Animal-Driven Modular Biogas Plant

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This paper presents a generalized description of a new design for the biogas plant. In this biogas plant (unlike in the conventional ones) : the animal urine is better utilized, the animal energy is taken advantage of in the feeding and stirring processes, and the expansion and interlinking are convenient.

Biogas plants are used for producing fuel gas as well as manure from an anaerobically-digestible bio-mass. There exist several designs for bio-gas plants. In the KVIC-design plant, the bio-mass is digested in an open-top cylindrical well and the bio-gas is collected in a separate bio-gas holder lying inverted on the cylindrical well. In the Chinese-design plant, the bio-mass is digested in a closed-top cylindrical well and the bio gas is collected in the space available on the bio-mass and below the top lid of the cylindrical well. In the Fry-design plant, the bio-mass is digested in a horizontal cylindrical tank and the bio-gas is taken out from this tank. The bio-gas plants of the KVIC, Chinese, Fry, and similar other designs are continuously operatable and have been well accepted by the user community. However, they suffer inter alia from their following drawbacks :

The urine given by the animals is not effectively utilized and instead much water is utilized in these bio-gas plants ;

The feeding and stirring of these bio-gas plants require cumbersome and time-consuming procedures ;

The expansion and interlinking of these bio-gas plants are almost impossible.

After studying the pros and cons of the various designs, a new design has been evolved for the bio-gas plant in which good points of the earlier designs are retained but the forementioned drawbacks are eliminated. This paper presents a generalized description of the new design.

Design Outline

The construction of a bio-gas plant of the new design is described below and through Figure 1.

There is a rectangular well of length a, width b, depth c, and with masonary metallic/synthetic walls of appropriate thicknesses.

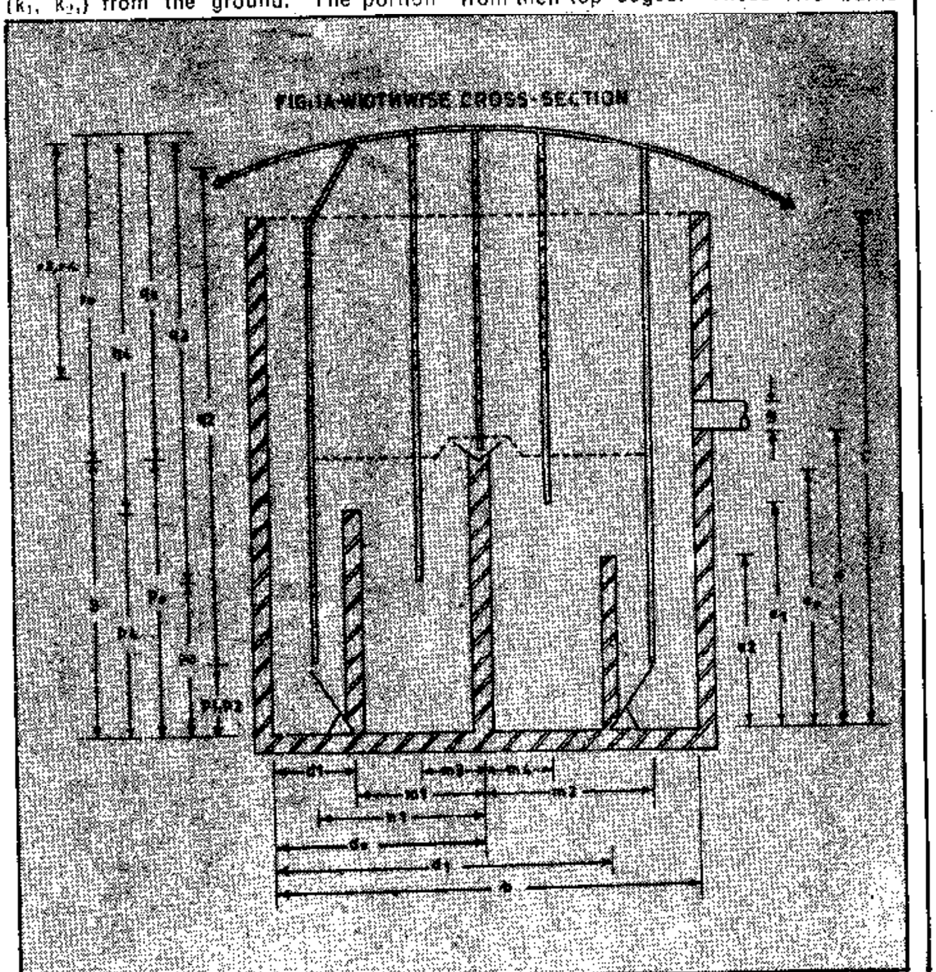
Inside the rectangular well, perpendicular to and touching the bottom and two widthwise side walls at distances (d_0, d_1, d_2) from the "first" lengthwise side wall : there are three partition walls of heights (e_0, e_1, e_2) and with masonary/metallic/synthetic walls of appropriate thicknesses.

On the "Second" lengthwise side wall, upwards from the height f : there is a slot of width g and height h.

If the slurry coming out of the well is to be directly utilized, there is a pipe to take slurry from the slot to the point of utilization. If the slurry coming out of the well needs to be stored before its utilization, there is a storage tank and there is a pipe to take slurry from the slot to the storage tank. The levelling of the bio-gas plant and/or storage tank is such that the slurry coming out of the slot can flow itself by gravity.

There is a metallic/synthetic walled gas holder lying inverted on the rectangular well. The lengthwise cross-sections of the top wall of the gas holder are straight lines, each one of length i and perpendicular to and confined within the two widthwise side walls of the well. The widthwise cross-sections of the top wall of the gas holder are parabolae, each one of focal length j and with its axis passing through the central partition wall during its initial position and with its first and second edges at heights (k_1, k_2) from the ground. The portion of the top wall of the gas holder, which projects in between the first lengthwise side wall and a plane at a distance from the first lengthwise side wall towards the central partition wall, is perforated in such a way that the cattle dung can easily pass through the perforations.

There are five baffle surfaces whose top edges are welded along straight lines at distances (O, m_1, m_2, m_3, m_4) from the central partition wall. The first baffle surface consists of two plane surfaces interconnected at an angle of about 150° ; its lower plane surface is at a distance n_1 from and parallel to the central partition well. The other four baffle surface are plane surfaces. The bottom edges of the five baffle surfaces are at heights (p_0, p_1, p_2, p_3, p_4) from the bottom of the well and at distances (q_0, q_1, q_2, q_3, q_4) from their top edges. These five baffle



surfaces are highly perforated in their upper portions starting from their top edges upto distances (r_0, r_1, r_2, r_3, r_4) from their top edges.

The top edge of the central partition wall is so constructed that the bottom edge of the central baffle surface does not slip out even when the gas holder is swinging. There may be a nonreturn valve mechanism attached with the bottom edge of the first baffle surface in such a way that the cattle dung can move only inwards the well. There may be another nonreturn valve mechanism attached with the bottom edge of the second baffle surface in such a way that the slurry can move only outwards the well.

There are two widthwise side walls welded with the edges of the top wall and five baffle surfaces of the gas holder. The bottom edges of these side walls are at a height s from the bottom wall of the well.

There is an appropriate provision for taking out the gas from the gas holder as and where required.

There is an appropriate provision for accommodating animals on the gas holder. The animals have their heads facing the second lengthwise side wall and have their backs facing the first lengthwise side wall, so that the dung excreted by the animals can straightway flow into the well through the perforated portion of the top wall of the gas holder.

Design Dimensions

The explanatory formulae for calculating the various parameters referred to in the above description are given below :

- a = 2.4 times the sum of the breadths of the animals to be accommodated on the top wall of the gas holder
- b = 1.6 times the maximum of the lengths of the animals to be accommodated on the gas holder
- $c = 1.5\ f$
- $d_0 = 0.5\ b$
- $d_1 = 0.2\ b$
- $d_2 = 0.8\ b$
- $e_0 = 0.8\ f$
- e_1 = any value between 0 and 0.75 f
- e_2 = any value between 0 and 0.75 f
- $f = 1/(a \times b)$ times the volume of the cattle dung put into the well during a typical retention period
- g = any value between 0.01 a and 0.5 a
- h = any value between 0.01 f and 0.2 f
- $i = a - 100$ mm
- $j = 0.5\ b$
- k_1 = any value between 100 mm and 1000 mm
- $k_2 = 100$ mm
- $l = 0.2\ b$
- $m_1 = 0.3\ b$ (on the side of the first lengthwise side wall)
- $m_2 = 0.4\ b$ (on the side of the second lengthwise side wall)
- $m_3 = 0.15\ b$ (on the side of the first lengthwise side wall)
- $m_4 = 0.15\ b$ (on the side of the second lengthwise side wall)
- $n_1 = 0.4\ b$ (on the side of the first lengthwise side wall)
- $p_0 = 0.8\ f$
- $p_1 = 0.2\ f$
- $p_2 = 0.2\ f$
- $p_3 = 1.5\ f - 1.625\ e_1$
- $p_4 = 1.5\ f - 1.625\ e_2$
- $q_0 = 0.7\ f + 0.2\ b$
- $q_1 = \sqrt{1.69\ f^2 + 0.312\ fb + 0.0244\ b^2}$
- $q_2 = 1.3\ f + 0.155\ b$
- $q_3 = 1.625\ e_1 + 0.08625\ b$
- $q_4 = 1.625\ e_2 + 0.08625\ b$
- $r_0 = 0.7\ f + 0.2\ b$
- $r_1 = 0$
- $r_2 = 0$
- $r_3 = 0.45\ f + 0.08625\ b$
- $r_4 = 0.45\ f + 0.08625\ b$
- $s = 0.8\ f$

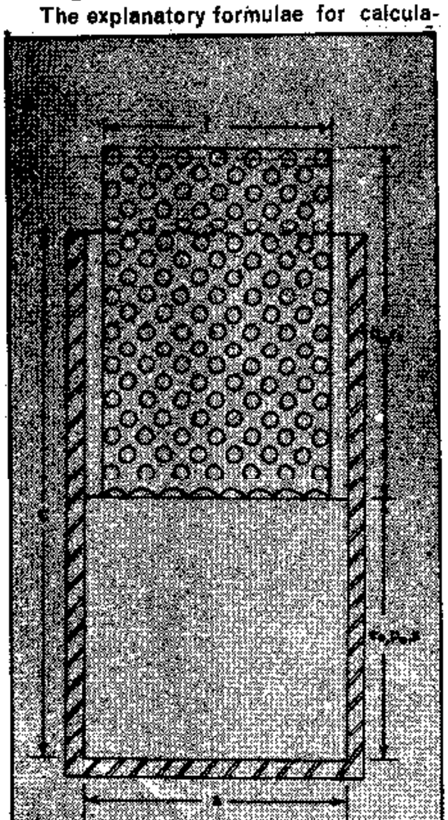


FIG.18 LENGTHWISE CROSS-SECTION

Performance

The performance of a bio-gas plant of the new design is described below :

The cattle dung and/or urine excreted by the animals flows towards the perforated portion of the top wall of the gas holder. It then flows into the chamber between the first lengthwise side wall of the well and the first baffle surface of the gas holder. The introduction of this cattle dung and/or urine leads to a displacement of an equal amount of biomass from one chamber into its subsequent chamber. Consequently, an equal amount of slurry is pushed into the outlet pipe from the chamber between the second lengthwise side wall of the well and the second baffle surface of the gas holder.

When the animals make any movements on the gas holder, the baffle surfaces of the gas holder also make corresponding movements. As a result, the bio-mass is stirred inside the well. This stirring might push some slurry into the outlet pipe.

The microbial action on the biomass inside the well converts the bio-mass into a digested slurry and generates the so-called bio-gas. The bio-gas is collected on the top level of the bio-mass inside the well and confined by the outer walls of the gas holder. The bio-gas is taken out through the gas outlet pipe as and where required.

Alternatives

Several additions/alterations are possible in the above mentioned new design. A few of these are described below :

A green-house type arrangement may be added on the gas holder so as to prevent the digestion rate from falling down.

Instead of accommodating animals, latrines for human use can be constructed on the gas holder.

The top wall of the gas holder may be of a shape other then the paraboloidal one suggested hereabove.

The formulae given hereabove for calculating the various parameters need not be strictly adhered to so far as the qualitative aspects of the new design are taken care of. ☐