Tanzania Domestic Biogas Programme

Research on the operation and performance of the MCD – 9 m^3 Solid State Biogas Plant

Plant description and operation

The CAMARTEC Solid State – domestic biogas plants have been designed and modified by TDBP from the popular MCD to allow use of fresh undiluted cattle dung as substrate/feeding material that will suit the potential group of livestock keepers living in dry or semi arid areas of Tanzania.
Such a group includes the pastoralists in the northern, central, western and the Lake Zone.

Modifications

Major modifications that have been incorporated in SSD are:

- Its large cylindrical inlet opening of 80 centimeters diameter instead of the current 10 centimeters diameter PVC inlet pipe which will allow a stiff organic material to enter into the digester.
- A separate cylindrical dung mixing chamber with a conical bottom of 90 centimeter diameter where removal of unwanted materials or debris takes place.
- Increased digestion volume via its deeper inlet and outlet openings and the conical shaped bottom of the digester that compensates for the lost volume due to expected siltation.
- Placement of the expansion chambers manhole directly on top of the slurry outlet opening to facilitate removal of inorganic solids

Literally under normal operations such biogas plants require very little or no water for mixing with cattle dung, and can generate about 50% more biogas due to the fact that what influences the amount of gas production is the quantity of total organic solid contents (TSC) in the mixture.
The total solid content (TSC) of the fresh cattle dung normally varies between 15–19%. If dung is thoroughly mixed with an equal quantity of water, a case with our popular MCD will produce a mixture with TSC of between 8–10%, and the digested slurry discharged from these biogas units is watery, containing up to 94–96% of water and the Total Solid Content 4–6%.
The slurry is spread on to the ground or collected into open slurry pits for drying, over a period of up to 45 days, to facilitate its transportation to the fields for use as manure.

Like for the popular MCD, initial feeding has to start with a mixing ratio of dung to water/urine 1:1, and once a plant has started producing gas, the ratio/consistency can now be changed gradually, i.e. from 1:1, 3:1, 4: 1 and lastly undiluted fresh dung only without varying the amount of fresh dung to be fed into the digester provided that slurry will be able to flow by itself in and out of the system.

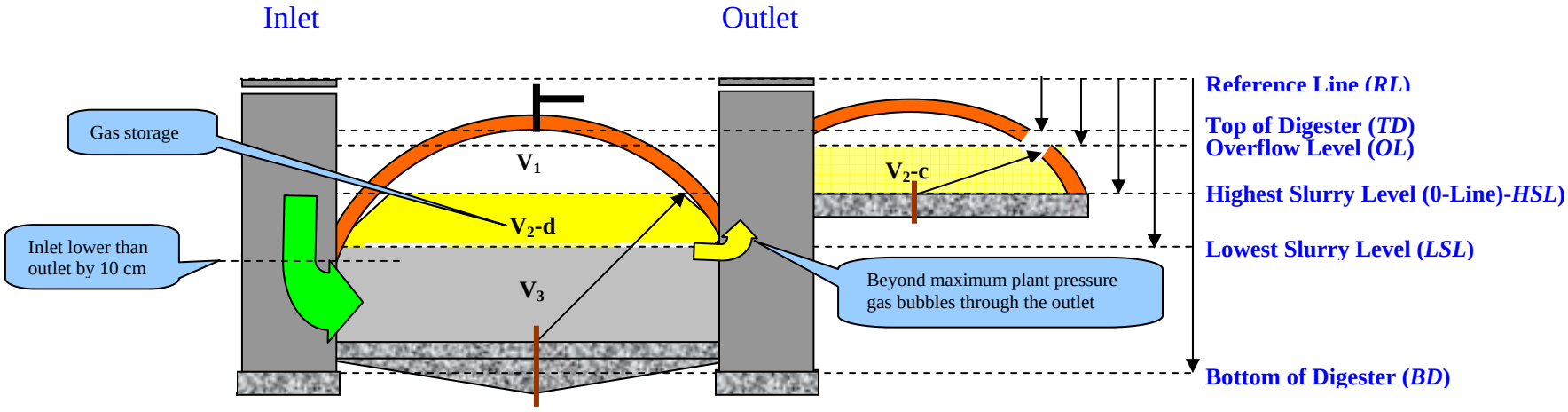
Testing will be conducted in several phases, basing on the convenient consistency of the influent to determine the amount of gas production/day as well as the optimum hydraulic retention time which is also likely to prolong from i.e. 50 days to 100 days.

Since this process occurs at high TSC i.e. the substrate fed into the plant does not flow by itself. This method requires a much smaller quantity of water, makes handling of the digested slurry easier, utilizes a variety of agro-residues as substrate, and conserves nutrients in the digested slurry to provide excellent manure for crop cultivation.
The appearance of the biogas unit may be much cleaner than it is for the common biogas plant (MCD) and thus may help overcome the farmers' reluctance to locate the plants near their houses.
If at all urine can be tapped through a trough to be built within a kraal, then its quantity must be sufficient to mix with dung, and therefore water will no longer be required.

Plant operation

The modified plant will initially be charged as usual with a 1:1 mixture of cattle dung and water/urine (TSC of the mixture 8–10%) along with the innoculum.
This is the material that is used to start the digestion process, and fresh digested slurry collected from a working biogas plant is used as innoculum. Thereafter, the plant is fed every day with a mixture of 78.70 kg of cattle dung and 78.70 litres of water/urine for a period of about fifty days (At 50 days HRT). The operation of the plant gets stabilized during this period. The stabilized operation will be indicated by a relatively uniform gas yield of 2300 - 3440 litre/day and a normal flow of well digested slurry through the plant and the outlet chamber/channel.
After the plant operation becomes stabilized, the substrate is changed to fresh undiluted cattle dung.
About 78.70 kg of fresh cattle dung will be poured everyday into the inlet opening of the modified CAMARTEC biogas plant (Figure 01).
The dung should be free from foreign matter such as straw, grass, dust, etc with TSC of less than 18%. (To determine whether the TSC is less than 18%, make a round ball of fresh cattle dung (diameter around 12.5cm) and put it on a flat surface.
If the ball does not retain its spherical shape, the dung is fit for feeding into the plant.)

Fig 01:



- **V_1** (white) = Dead digester Volume above readily available Gas storage volume (V_2-d) at the top of the dome.
- **V_2-d** (yellow)= Readily available Gas storage volume at mid of the dome equals the slurry storage Volume of the expansion chamber (V_2-c)
- **V_3** (grey) = Digesters minimum digestion volume at the bottom of the dome, just below the gas storage and under the outlet ring beam.
- **(V_2-d) + V3** = Digesters maximum digestion volume at the 0-line level (Highest Slurry Level)
- **V_3 + ½(V_2-d)** = **{(V_2-d) + V3}/2** = (min. vol + max. vol) /2 = mean digesters volume = Digesters active volume

Fig 02:

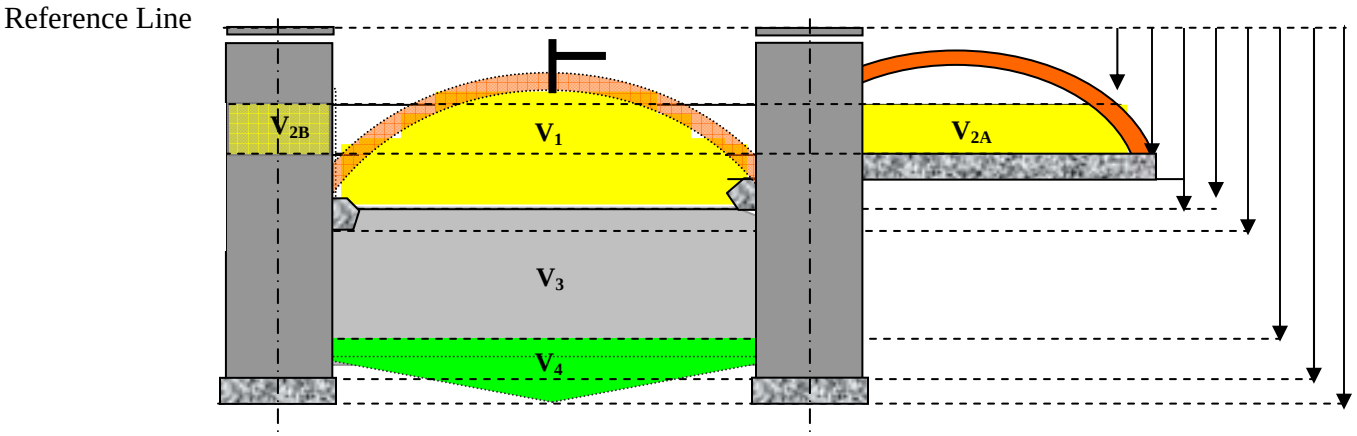


Figure 03: Perspective view of a popular MCD – 9 m^3 biogas plant with a flat bottom in 3D

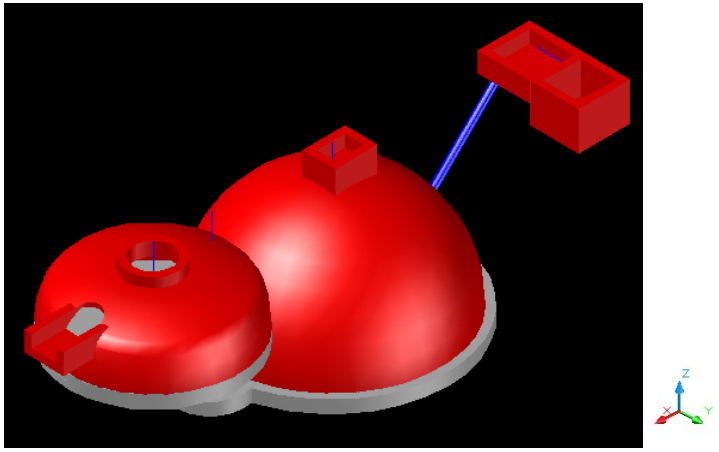
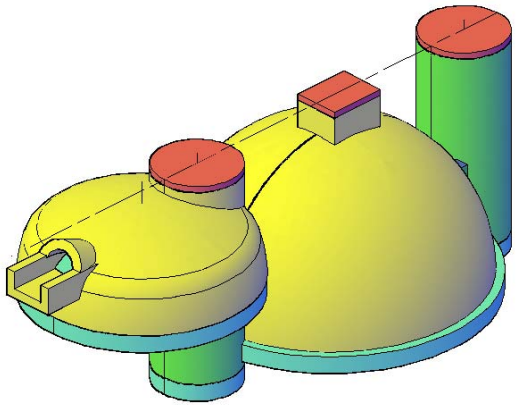


Figure 04: Perspective view of a modified SSD - 9 m^3 biogas plant with a conical bottom in 3D



If the TSC of the available cattle dung is more than 18% then it has to be lowered to around 16% by mixing with a little amount of water (Dilution).
The cattle dung slowly slides into the digester by gravity and the digested slurry flows out through the outlet opening into the expansion chamber and finally out via overflow outlet opening. A smooth flow of the digested slurry along the canal will be facilitated by gravity by retaining the current slurry overflow outlet opening width of 40 cm.

Cost of the plant

The cost of the modified MCD biogas plant has been found to be a little bit higher than that of the popular MCD of 9 m^3 and 13 m^3 capacity respectively in terms of the material consumption and a bit more time taken in construction (Labour).
NB: The exact cost of a plant may be established on locality basis, i.e. depending on the prevailing prices of the material in a respective place. (See the BOQ below):

Table 01: BOQ FOR THE MCD – SOLID STATE-FIXED DOME BGPs May 2011

S/N	ITEM	PLANT SIZE			
		9 m^3		13 m^3	
		Qty	Cost (Tas)	Qty	Cost (Tas)
1.0	**Construction material**				
1.1	Bricks (23 cm × 11 cm × 7 cm) ~ pcs	1400		1700	
1.2	Cement (50 kg bag) - bags	27		34	
1.3	Lime (25 kg bag) - bags	6		8	
1.4	Sand (ton)	7		8	
1.5	Gravel (ton)	5		7	
1.6	Stones (ton)	4		5	
1.7	Chicken wire-180 cm wide (metre)	24		34	
1.8	Water proof cement (1 kg. pkt)	5		6	
1.9	Welded/ Square wire mesh (piece)	1		1	
1.10	Round iron bar - 10 mm (piece)	1		2	
2.0	**Fittings & accessories**				
2.1	Dome gas pipe + ¾” Main ball valve	1	By the Programme	1	By the Programme
2.2	*Plastic/Galvanized steel pipe ½”				
2.3	*Plastic/Galvanized steel pipe ¾”				
2.4	*Stove valve – ½” - pc				
2.5	Lamp valve – ½” – pc	1	By the Programme	1	By the Programme
2.6	*Water trap/drain + ball valve (std)				
2.7	Pressure gauge (max. 16 kPa) – pc	1	By the Programme	1	By the Programme

3.0	**Biogas appliances**				
3.1	*S/B biogas stove ~ pc	1		1	
3.2	*D/B biogas stove ~ pc		Optional		Optional
3.3	*Biogas lamp ~ pc	1		1	
4.0	**Labour**				
4.1	Excavation of pits		By the client		By the client
4.2	Installation fee		By the Programme		By the Programme
4.3	M & O + AfSS		By the Programme		By the Programme
TOTAL					

Plant performance

The modified plant is expected to work satisfactorily.

The average retention period for the new SSD works out to be more, i.e. between 60 - 100 days as compared to 50 days for the current MCD.

The modified plant is also expected to perform far better than the popular MCD plant for the diluted cow dung.

Testing of MCD-SSD plants constructed in Mgagao-Mwanga & Terrat-Arusha

In order to come up with a well functioning and performing plant design with very minimum maintenance requirements, the following parameters need to be observed, measured and analyzed:

- The right mixing ratio of dung to water/urine apart from the fresh dung alone that will allow easy in and out flow of fresh and digested dung respectively, good consistency, and convenient operation of the plant by the user.
- The right mixing ratio that will enhance more gas production in litres/kg of dry mass
- The right mixing ratio that will enhance higher degradation of total solids and volatile solids in the substrate

NB: ***Digester - Plant size = 9 m^3; Active digester volume = 7.87 m^3; Digestion temperature = $20^0C – 34^0C$;***

Table 02:

Average Feeding			**Total feeding Dung+liquid Ltr/day**	**Average HRT (days)**	**Gas yield (litres/kg/day)**	**Total solids degradation (%)**	**Volatile solids degradation (%)**	**TSC Organic (%)**
Ratio	**Fresh Dung (kg/day)**	**Liquid Water/urine (ltr/day)**						
1:1 (***std***)	78.70	78.70	157.40	50				
2:1	78.70	39.35	118.05	67				
4:1	78.70	19.675	98.375	80				
8:1	78.70	9.8375	88.5375	89				
No liquid	78.70	0	78.70	100				

Table 03: 'MCD' SSD - 0001 – 9 m^3 CAPACITY BIOGAS DIGESTER - TECHNICAL DATA

PARAMETER	VALUE
DOME VOLUME	*10.26 m^3*
ACTIVE DIGESTER VOLUME	*7.87 m^3*
GAS STORAGE VOLUME (Vg)	*2.10 m^3*
GAS STORAGE CAPACITY – (Vg)/Vgp-max)	*61.00%*
PLANT MAXIMUM GAS PRESSURE	*80 cm of H_2O column (8 kPa)*
CATTLE DUNG SPECIFIC GAS PRODUCTION	*0.03 – 0.04 m^3/kg/day*
MINIMUM DAILY FEEDING (Vfs-min) at HRT = 60 days	*65.58 kilograms*
MAXIMUM DAILY FEEDING (Vfs-max) at HRT = 40 days	*98.38 kilograms*
MINIMUM DAILY GAS PRODUCTION (Vgp-min)	*2.30 m^3 (2,300 litres)*
MAXIMUM DAILY GAS PRODUCTION (Vgp-max)	*3.44 m^3 (3,440 litres)*
MINIMUM HYDRAULIC RETENTION TIME	*40 days*
MAXIMUM HYDRAULIC RETENTION TIME	*60 days*
# CATTLE UNDER FREE RANGE GRAZING SYSTEM	*20 - 24*
DIGESTION TEMPERATURE RANGE	*Mesophilic range (22^0 C – 34^0 C)*
INITIAL FEEDING-MIXING RATIO (starter)	*Dung: water/urine = 1: 1 (at initial stage)*
FEEDING RATIO UNDER NORMAL OPERATION	*Only fresh dung (under solid state condition)*
TYPE OF FEED STOCK/SUBSTRATE	*Fresh cattle dung*

Figure 05: <u>MAP SHOWING THE LOCATION OF TDBP's FIRST OPERATING SSD BIOGAS PLANT</u>

Figure 06: <u>A MAP SHOWING THE LOCATION OF TDBP's SECOND CONSTRUCTED SSD BIOGAS PLANT</u>