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JFE-Bigadan Biogas Process as an Energy Recovery and Digestion System†

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Abstract:

In 2001, JFE Engineering was licensed to use the Bigadan process biogas system. This highly efficient methane fermentation process is suitable for energy recovery from livestock manure, food-industry waste, kitchen waste, and presorted household organic waste. JFE Engineering is currently conducting tests with a demonstration plant for livestock manure digestion and has also constructed and delivered a commercial biogas plant for food-industry waste. This paper describes the features of the Bigadan process, test results at the demonstration plant, and the features of the food-waste treatment plant.

1. Introduction

A variety of recycling laws have been enacted in Japan in recent years in a national effort to encourage the transition to a recycling society which maximizes recycling/reuse of wastes that had conventionally been incinerated or buried in landfills, with accompanying seepage into the ground. As part of this trend, the methane fermentation treatment process has attracted renewed interest as a basic technology for recovering energy (electricity, heat, fuel) and fertilizer (liquefied fertilizer, compost) from highly concentrated wastes such as sewerage and human waste sludge, livestock manure, kitchen waste, and presorted household organic waste.

The methane fermentation process has long been used, and has been the object of extensive research and development. However, the main trend in recent development work has focused on higher efficiency in gas generation (high decomposition rate) and reduction of the post-treatment load. In all cases, efficient heat recovery is a necessary element technology for maximizing energy recovery. Moreover, a high temperature sterilization process is also desirable for safe and worry-free use of liquefied fertilizer and compost, further increasing the need for efficient heat recovery.

In Europe, energy recovery from organic wastes such as livestock manure began in response to the Oil Crises of the 1970 s. For 20 years, government-subsidized research and development was conducted on a wet methane fermentation treatment technology which includes a high temperature sterilization process as a measure to prevent the spread of livestock pathogens and weeds due to regional recycling of manure to farmland.

The Bigadan A/S in Denmark owns the technology for a process (hereinafter called the Bigadan Process) which enables pasteurization in the upstream stage before the methane fermentation process using a slurry/slurry heat exchanger capable of recovering heat from concentrated slurry. In 2001, JFE Engineering obtained a license to the basic technology from Bigadan A/S, and in 2002, JFE Engineering, Hitachi Plant Engineering & Construction Co., Ltd., and Kobelco Eco-Solutions Co., Ltd. jointly constructed and began operation of a demonstration plant in Japan.

As a commercial project, JFE Engineering has also constructed a methane fermentation plant (Chiba Biogas Center) for Japan Recycling. This plant processes waste from the food-manufacturing industry.

This report describes the demonstration plant for livestock manure, including results from the demonstration plant, and also presents an outline of Chiba Biogas

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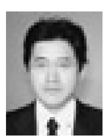

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2. Outline of Bigadan Process

The Bigadan Process consists of the following equipment:

(1) Pretreatment

As pretreatment, the raw material slurry is shredded and homogenized. In cases where food-industry waste or kitchen/household organic waste is to be treated, pretreatment also includes functions for pulping, classification (separation), and dilution (mixing).

(2) Sterilization

Wastes are pasteurized by heat treatment at 70°C for 1 h or longer to kill pathogenic bacteria and render weed seeds infertile.

(3) Methane Fermentation

The fermentation stage applies a biological process to decompose organic matter and extract biogas with a 60–70% methane content. The raw material is charged in slurry form and fermented while stirring in a perfect mixing tank.

(4) Gas Utilization

After H_2S and other impurities are removed from the biogas, the gas is used as fuel for a power generator or boiler, recovering energy in the form of electricity or heat.

(5) Post-Treatment

When it is possible to use the digested liquid as liquefied fertilizer, foul odor is removed by an air exposure treatment, and the liquid is stored in a storage tank. Where liquefied fertilizer cannot be used, the solid and liquid fractions are separated by dehydration. The liquid is purified and released into the sewerage system or public waters. The solids are effectively used by composting or are treated as waste, depending on local conditions and raw materials.

The general flow sheet of the Bigadan process is shown in **Fig. 1**.

3. Features of Bigadan Process

The Bigadan process offers outstanding reliability, as demonstrated in operation for more than 20 years at some 30 locations in Europe and elsewhere. As a methane fermentation process, it is classified as a wet-type perfect-mixing process. Medium- or high-temperature fermentation is adopted, depending on the raw material. The features of the process are summarized below.

(1) Sterilization (Pasteurization Process)

When digested liquid is to be recycled to agricultural land as liquefied fertilizer, the EU requires sterilization at a minimum temperature of 70°C for 1 h or longer. The Bigadan process applies pasteurization to 100% of the raw material in the pretreatment process for methane fermentation, ensuring safety while also improving decomposition performance and increasing the amount of gas recovered.

It should be noted that a sterilization process is also necessary when the digested liquid is to be dehydrated, followed by composting of the solid portion. However, because easily-decomposed organic matter is consumed in the methane fermentation process, adequate fermentation heat cannot be obtained in com-

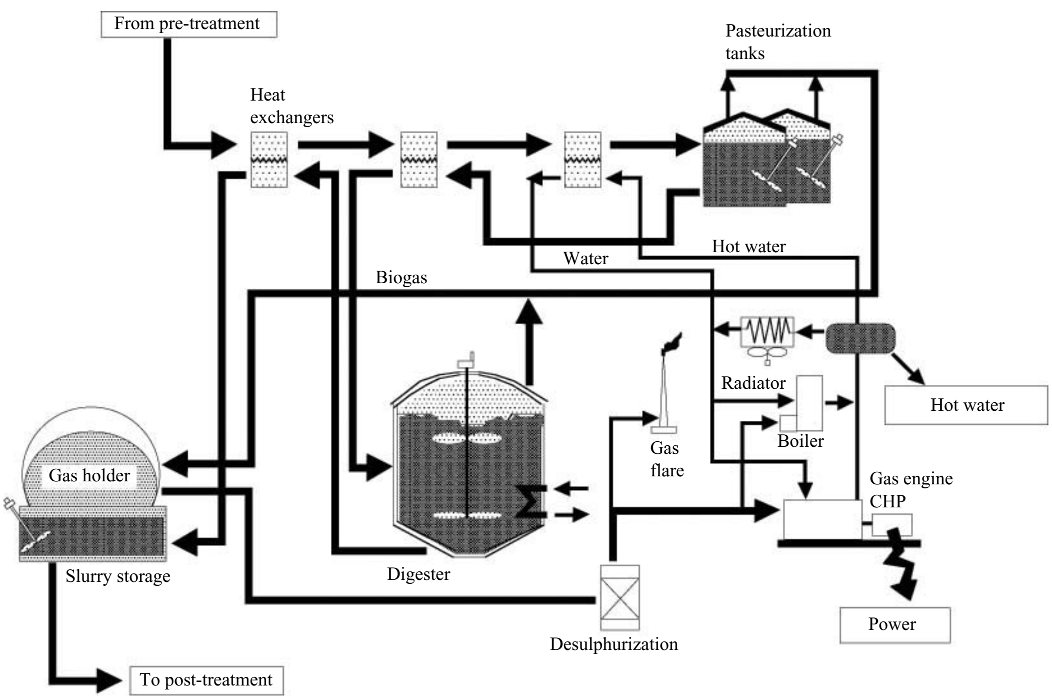

Fig. 1 General flow sheet of Bigadan Biogas Process

Photo 1 Heat exchangers and pasteurization tanks

posting, and as a result, the high temperature required for sterilization is not achieved in the composting stage. The Bigadan process solves this problem by adopting an innovative heat exchanger, as described below.

(2) Non-Blocking Type Slurry/Slurry Heat Exchanger

If a system is not equipped with a heat exchanger which is capable of recovering heat from high concentration slurry with a high temperature of 70°C or more, sterilization treatment will greatly increase energy consumption for heating. Therefore, a screw-type heat exchanger (**Photo 1**) with an adequate flow-route sectional area is adopted in the Bigadan process, making it possible to perform sterilization at 70°C while minimizing external energy consumption. This system is capable of meeting slurry heating requirements using only waste heat from the power generating system, and does not require an external heat source except when starting the process. This means that 100% of the biogas produced by the Bigadan process can be used in power generation, also increasing surplus power output. Owing to the turbulence generated by the helical flow in the heat exchanger, this device has a high heat transfer efficiency and can be used with no worry of blockage.

In the standard Bigadan Process plant, the heat exchanger is divided into three stages. Number 1 heat exchanger is used to preheat the raw material slurry by recovering heat from the slurry from the digester, which is extracted at 37°C. Number 2 heat exchanger heats the material by heat recovered from slurry which has completed the pasteurization process and is discharged at 70°C. Number 3 heat exchanger then performs final heating of the material slurry to 70°C using hot water recovered at the power plant as a heat source. The temperature in the digester is controlled at around 37°C by adjusting the digester charging temperature, using No. 2 heat exchanger to cool the hot slurry from the pasteurization tanks.

By applying the complete heat recovery system, the Bigadan process realizes a superior thermal efficiency.

4. Demonstration Test for Livestock Manure Treatment Process[1)]

The Bigadan process is a completed technology with a proven record in many plants, particularly in northern Europe. However, in Japan, potential clients frequently attach importance to the results of domestic operation. Therefore, as part of its effort to expand sales, JFE Engineering, together with Hitachi Plant Engineering Construction Co., Ltd., and Kobelco Eco-Solutions Co., Ltd., jointly constructed a demonstration test plant for livestock manure with a treatment capacity of 5 t/d and is currently conducting demonstration tests.

4.1 Outline of Demonstration Tests

The outline of the demonstration plant is as follows:

(1) Waste Treated: Dairy cow manure slurry (Treatment is being performed on a test basis using slurry with various properties obtained from multiple farms.)
(2) Treatment Capacity: 5 t/d
(3) Treatment Flow: Shown in **Fig. 2**
(4) Test Period: June 2002–Mar. 2004
(5) Location: Fujigamine District, Kamikuishiki Village, Yamanashi Pref.
(6) Main Equipment
  (a) Digester (Steel plate panel type tank, 100 m^3)
  (b) Pasteurization tank (Steel, 2.5 m^3 × 2 units)
  (c) Heat exchanger (10 m^3/h type × 6 units)
  (d) Gas holder (Gas bag installed in container, 40 m^3)
  (e) Desulphurization equipment (Bio scrubber de-S + Dry de-S)
  (f) Hot water boiler (50 Mcal/h, With digested gas/LPG switching)

4.2 Results of Operation

The main operational data for the 10-month period since startup are shown in **Fig. 3**.

Until the middle 10-day period of Sept. 2002, raw materials were obtained only from slurry pits at tethered dairy barns without stall litter. However, the slurry concentration was lower than expected due to mixed water, etc., resulting in unstable performance. In subsequent operation, the total solid (TS) concentration was adjusted to approximately 8–10% by mixing with green compost (mixture of stall litter and excrement).

In the steady operation period after November, when the TS concentration in the digester had been stabilized, gas production ranged between 90 and 130 Nm^3/d (average: 100 Nm^3/d) with a methane concentration of 58–67% (average: 61%).

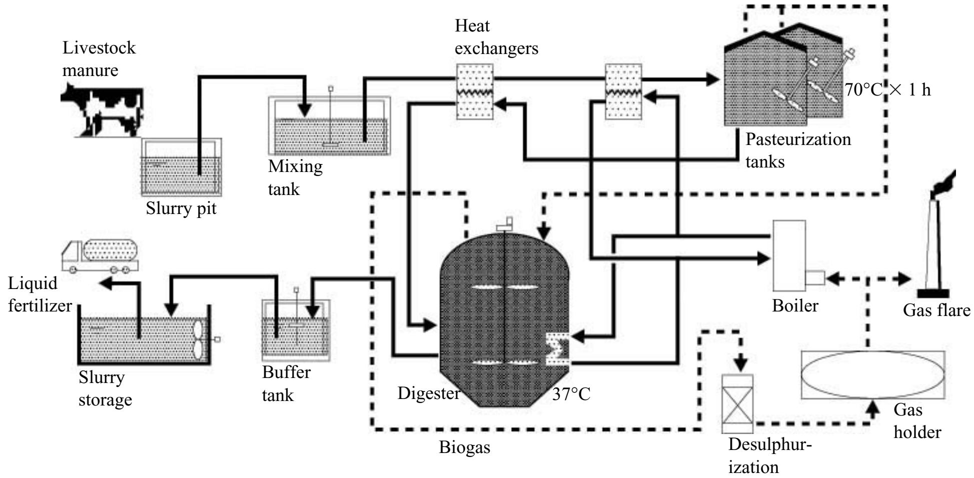

Fig. 2 Process flow sheet of demo-plant

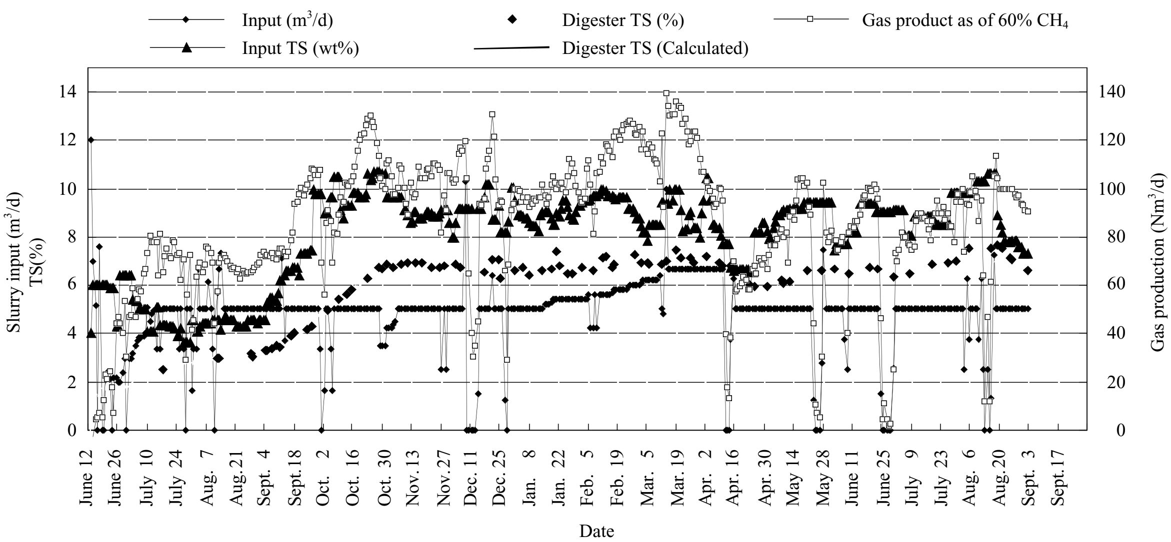

Fig. 3 Operation data of the demo-plant

The heat exchangers were cleaned in the middle 10-day period of Dec. 2002. With the exception of blockage of the biogas piping by sand deposits at the end of Sept. 2002 (subsequently solved by piping improvements), no serious mechanical problems have occurred, and the plant is normally being operated in an unmanned condition.

An experiment aiming at shortening the holding time was conducted in Jan. 2003, and satisfactory operation was confirmed until performance was finally deteriorated after a digestion time of 15 d. Trouble-free digester temperature control has been confirmed in both winter and summer. Sterilization in the pasteurization process shows sufficient effectiveness, as the coli group count after treatment is substantially zero.

Satisfactory digested gas desulphurization has also been achieved. Because the H_2S concentration is virtually zero after biological desulphurization (de-S) in normal periods, only biological de-S is required for operation of a digested gas-fired boiler or gas-fired engine generator. However, various factors affect the efficiency of biological de-S. For example, approximately 1 month is required to start up the biological de-S system, the biological system is inadequate for quick following of sudden changes in gas volume or H_2S concentration, but relatively high transient concentrations of H_2S occur in the treatment gas, and cleaning is required 1–2 times/year. Considering these conditions, it was concluded that a dry de-S system is necessary as a backup.

4.3 Future Schedule

Because buckwheat husks and waste paper are frequently used as stall litter, the apparent decomposition rate and gas production rate are relatively low with green compost containing those materials. Therefore, continuing tests will be conducted using only manure, with mixed water and litter removed to the minimum possible levels.

The system is currently being operated with a 20-day digestion cycle, but future plans include successive comparison tests of operation without pasteurization and high temperature digestion tests.

5. Commercial Plant for Food-industry Waste

5.1 Outline of Plant

The Bigadan process biogas system is applicable not only to livestock manure, but also as a methane fermentation process for various other types of organic waste. As an example, in Mar. 2003, JFE Engineering delivered a methane fermentation gasification plant (Chiba Biogas Center) for food-industry waste treatment to Japan Recycling. The outline of the facility is described below.

(1) Waste Treated: Food-manufacturing industry waste (Excluding general waste from the food-service industry)
(2) Capacity: 30 t/d
(3) Treatment Flow: Shown in **Fig. 4**
(4) Biogas Utilization: Used at the adjacent Chiba District of East Japan Works, JFE Steel.
(5) Post-Treatment: After dehydration and drying, solids are gasified at the gasification & melting plant (Chiba Recycling Center) operated by Japan Recycling for recycling as fuel.
(6) Location: Chuo-ku, Chiba City, Chiba Pref.
(7) Main Equipment:
  (a) Digester (Steel plate panel type tank, 1 650 m^3, **Photo 2**)
  (b) Pasteurization tank (Steel, 15 m^3 × 2)
  (c) Heat exchanger (10 m^3 × 12)
  (d) Gas holder (Double membrane type, 570 m^3)
  (e) Desulphurization equipment (Dry de-S)
  (f) Deodorization equipment (Chemical purification deodorization)
  (g) Dehydrator (Centrifugal dehydrator + Belt press dehydrator)
  (h) Dryer (Steam coil type)

Photo 2 Digester at Chiba Biogas Center

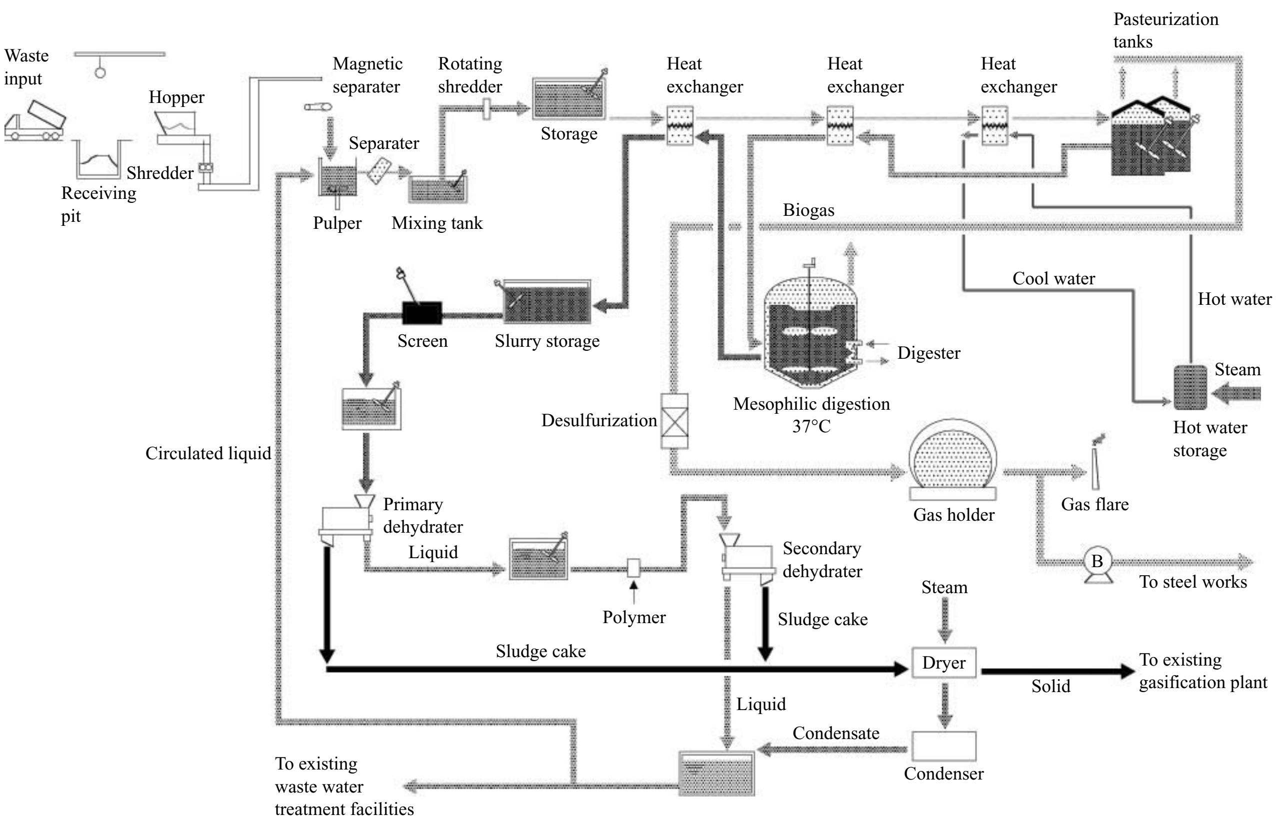

Fig. 4 Process flow of Chiba Biogas Center

5.2 Features of Plant

In addition to the common features of the Bigadan process, distinctive features of this plant include the following:

(1) Effective Use of Existing Steel Works Infrastructure

Infrastructure in the adjoining steel works is effectively used in power generation and water treatment, eliminating the need for separate equipment in the biogas plant. The biogas produced by the plant is not used to generate power in the facility itself; rather, the entire output is used as an energy source in the steel works. The steel works supplies the power and steam necessary for operation of the biogas plant, and water separated from the digested liquid by dehydration is transferred to an existing water treatment plant in the works.

(2) Cascade Treatment

After dehydration and drying, residual solid waste from the digested liquid is converted to fuel gas at the adjacent gasification & melting plant. As a 2-stage cascade-type treatment process, this is an unprecedented facility in Japan.

This biogas plant was constructed with a financial assistance from Japanese Ministry of the Environment in fiscal years 2001 and 2002 based on an evaluation of its advanced features. The plant has also been certified under the Food Recycling Law.

6. Summary

Based on the Biomass Japan Strategy, biogas systems have received a renewed attention as a method of effectively using organic wastes such as livestock manure, food-industry waste, kitchen waste, and presorted household organic waste. However, unlike in Europe, where liquefied manure can be recycled to agricultural land without further treatment, post-treatment of residual waste is required in most parts of Japan.

As described in this report, the Bigadan process biogas system has proven its effectiveness as a methane fermentation process from the viewpoints of sterilization, thermal efficiency, and stable operation. To gain an increased acceptance of the methane fermentation waste treatment process, it will be necessary to demonstrate post-treatment equipment which offers greater economy combined with high performance and optimize the pretreatment process (shredding/classification) to enable efficient treatment of diverse raw materials.

As an environmental plant maker, JFE Engineering believes that it has a responsibility to contribute to solving Japan's energy and CO_2 emission problems, and will therefore endeavor to improve and further develop the Bigadan process and related peripheral technologies and encourage wider use of methane fermentation technology.

Reference

1) Kumasaki, K. et al. "Methane fermentation technology applying sterilization by the high temperature and utilizing the slurry/slurry heat excharger as the pre-treatment". The 4th Annual Conf. of Jpn. Semage Works Assoc. 2003, p. 1045–1047.