



Standard Test Method for Performance Evaluation of Anaerobic Digestion Systems¹

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1. Scope

1.1 This test method is applicable to all anaerobic digestion systems.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 1126 Terminology Relating to Biomass Fuels²

2.2 *Standard Methods (SM) for Analysis of Water and Wastewater:*³

2540 D Total Suspended Solids

2720 B Sludge Digester Gas (Volume)

4500 F NH_3 Nitrogen (Ammonia)

4500 B Nitrogen (Organic), Total Kjeldahl Nitrogen

5210 B Biochemical Oxygen Demand

5220 B Chemical Oxygen Demand

5520 D Oil and Grease

3. Terminology

3.1 *Definition*—see Terminology E 1126.

3.1.1 *biogas*—a composition of methane and carbon dioxide and minor constituents produced by the digestion of organic substrates in the absence of oxygen.

4. Summary of Test Method

4.1 This test method measures the concentration and mass of the influent and effluent wastes, respectively, as well as other operational parameters such as input energy, output gas production, and waste biomass, to provide a methodology for evaluation of the operation of an aerobic digester.

5. Significance and Use

5.1 This test method will yield data that will form a performance profile for an anaerobic digester facility. The significance of this profile is that it can be compared directly to another facility's performance profile and yield a measurement of expected facility performance under field conditions.

5.2 This test method will also yield data that can be used to verify the operation of a system to a regulatory agency.

5.3 The single black box technique applied to performance evaluation examines only the overall input/output relationship. This implies that the operation of the facility during the tests will be conducted to achieve design conditions in accordance with established procedures.

6. Procedure

6.1 Conduct the test for a predetermined period mutually agreed upon by all parties participating in the testing program. Start the test period when the system manufacturer determines that the system has reached normal operating conditions. Record the time period between the initial loading of the system with waste and the start of the test period. A minimum test period of 90 days is suggested.

6.2 Determine the influent and effluent concentrations of the following, using the methods recommended, total suspended solids (TSS) SM 2540 D, NH_3 nitrogen (ammonia) (AN) SM 4500 F, nitrogen (organic)-total kjeldahl nitrogen (TKN) SM 4500 B, biochemical oxygen demand (BOD) SM 5210 B, chemical oxygen demand (COD) SM 5220 B, and oil and grease (OG) SM 5520 D. The sampling frequency and location of sampling shall be mutually agreed upon by all parties involved in the project. As a minimum, weekly sampling of a composite sample of 24 h of influent and effluent is suggested.

6.3 Measure the gas production continuously, using SM 2720 B, or equivalent. Analyze the gas compositions using a gas chromatograph (GC) to determine the composition of CH_4 . The GC analysis frequency shall be mutually agreed upon by all parties participating in the testing program.

6.4 Measure the thermal energy input. The most common method of thermal energy input is hot water supplied to the system using a heat exchanger. Monitor the energy input on a continuous basis by measuring the flow rate of hot water to the

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² *Annual Book of ASTM Standards*, Vol 11.05.

³ Available from American Public Health Association, 1015 15th St. N.W., Washington, DC 20005.

system and the influent and effluent flow temperatures, using the reference procedures and equipment.

6.5 Record the horsepower of any motors connected more than 50 % of the time during a 24 h operation.

6.6 Record the weight of any material removed from the system during the test period.

7. Calculation

7.1 *Data Collection*—See Table 1.

7.2 *Data Calculations*—See Table 2.

7.3 *Data Summary*—See Table 3.

8. Precision and Bias

8.1 The precision and bias of this test method are still under evaluation.

9. Keywords

9.1 anaerobic digestion; biogas; biomass; waste treatment

TABLE 1 Data Collection Form for Anaerobic Digestion System Performance Evaluation

(1) Date:		
(2) Influent concentrations, mg/L		
Total suspended solids (TSS)		
Ammonia nitrogen (AN)		
Total Kjeldahl nitrogen (TKN)		
Biochemical oxygen demand (BOD)		
Chemical oxygen demand (COD)		
Oil and grease (OG)		
(3) Effluent concentrations, mg/L		
Total suspended solids (TSS)		
Ammonia nitrogen (AN)		
Total Kjeldahl nitrogen (TKN)		
Biochemical oxygen demand (BOD)		
Chemical oxygen demand (COD)		
Oil and grease (OG)		
(4) Cumulative system parameters measured during test		
Volume of waste processed, gal		
Waste density, lb/gal		
Volume of biogas produced, ft ³		
Biogas methane content, weight %		
Solids wasted from reactor, gal		
Heating water supplied, gal		
Heating water supply temperature, °F		
Heating water return temperature, °F		
Total continuous horsepower, hp		
Chemicals added, name of chemical		
Chemicals added, lb		
Brief description of facilities included in test program.		
Data recorded by:		

TABLE 2 Performance Calculation Procedures

Calculation Results		
(1) Influent mass calculations		
TSS _I	= TSS _I × WF × WD	_____ lb
AN _I	= AN _I × WF × WD	_____ lb
TKN _I	= TKN _I × WF × WD	_____ lb
BOD _I	= BOD _I × WF × WD	_____ lb
COD _I	= COD _I × WF × WD	_____ lb
OG _I	= OG _I × WF × WD	_____ lb
(2) Effluent mass calculations		
TSS _E	= TSS _E × WF × WD	_____ lb
AN _E	= AN _E × WF × WD	_____ lb
TKN _E	= TKN _E × WF × WD	_____ lb
BOD _E	= BOD _E × WF × WD	_____ lb
COD _E	= COD _E × WF × WD	_____ lb
OG _E	= OG _E × WF × WD	_____ lb
(3) Pollutant reduction		
Total suspended solids reduction	= (TSS _E – TSS _I)/TSS _I	_____ %
Ammonia nitrogen reduction	= (AN _E – AN _I)/AN _I	_____ %
Total Kjeldahl nitrogen reduction	= (TKN _E – TKN _I)/TKN _I	_____ %
Biochemical oxygen demand reduction	= (BOD _E – BOD _I)/BOD _I	_____ %
Chemical oxygen demand reduction	= (COD _E – COD _I)/COD _I	_____ %
Oil and grease reduction	= (OG _E – OG _I)/OG _I	_____ %
(4) Energy balance		
Net energy balance	= (BP × BMC × a) – (HWS × b × (HWST – HWRT)) – (TCHP × c × d × e)	_____ Btu

Where:	=	
TSS	=	total suspended solids concentration, mg/L
AN	=	ammonia nitrogen concentration, mg/L
TKN	=	total Kjeldahl nitrogen concentration, mg/L
BOD	=	biochemical oxygen demand, mg/L
COD	=	chemical oxygen demand, mg/L
OG	=	oil and grease concentration, mg/L
TSSM	=	total suspended solids mass, lb
ANM	=	ammonia nitrogen mass, lb



TKNM	=	total Kjeldahl nitrogen mass, lb
BODM	=	biochemical oxygen demand mass, lb
CODM	=	chemical oxygen demand mass, lb
OG	=	oil and grease mass, lb
X _I	=	influent value of Parameter X
X _E	=	effluent value of Parameter X
WF	=	waste flow, gal ^A
WD	=	waste density, lb/gal
BP	=	volume of biogas produced, ft ^{3A}
BMC	=	biogas methane content, %
HWS	=	heating water supplied, gal
HWST	=	heating water supply temperature, °F
HWRT	=	heating water return temperature, °F
TCHP	=	total connected horsepower
a	=	1000 Btu/ft ³ , typical methane higher heating value
b	=	8.32 lb/gal, water density ^A
c	=	0.74 kW/hp, energy conversion
d	=	24 h/day, typical operation
e	=	10 500 Btu/kWh, optimum efficiency of coal-fired steam electric power plant

Sample calculation:
Assume the following:

Influent parameters:

TSS_I = 1200 mg/L; AN_I = 30 mg/L; TKN_I = 50 mg/L;

BOD_I = 1200; COD_I = 2400; and OG_I = 600 mg/L

Effluent parameters:

TSS_E = 200 mg/L; AN_E = 40 mg/L; TKN_E = 40 mg/L;

BOD_E = 200; COD_E = 400; and OG_E = 100 mg/L

System parameters:

WF = 1 000 000 gal; WD = 8.32 lb/gal;

BP = 1000 ft³; BMC = 75 %; SW = 0 gal;

HWS = 5000 gal; HWST = 120°F; HWRT = 95°F; and

TCHP = 15 hp

(1) Influent mass calculations

TSSM_I = 1200 × 1 000 000 × 8.32 lb

ANM_I = 30 × 1 000 000 × 8.32 lb

TKNM_I = 50 × 1 000 000 × 8.32 lb

BODM_I = 1200 × 1 000 000 × 8.32 lb

CODM_I = 2400 × 1 000 000 × 8.32 lb

OGM_I = 600 × 1 000 000 × 8.32 lb

(2) Effluent mass calculations

TSSM_E = 200 × 1 000 000 × 8.32 lb

ANM_E = 40 × 1 000 000 × 8.32 lb

TKNM_E = 40 × 1 000 000 × 8.32 lb

BODM_E = 200 × 1 000 000 × 8.32 lb

CODM_E = 400 × 1 000 000 × 8.32 lb

OGM_E = 100 × 1 000 000 × 8.32 lb

(3) Pollutant reduction

Total suspended solids reduction = %

Ammonia nitrogen reduction = %

Total Kjeldahl nitrogen reduction = %

Biochemical oxygen demand reduction = %

Chemical oxygen demand reduction = %

Oil and grease reduction = %

(4) Energy balance

Net energy balance = (1000 × 0.75 × 1000) Btu

–(5000 × 8.32 × (120 – 95))

–(15 × 0.74 × 10 500)

= (1000 × 0.75 × 1000) Btu

–(5000 × 8.32 × (120 – 95))

–(15 × 0.74 × 10 500)

**TABLE 3 Data Summary Form for Fuel Anaerobic Digestion
System Performance Evaluation**

Test report for:	
(Indicate daily, weekly, monthly, total test)	
Influent concentrations	
Total suspended solids	_____ mg/L
Ammonia nitrogen	_____ mg/L
Total Kjeldahl nitrogen	_____ mg/L
Biochemical oxygen demand	_____ mg/L
Chemical oxygen demand	_____ mg/L
Oil and grease	_____ mg/L
Effluent concentrations	
Total suspended solids	_____ mg/L
Ammonia nitrogen	_____ mg/L
Total Kjeldahl nitrogen	_____ mg/L
Biochemical oxygen demand	_____ mg/L
Chemical oxygen demand	_____ mg/L
Oil and grease	_____ mg/L
Effluent mass	
Total suspended solids	_____ lb
Ammonia nitrogen	_____ lb
Total Kjeldahl nitrogen	_____ lb
Biochemical oxygen demand	_____ lb
Chemical oxygen demand	_____ lb
Oil and grease	_____ lb
Pollutant reduction	
Total suspended solids	_____ %
Ammonia nitrogen	_____ %
Total Kjeldahl nitrogen	_____ %
Biochemical oxygen demand	_____ %
Chemical oxygen demand	_____ %
Oil and grease	_____ %
Net energy	_____ Btu
Chemicals added, <i>name</i>	_____ lb
Solids wasted	_____ lb

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