efficiency is a measure of the proportion of a given component in the input slurry that ends up in the solid

Word	DANETV
	fraction (expressed as a percent).
Slurry	Faeces and urine produced by housed livestock, usually mixed with some bedding material and some water during management to give a liquid manure with a dry matter content in the range from about 1 – 10%. A slurry is a mixture of liquid and solid materials, where typically the solid materials are not dissolved in the liquid phase, and will precipitate out of the slurry under a prolonged period of storage.
Slurry additive	Manufactured or naturally occurring products or substances that are added to manures to modify their biological, chemical or physical properties. Many additives are commercially available but most have not been subjected to independent testing so their effectiveness has not been assessed.
Slurry separator	Slurry separators (separation technologies) are here defined as technologies that divide liquid livestock manure (slurry) into one or more solid fractions and one or more liquid fractions.
Solid fraction	A fraction from separation with a higher content of solids (e.g. dry matter or phosphorus) than the input material. Normally the solid fraction is stackable.
Standard	Generic document established by consensus and approved by a recognized standardization body that provides rules, guidelines or characteristics for tests or analysis
Target	The property that is affected by the product
Test center, test sub-body	Sub-body of the test center that plans and performs test
Test center, verification sub-body	Sub-body of the test center that plans and performs the verification
Test/testing	Determination of the performance of a product for parameters defined for the application
Vendor	The party delivering the product to the customer
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance



## ***A P P E N D I X 2***

### ***References***

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## ***A P P E N D I X 3***

### ***Application and performance parameter definitions***

This appendix defines the application and the relevant performance parameters as input for the verification and test of SB 250 slurry separator following the DANETV method.

## **1. Applications**

The intended application of the SB 250 is defined in terms of the matrix, the target and the effect of the slurry separator.

### 1.1 Matrix

The matrix is the type of material that the product is intended for. In the case of SB 250 the matrix of the application is cattle slurry representing prevalent combinations of cattle housing systems, management systems and feeding strategies in Denmark, Germany, the Netherlands and other countries with similar cattle production systems.

Normally the dry matter content of such cattle slurry is between 6,5 and 11 % TS. Cattle slurry is typically composed of the following elements: faeces, urine, waste water (e.g. from cleaning of milking equipment, water spilt during drinking, etc.), fodder remnants, bedding material (typical straw), sand and sometimes things that end up in the slurry unintended (tools, packing materials, etc).

The cattle slurry shall be regularly stirred to avoid sedimentation in the tank from which the slurry is led into the separator. Stirring secures that the separator is fed with relatively homogenous input slurry.

The temperature of the slurry will vary throughout the year. In cold winters the slurry temperature can be around 0 degree C. In the summer period the slurry temperature can be up to around 20 degree C.

### 1.2 Targets

Targets are the measurable properties that are affected by the technology product. In the case of SB 250 the targets are:

- Methane potential in solid fraction resulting from separation of cattle slurry.
- Concentrations of total solids (TS) and volatile solids (VS) in input slurry, liquid and solid fractions respectively.
- Concentrations of total-nitrogen, ammonium-nitrogen, phosphorous (P) and potassium (K) in input slurry, liquid and solid fractions respectively.
- Weight of liquid fraction and solid fraction.

### 1.3 Effects

The effects describe how the targets are affected by the technology product.

In the case of SB 250 the effects are:

- Increased concentrations of total solids (TS) and volatile solids (VS) in solid fraction compared to input slurry.
- Increased concentrations of total-nitrogen and phosphorous (P) in solid fraction compared to input slurry.
- Increased methane yield of solid fraction per unit of weight compared to slurry.

Based on the weights of input slurry, liquid fraction and solid fraction and the measured concentrations of TS, VS and nutrients in the fractions mass balances and separation efficiencies are calculated.

#### 1.4 Exclusions

SB 250 can be used for separation of other slurry types like pig slurry and mink slurry. However, these slurry types differ from cattle slurry in a number of aspects.

Consequently, the results of the verification of SB 250 for separation of cattle slurry are not necessarily valid for separation of pig and mink slurry. Additional tests are necessary to verify the performance of SB 250 for separation of pig and mink slurry.

## **2. General performance requirements**

### 2.1 Regulatory requirements

Dairy cow farms that separate slurry and dispose the solid fraction for uses outside the farm can achieve a reduction in the area that shall be available for application of slurry ("harmony area").

The maximum allowable reduction in harmony area is equivalent to the separation efficiency with respect to total nitrogen. Thus, the larger the share of total nitrogen from the input slurry that is recovered in the solid fraction, the larger the reduction in harmony area.

In some areas phosphorous are lost to vulnerable surface waters leading to Eutrophication. In such areas farmers are sometimes met by restriction on the application of phosphorous on their fields. Here slurry separators can be a tool to reduce phosphorous content in the slurry and thereby balancing the amount of phosphorous applied via slurry to the needs of the crops.

### 2.2 Application based needs

Typically, dairy cow farmers considering investing in a slurry separator prefer separators with high separation efficiency with respect to total nitrogen. But farmers also prioritise separators with low initial investment costs, low operational costs (electricity, man power, etc.) and high operational stability.

## **3. State of the art performance**

A draft version of a technology description for screw presses used for separation of slurry has been published on the internet by the Danish Environmental Protection Agency in 2009. This technology description will be used for evaluation of screw presses as best available technologies for intensive livestock production.

According to this technology description the expected performance of screw presses used for separation of cow slurry is:

- Total nitrogen separation efficiency: 18 % with variations from 10 % to 22 %
- Total phosphorous separation efficiency: 30 with variations from 16 % to 35 %

## **4. Performance parameter definitions**

The performance parameters are defined in section 5.4 above.



## ***A P P E N D I X 4***

### ***Test report***



The test report is attached as a separate file.



## ***A P P E N D I X 5***

### ***Review reports***



Comments, questions and proposals for improvements of plan documents and report documents have been communicated from internal and external reviewers both by e-mail and by telephone and at meetings.

These comments, questions and proposals for improvements are stored according to the archiving procedures described in the AgroTech Test Centre Quality Manual.



## ***A P P E N D I X 6***

### ***Amendment and deviation report for verification***

During the test the following deviations from the test report were registered:

The methane yield test had to be repeated because the test on reference material (Avicel, cellulose material) did not meet the analytical performance requirements during the first test.

During the test one of the persons involved, Marie Louise Nielsen moved to a new job. Consequently, a new person, Hans Jørgen Tellerup, was involved in the test.

Due to time constraints external review (by Maibritt Hjorth, Aarhus University) was performed for the test report only and not for the verification report.