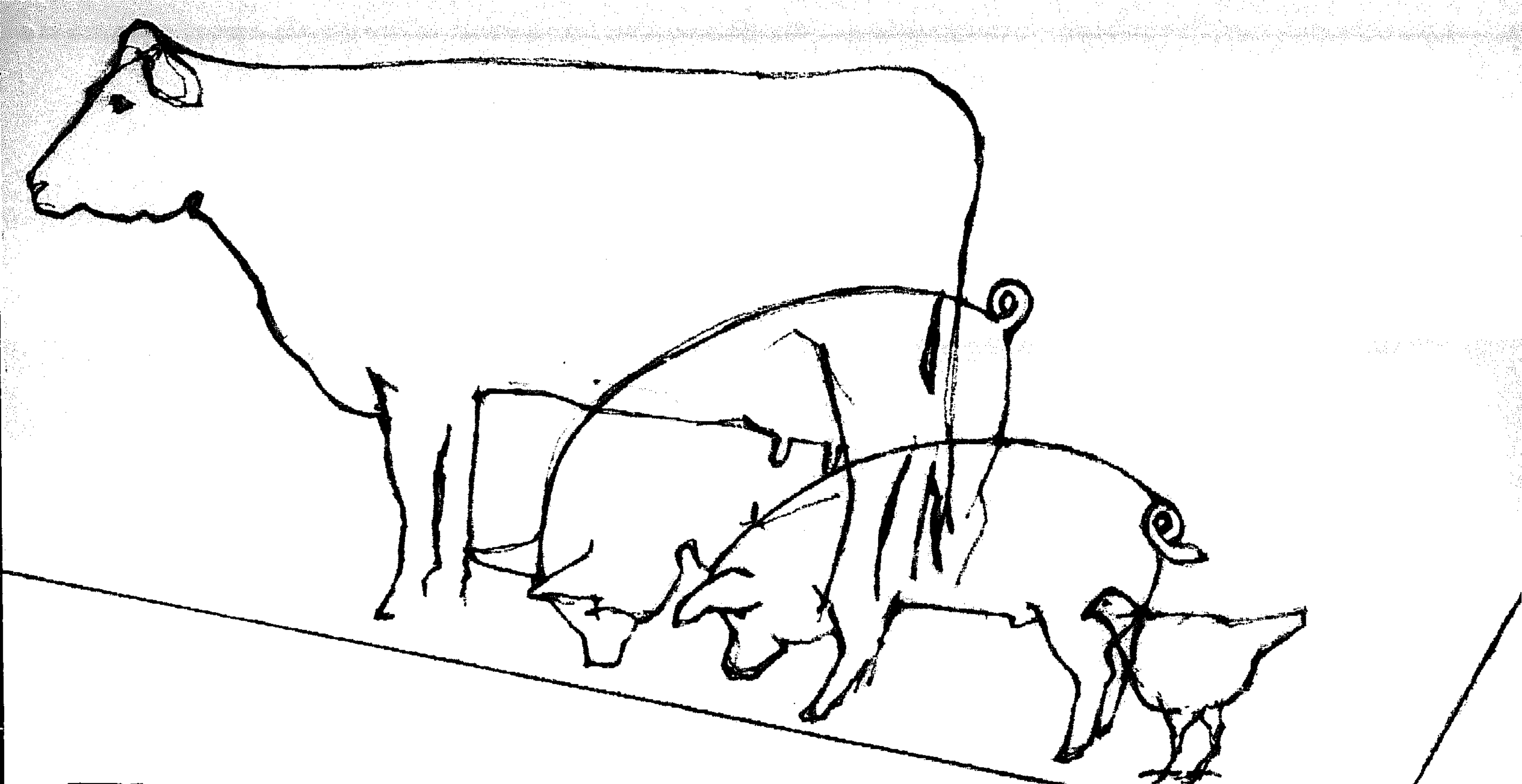
The Anaerobic Digestion of Livestock Wastes to Produce Methane: 1946 to June 1975, A Bibliography with Abstracts

by: Gregg Shadduck and James A. Moore

Published by:
University of Minnesota
Agricultural Engineering Department
1390 Eckles Avenue
St Paul, MN 55108 USA

Paper copies are $ 3.00.

Available from:
James A. Moore
Agricultural Engineering Department
University of Minnesota
St Paul, MN 55108 USA



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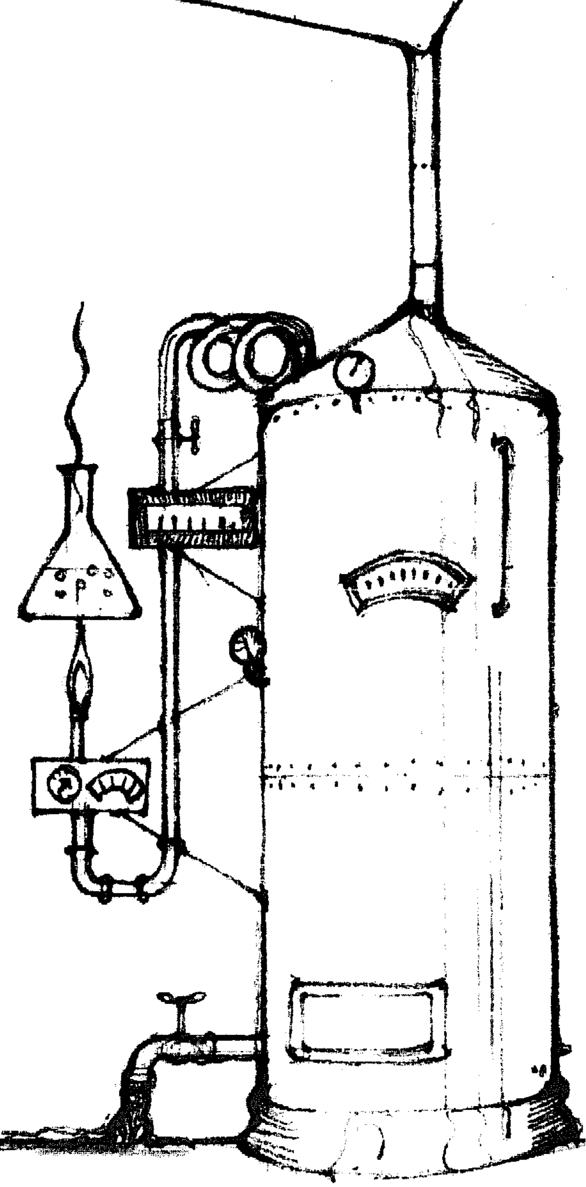

UNIVERSITY OF MINNESOTA

Gregg Shadduck compiled this while he
was a resource specialist at the
Center for Studies of Physical Environment, Institute of Technology.
James A. Moore, Assistant Professor,
Department of Agricultural Engineering,
assisted in this venture.
University of Minnesota

Additional copies of this may be purchased
for $2.00 by writing J. A. Moore, Ag Engr
Dept., Univ. of Minn., St. Paul, MN 55108.

PREFACE

The search which yielded this bibliography was conducted in support of studies at the University of Minnesota relating to the anaerobic digestion of cattle and swine wastes.

Sources of the bibliography entries and abstracts (where present) are indicated within brackets following the entries. The titles of the following sources are abbreviated as below:

Bibliography of Agriculture	BA
Bibliography of Agriculture computer search	CAIN
Chemical Abstracts	CA
Water Pollution Abstracts	WPA
Commonwealth Bureau of Soils annotated bibliography no. 874; Manure Gas	CBS
London Science Museum Science Library bibliographical series no. 794; Some Post-War References to "Bio-Gas"	SL
Dokumentation Landtechnik, Braunschweig-Volkenrode, bibliography; Biogas	DL
Commission Internationale des Industries Agricules bibliography 2650; Bibliographie Sur La Production Du Gas De Methane Par Fermentation Du Fumier Et Des Residus Agricoles, En Vue De Son Utilisation A La Ferme	CI

Bibliography entries having sources which are other entries are acknowledged by the assigned number of the source within backets. Abstracted entries without source credit are publications which we have seen and abstracted. We have tried to fairly convey the essence of the papers; ommission of desired information in the abstracts most often reflects a lack of those particulars in the original. In many instances authors' abstracts convey the substance of the publication as well or better than we would have been able, and for that reason are included. English units of measurement have been converted to SI units.

Recent popular articles have generally been excluded, and we suggest that readers interested in them see such periodicals as Popular Science, Mother Earth News, Alternative Sources of Energy, or popular farming magazines.

We will be pleased if this work helps in answering some questions which others have and helps raise additional questions. We solicit readers' comments, additions, or corrections.

Thanks go to Dianne Legg and Mary O'Reilly, mentors in the use of libraries and for their aid and encouragement, and to the Minnesota Resources Commission for funding this work.

Gregg S. Shadduck
James A. Moore

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ERRATA

The Anaerobic Digestion of Livestock Wastes to Produce Methane, 1946 - June 1975: A Bibliography with Abstracts.

Note that date of publication is December 1975.

	For:	Read:
p.iii, lines 17-20	Commission Internationale des Industries Agricules bibliography 2650; Bibliographie Sur La Production Du Gas Methane Par Fermentation Du Fumier Et Des Residus Agricoles, En Vue De Son Utilization a La Ferme.	Commission Internationale des Industries Agricoles bibliography 2650; Bibliographie Sur La Production Du Gaz De Methane Par Fermentation Du Fumeir Et Des Residus Agricoles, En Vue De Son Utilisation À La Ferme.
pages vii and viii	vii and viii	v and vi
p. 82, line 39	fumier et des residus agricoles, en rue de son utilisation a la ferme.	fumier et des résidus agricoles, en vue de son utilisation à la ferme.
p. 83, line 1	The following tables, as nearly as possible, the figures are given.	The following tables present, as nearly as possible, the figures as given.
p. 83, line 6	vs	ours,

It is neither our task nor this the place to again present a short primer on the basics of the process of anaerobic digestion of wastes. For such a description the reader is referred to Raymond Loehr's Agricultural Waste Management: Problems, Processes, and Approaches (Academic Press, 1974) for waste characterization and treatment technique information. One might also consult any number of texts on wastewater treatment plant design and operation or several of the publications found among the later entries in this bibliography.

A short synopsis of the literature should suffice in making clear several changes of emphasis and several enduring points of interest regarding the anaerobic digestion of agricultural wastes. Among the central points of change are the following:

(1) The literature reflects a switch in emphasis from digester operation in Europe some decades ago to numerous laboratory studies in North America. The post-war flurry of anaerobic digestion studies and digester construction in Europe, which was motivated by fuel and fertilizer shortages, abated with increases in the availability of fuel. The value of the fuel and fertilizer produced by the process decreased as the cost of the traditional goods declined. North American studies have explored the possibilities of the process as a waste treatment technique and have also engendered what is probably an overly optimistic opinion of the fuel potential available through the process.

(2) The Germans built only about 20 biogas plants of several designs while the French constructed perhaps a thousand installations along the lines of the Ducellier-Isman design. The later technique of batch digestion, where a mass of waste is placed in a sealed vessel and allowed to decompose, has been largely superseded in the literature by the study of continuous-feed digester designs which are kin to municipal digesters. Wastes equal to a fraction of the digester capacity are introduced into the digester at regular intervals, often daily, while an equal volume of the digester contents are removed. In many situations such stability in the workload has greater advantage than the periodic effort required in charging batch digesters, gas production should be even, and the practice uses digester volume more efficiently than the batch process.

(3) Digestion of mixed wastes ("stable manure"; feces, urine, and litter) has been displaced by digestion of feces and urine or feces alone due to changes in methods of livestock management.

Yet, there are features common to both the earlier and contemporary researches:

(1) The cool temperature of winter causes a reduction of gas output from unheated digesters and results in decreased net gas production from heated digesters. Efforts to maintain digester temperature and decrease heat losses have included building digesters below ground, insulating the digesters with the normal range of insulating materials or being so ingenious as to surround the tank with heat-yielding compost, attempts at solar heating the digester, and the ploy of Ducellier and Isman who aerobicly fermented the wastes in batch digesters for a day before insuring anaerobic conditions, thereby raising the temperature of the mass to 70°-80°C through the bacterial oxidation of a significant amount of the nutrients.

(2) The conception of the "tank" persists, be it hand-laid brick, poured concrete, or erected Harvestore. The symmetric tank, with its common components of steel, concrete, and labor, incurs the expenditure of a sizeable amount of capital and materials. Alternative construction along the lines of a trench sealed with plastics or emulsions has been proposed, and we understand that such a trench digester is operating in Michigan. Yet experience with alternate construction materials appears to be totally lacking in the literature.

(3) But those which have changed least are the factors which must coincide to make the anaerobic digestion of agricultural wastes to produce gas economically feasible. Farm labor should be reduced by the introduction of the process, or suitably compensated for any additional labor involved, the effluent must find value locally as fertilizer, and the gas should be used to best advantage in applications wherein its attributes as a fuel find fullest use; and this within the constraints of alternate fuel and fertilizer cost and availability.

1946–1950

1 Abiet, P. Une source d'énergie à la disposition des agriculteurs "le gaz de fumier." Agr. Prat. 114:275-277. June 1950. [BA 14 70379]

2 ________. Une source d' énergie à la disposition des agriculteurs "le gaz de fumier." Colon Franc. de Tunisie 60(2156):2. July 29, 1950. [BA 14 85966]

3 Axelson, J. The amount of produced methane energy in the European metabolic experiments with adult cattle. Sweden. Landbrukah'ogsk. Ann. 16:404-419. 1949. [CI]

4 Ballu, T. Sur l'utilisation du gaz de fumier en motoculture. Acad. d'Agr. de France. Compt. Rend. 32 (7):298-301. Apr. 3/17, 1946. [BA 9 21773]

5 Ballu, Tony. Le gaz de fumier. Mach. Agr. et Èquip. Rural no. 55:1-3. July 1946.

Ballu describes the technique of Ducellier and Isman, at the Institute of Agriculture in Algeria. Wastes are batch-fermented by placing them in tanks and aerating the mass for 20 hours in order to raise the temperature to 70° - 80°. The wastes are then flooded with water and liquid manure, and the anaerobic process commences. A floating gas-holder covers the tank and manure and straw are packed to a thickness of 40 cm. about the walls to serve as insulation. In unmixed tanks of several tens of m^3 size gas production was 70 - 90 m^3/tonne waste, or 40 - 50 m^3/ m^3 tank capacity, averaging 0.4 tank volumes/day for the duration of the fermentation. There follows a lengthy description of an installation owned by Mr. Renandat, a farmer at Levroux (Indre), which consists of a battery of 4 tanks (100 m^3 total volume), gas-holder and compressor, pressure storage tank, and gas-fueled tractor. Ballu estimates that such an installation would pay for itself within 10 years of construction by the production of gas and savings in fertilizer costs.

6 Blachère, C. Le gaz de fumier. Voix des Colons 31 (1503):1. May 9, 1949. [BA 13 62988]

7 Boelhouwer, G. [Farm-produced methane.] (It.) Avvenire Agr. 57:81-85. Apr. 1949. [BA 13 62989]

8 Carillon, R. Le methane biologique ou gaz de fumier. Génie Rur. 43:251-254. July/Aug. 1950. [BA 14 85967]

9 Carré, Isabelle. Le gaz de fumier. Chimie et Industrie 57(5):448-452. May 1947.

A short description of the process is given, with gas yields from various feedstocks, and the composition of the gas. Short descriptions of several batch digester designs are given, being; Algerian, Salubr, Bétur, Baudot-Hardoll and Ofta, and Somagaz. Short notes on the utilization and the economics of the process follow. Two diagrams of Ducellier and Isman designs **are included**.

10 _______ Les cuves de production de gaz de fumier. Mach. Agr. et Equip. Rural, No. 66:10-12. June 1947. [BA 11 24445]

11 _______ Le gaz de fumier. Nature [Paris] 3163: 346-348. Nov. 1948.

Descriptions of several batch digesters are given; viz. the Algerian, Salubra, Bétur, Baudot-Hardoll and Ofla, and Somagaz designs. Sketches of two Ducellier and Isman designs are given with a photograph of an installation consisting of four contiguous, rectangular concrete tanks. There are short explainations of the fundamentals and economics of the process, and of the use of the gas. This article is nearly identical to the 1947 paper by Carré in Chimie et Industrie.

12 Charrier, M.F. Gas producer. U.S. patent 2,462,720. 1949. [SL]

13 Cisneros, L. Un nuevo combustible: el gas de estiércol. Agricultura [Madrid] 19:335-338. July, 1950. [BA 15 6946]

14 Coppenet, M. and G. Ducet. Transformation du fumier au cours d'une expérience pour le production du gaz de fumier. [Transformations of manure during the course of an experiment on the production of gas from manure.] Ann. Agron. 18:33-38. Jan/Feb. 1948. [CA 42 5600d, CBS 37]

A concrete vat was filled with a mixture of horse and cow manure and liquid manure and fermented for 106 days at 28-30°C. A daily average of 524 liters gas/ tonne was produced, the gas consisting of equal parts CO_2 and CH_4, with H_2 varying from almost none to 25%. It was determined that the gas was produced by the destruction of cellulose and pentosans with little contribution from the lignins and humic acids.

15 Dragon, J. Le gaz de fumier. Blé et le Vin 25(1110): 1,3. Sept. 5/12,1948. [BA 13 13320]

16 Ducellier, G., and Isman, M. Un carburant spécifiquement agricole, le gaz de fumier. Tech. et Agr. No. 11/13:23-24. 1946. [BA 10 23364]

17 Ducellier, Gilbert L.R. and Marcel A. Isman. Methane. Brit. patent 621, 746. April 19, 1949. [CA 44 2767]

CH_4 is produced by the fermentation of manure or analogous substances in a vat having a dome covering the vat, the lower edge of the dome being immersed in a liquid seal, and the dome being arranged to rise vertically in order to hold the CH_4 produced. P.J. Wilson, Jr.

18 _______ and Marcel A. Isman. Combustible gas from fermentation of organic matter. British patent 621,747. April 19, 1949. [CA 43 6781d]

Organic matter is subjected to two successive fermentations, viz. thermophilic and anaerobic, to produce CH_4. In the first, the formation of

butyric acid is prevented by combustion of sugars and starches, and heat produced contributes toward maintaining the temp. of the mass. In the second, the cellulose is decompd. giving CH_4 and CO_2. A drawing illustrates four arrangements for fermenting vats. T.R. Zegree

19 ________ and Marcel A. Isman. Auto-vinificateur - gaz de fumier et humus. Soc. des. Agr. d'Algérie. B. 92:45-47. May 1949. [BA 13 71425]

20 ________ and M. Isman. Les enseignments de dix années de travaux sur la production du gaz de fumier. Elevage et Culture 20. 1950. [414]

21 The dung heap as a power house; methane from muck was answer to wartime fuel shortage. Farmer's Weekly [London] 24(22):35. May 31, 1946. [BA 9 16004]

22 Elia, G.D'. [Methane gas from manure fermentation as a source of heat, light, motive power, and super fertilizers.] (It.) Riv. di Zootec. 23:292-294. Sept. 1950. [BA 15 23349]

23 Formigoni, L. Dal letame si può ottenere gas? Campagna 46:312. November 1, 1947. [BA 12 26902]

24 Frère, J. L'utilisation du fumigaz dans les territoires francais d'outre-mer. Agron. Trop. 2(1/2): 76-79. Jan./Feb. 1947. [BA 11 4692]

25 Gautier-Walter, A. Un nouveau carburant pour l'agriculteur: le gaz de fumier. Monit. Agricole 2(66/67):3. April 17/24, 1949. [BA 13 54990]

26 Hisserich, H. Mehr Energie und Dünger aus der Landwirschaft. Landtechnik 2(7):3-4. March 31, 1947. [BA 13 5174]

27 ________ Energie aus der Landwirschaft: über die Heiz- und Triebgasgewinnung und Verlustlose Düngerbereitung auf jedem landwirtschaftlichen Betrieb. Land, Wald u. Gart. 2:131-133. May 1947. [BA 11 31707]

28 Humbert, W. Grâce au métagaz ou gaz de fumier toutes les fermes doivent avoir le gaz. Acclimatation 75:42. Feb. 14, 1948. [BA 12 34063]

29 Imhoff, K. The production of gas for motor fuel from solid wastes. Gesundh. - Ing. 68:3-5. 1947. Chem. Zentr. 1947, II: 91-2. [CA 44 2729d]

The production of methane from such materials as chaff, pine needles, paper, whey, or animal manure is discussed. M.G. Moore

30 ________ Digester gas for automobiles. Sewage Works J. 18:17-25. 1946.

Imhoff presents a number of designs of digesters using animal waste, but "No gas plants are as yet [ca. 1945] operating on stable manure..." in Germany. He estimates that the power to heat and operate a digester is 1/4 the energy of the CH_4 produced. Includes design of continous digester.

31 ________ Treibgasgewinnung aus festen Abfallstoffen. Ebenda 68:3. 1947. [140]

32 Kriebel, M. Biogas, eine neue Energiequelle für die landwirtschaft. Neue Mitt. f. die Landw. 3:290-291. Sept. 21, 1948. [BA 13 21227]

33 Lagarde, J. Le gaz de fumier. Acclimatation 76:192. Sept. 3, 1949. [BA 14 6007]

34 Leroy, A. Un gisement de carburant dans votre ferme. Vie à la Campagne 38:24-25. Jan. 1949. [BA 13 38949]

Manure gas equipment.

35 ________.Le métagaz, ou gaz de ferme. Cour. Agr. 15(15):1-2. July 12,1950. [BA 14 85968]

36 Longi, G. Un carburant gratuit source de confort à la campagne: le méthane ou "gaz de fumier." Moisson 3(99):3 Aug. 1/7, 1947. [BA 11 24459]

37 Marcilla, J. Neuvas industrias de fermentation, a base de productos y residuos agricolas. Agriculture [Madrid](XIX) No. 215:98-103. March 1950. [CI]

38 Martinet, R. L'utilisation du "gaz fumier" a la ferme. Nord. Agr. 5(25):2. April 22, 1949. [BA 13 55125]

39 Massot, R. Dans l'Indre, un tracteur marche au gaz produit à la ferme. J. de la France Agr. 6:1089. Sept. 1/7,1950. [BA 15 6806]

Methane from manure.

40 Miège, E. Le gaz de fumier. Inform. Maroc. 416:1,4. Jan. 1, 1949. [BA 13 46852]

41 Morales y Fraile, E. Aprovechamiento del gas metano del estiércol: luz y energía en la finca. Agr. Levantino 13(150): 20, 40. May 1947. [BA 11 16776]

42 ________ Aprovechamiento del gas de estiércol: luz y energia en la finca. Balearic Isl. Dip. Provincial B. Agr., No. 40:2. Jan. 1948. [BA 12 41030]

43 Müller, W. Faulversuche in Halle/Saale mit organischen Abfallstoffen. Z. Ges. Ing. 70:123. 1949 [140]

44 Peraire, M.D. Le gaz de fumier; construction des cuves. France Agr. 2(71):3. Oct. 1946. [BA 10 17276]

45 ________ Utilisation du gaz de fumier. France Agr. 2(73): 3. October 25, 1946. [BA 10 23372]

46 Pöpel, F. Gaserzeugung und Stoffverluste bei der Schlammfaulung. Z. Ges. Ing. 68:85. 1947. [140]

47 ________ Die gemeinsame Verwertung fester und flüssiger Abfallstoffe. Ebenda 69:17. 1948. [140]

48 Reinhold, F. Energiegewinnung aus Abfallstoffen. Z. Ges. Ing. 70(17): 309. 1949. [140, 241 Stauss]

49 Renaudat, J. Un exemple de production de gaz de fumier. France. Min. de l'Agr. B. Tech. d'Inform. 39:229. April 1949. [BA 13 85620]

50 Rieu-Peyroux. Le gaz de fumier. Unité Paysanne 4(198):2. Aug. 27, 1949. [BA 13 85621]

51 __________ Le gaz de fumier. Unité Paysanne 4(199):2. Sept. 3, 1949. [BA 14 6011]

52 Roberti, G. [Methane, natural, but also biological.] (It.) Cron. Econ. 91:11-14. Oct. 15, 1950. [BA 15 23356]

53 Roussiaux, P. En France: 1,000 fermières cuisinent au gaz de fumier. J. de la France Agr. 6:913,918. May 12/18,1950. [BA 14 70388]

54 Sbrana, M. [Agriculture & methane gas.] (It) Agr. delle Venezie 2:444-447 May/June 1948. [BA 13 40678]

55 Schimrigk, F. Gewinnung und Verwertung von Methangas unter Berücksichtigung des landwirtschaftlichen Humusbedürfnisses. [The production and and utilization of methane with regard to agricultural humus requirements.] Chem. Tech. 2:50-53. Feb. 1950. [CA 44 5510f, BA 14 45250]

A discussion of the production of CH_4 and compost from the manure of various farm animals is presented together with a cost analysis of the process. Paul H. Howerton

56 Schnellen, Charles G.T.P. Onderzoekingen over de methaangisting. Diss. Rijksuniversiteit Leiden. 1947. 137 p. with English summary. [CI, Bibliografie Van De Dissertaties Ter Verkrijging Van De Titel Van Doctor In De Technische Wetenschappen En Lijst Van De Promoties Honoris Causa 1905-1966. Technische Hogeschool Delft. 1967]

57 Sers, J. Où en est la question du gaz de fumier? Rustica 22:320-321. April 17, 1949. [BA 13 55127]

58 ________ Construction des cuves pour la fabrication du gaz de fumier. Rustica 22:339,341. April 24, 1949. [BA 13 85126]

59 Whallon, A.P. Organic farm power. Organic Farmer 1(4):53-55 Nov. 1949. [BA 14 14961]

Methane from manure.

60 Wilkinson, A.J. Utilization of waste. Trees [Dorchester] 12:196-197. Spring, 1949. [BA 13 59990]

Includes methane.

1951–1955

61 Abiet, P. A propos du gaz de fumier. Agr. Prat. 115:19. January 1951. [BA 15 39387]

62 ________ Les applications du gaz de fumier au chauffage des locaux et à l'alimentation des moteurs. Agr. Prat. 115:248-250. May 1951. [BA 15 61219]

63 Acharya, C.N. Cow-dung gas plants. Indian Farming. (n.s.) 3(9): 16-18, 28. Dec. 1953.

A description of experimental work in India and a variety of digesters is given. A small plant built at the Indian Agricultural Research Institute, New Delhi, was built in 1941 and had been operating on 4.5 kg of manure/day for 12 years. A plant capable of handling 1800-2300 kg of cow dung per day was built by Prof. V.N. Joshi on the sugarcane estate of Walchandnagar Industries. Shri Chandra Das Gupta experimented with a bamboo thatch cylinders sunk into the ground to form tanks, and with bamboo thatch plastered with earth and cement to form gasholders. The West Bengal Government Farm at Harenghatta houses a digestion plant consisting of a series of crude-oil drums through which the slurry passes, gas being collected from all drums.

64 ________ Cow-dung gas plants. Sci. Cult. 19:490-494. 1954. [SL]

65 ________ and P.C. Juneja. Studies on the production of combustible gas and manure from cattle dung. Indian Sci. Cong. Assoc. Proc. 41(3, abs.): 246. 1954. [BA 21 47341]

66 Akademiet For De Tekniske Videnskaber. Udvalget For Biologisk Gasfrem Stilling. Biologisk gasfremstilling af staldgødning og andre affaldsprodukter i landbruget [Biological manufacture of gas from manure & other farm waste products]. Akad. f. de Tek. Vidensk. Beret. 21, 16 p. Ref. 1953. [BA 18 2322]

67 Anderson, Y. [Manufacture of gas from manure and farm waste.] (Swedish) Lantmannen 36:65-67. Jan. 26, 1952. [BA 16 40951]

68 Arfeuilles, P. Ce qu'est l'usine à gaz de fumier. Prog. Agr. de France 3:1651-1652. Dec. 26, 1953 [BA 18 35758]

69 ________ Fonctionnement de l'usine à gaz de fumier. Prog. Agr. de France 4 (130):9. Jan. 2, 1954. [BA 18 26955]

70 Ballu, T. A propos du "gaz de fumier." Acad. d'Agr. de Franc. Compt. Rend. 41(11):487-489. June 22/29, 1955. [BA 20 7488]

71 Belmondo, Claudio, and Luca Chelini. Full utilization of manure for producing biological methane and enriching irrigation water. Italian patent 485,481. Oct. 13, 1953. [CA 51 6065b]

72 Berger, F. Biogasanlagen. Österr. Landtech. 6:123-127. May 1953. [BA 17 97808]

73 Blanc, A. L'installation de production de gaz de fumier de l'abbaye du Mont-des-Cats (Nord). [The installation for manure gas production at the Abbaye du Mont-des-Cats (Nord)] Acad. d'Agr. de France. Compt. Rend. 41 (7):318-320. Apr. 20/27, 1955. [BA 19 90725 , CBS 10]

The tanks were old floats of $13m^3$ capacity. Their installations and heat insulation, operation and gas-production capacity are described.

74 Boyer, J. Si vous voulez installer dans votre ferme une petite usine à "gaz de fumier." Rustica 26:1219. Dec. 20, 1953. [BA 18 26956]

75 Brüne, Heinrich. Über die Bedeutung des Stickstoffes beim Abbau verschiedener Stoffe im Bihugas-Verfahren. Dissertation, Göttingen. 1954. 62 p. [Jahresverzeichnis Der Deutschen Hochschulschriften 1955. V. 71. 1958.]

76 Christian, J. Le fumier de ferme produit un gaz qui est un excellent carburant. Bas-Rhin Agr. 19:218. May 12, 1951. [BA 15 61067]

77 Commission Internationale des Industries Agricoles. Bibliographie sur la production du gaz de methane par fermentation du fumier et des résidus agricoles, en vue de son utilisation à la ferme. Bibliography No. 2650. 3 Feb. 1955. 50 entries.

78 Creplet, L.E. Le gaz de fumier, une source nationale nouvelle de chaleur et d'énergie. Rev. de l'Agr. 4(11):1497-1509. Nov. 1951. [CBS 33, BA 16 25559]

Installations for the production of combustible gases from farmyard manure are described and the chemistry of the fermentation is outlined. It is claimed that the fertilizing value of the manure is increased by the process.

79 Demortier, G. La production de gaz combustible a la ferme. [Production of combustible gas on the farm] Rev. de l'Agr. 4(2):147-155. Feb. 1951. [CBS 34, BA 15 61220]

Organic matter, preferably fresh farmyard manure, is subjected to aerobic followed by anaerobic fermentation to produce CH_4 and H. Details of apparatus and procedure are described, and possibilities of application are discussed.

80 ________ La ferme, centre de production d'un carburant gazeux. Annales de Gembloux 58:252-263. Fourth Q. 1952. [BA 17 36493, CI]

81 Desai, B.P. Combustible gas from cattle dung. Poona Agr. Coll. Mag. 42:74-82. Aug. 1951. [CA 48 6672g, BA 16 25560]

The percentage moisture, ether ext., crude protein, crude fiber, ash, sol. carbohydrates, N, acid-insol., CaO, P_2O_5, and K_2O are given for

horse, cow, buffalo, and ox dung. Analysis is given for constituents of the gas produced by anaerobic fermentation of dung at various temps. for 3-15 days. At 40°, the gas produced during the first 2-3 days is mainly CO_2, after which CH_4 and H_2 are produced. Addn. of inorg. salts does not materially affect gas production, but the presence of sulfates depresses the fermentation and H_2S is evolved. Fermentation of dung contg. 5-10% molasses or mahua flowers gives rapid evolution of combustible gas contg. no CH_4. Results of analyses are given for the residue left after dung fermentation. Large-scale fermenting plants are described.

Martin Jacobson

82 Donadeo, M. Contributo sperimentals alla fermentazions metanica dal letame. [Experimental data on the methane fermentation of manure.] Cent. di Studi per l'Ingegn. Agr. Mem. et Atti. 9:26-33. May/June 1954. [BA 19 2933, CI]

Changes occuring during the anaerobic decomposition of manure in vats are discussed and analytical data of normally fermented and anaerobically fermented manure are compared.

83 Donadeo, Mario. [Methanic fermentation of manure.] (It.) Humus [Milan] 10(6):9-14. June 1954. English summary p. 2. [CA 49 2655h,BA 18 88668]

A comparison between the chem. compn. of manure ripened in the conventional ditches and that of manure anaerobically fermented in tanks led D. to conclude the latter was not satisfactory; the resulting manure was less valuable.

C. Scandura

84 Ducellier, G. Etat de la question du gaz de fumier et de ses possibilitiés d'avenir. Elevage et Cult. 4(44):14-15. Aug. 1952. [BA 17 8171]

85 Ehrmann, H. Die in Westdeutschl. angewandten Verfahren z. Gasgewinnung aus den Abgängen bäuerl. Wirtschaft u. d. Erfahrungen in ausgef. Anlg. Dissertation, Hohenheim. 1954. [140, unconfirmed in Jahresverzeichnis Der Deutschen Hochschulschriften]

86 Encontre, R. Le gaz de fumier à la ferme. Tarn-et-Garonne Agr. 16:103-104. June 1953. [BA 17 81305]

87 ________ La gaz de fumier à la ferme. Tarn-et-Garonne Agr. 16:113. July 1953. [BA 17 90370]

88 Fedele, F. [Fuel for all the farm from manure.] (It.) Agricoltura 1(8): 26-28. Aug. 1952. [BA 17 8173]

89 Feldmann, Friedrich. Biogas - energiewirtschaftlich gesehen. Landtechnische Forschung 4(3):65-79. 1954. Summaries in German, English, French, and Spanish. [DL]

90 ________ Biogas als Energiequelle. Landtechnik 9(21):616-620. Nov. 15, 1954. [BA 19 27237, DL]

91 Féraud, L. Le gaz de fumier. Acad. d'Agr. de France. Compt. Rend. 37(4): 175-180. Feb. 21/28, 1951. [BA 15 54154, CBS 35]

The energy content of methane is compared with that of other fuels and its production is described. Includes discussion.

92 ________ Agriculteurs avec votre fumier, produisez du gaz et assurez votre chauffage et éclairage. Terre-Nouvelle 98:5. May 5, 1951. [BA 15 61214]

93 ________ Expériences étrangères au sujet du gaz de fumier. [Experiences of gas production from manure in foreign countries] Acad. d'Agr. de France. Compt. Rend. 39(7):357-361. Apr. 15/22,1953. [BA 17 90380]

94 ________ Le gaz de fumier au service de la ferme de grande [illegible]e. [Manure gas for use on the large-scale farm Acad. d'Agr. de France. Compt. Rend. 40(15):580-583. Oct. 13/20,1954. [CBS 16, BA 19 13487]

A brief description is given of German installations for producing gas and fertilizer from farmyard manure by fermentation. The fertilizer is a semi-liquid sludge and has given better results with grass-land and potatoes than ordinary farmyard manure + balancing NPK has given.

95 ________ A propos d'expériences récentes effectuées en Allemagne Occidentale sur l'utilisation du gaz de fumier en agriculture. [Recent experiences with the agricultural utilization of manure-gas in Western Germany] Acad. d'Agr. de France. Compt. Rend. 41(15):648-650. Nov. 16/23,1955. [BA 20 33918, CBS 12]

96 Franz, H. Die biologische Methangaserzeugung. Kärntner Bauer 101:77. Feb. 15, 1951. [BA 15 61215]

97 Garcia-Noblejas, V. Gas metano del estiércol. Rev. Indus. y Fabril 10:428-429. Aug. 1955. [BA 20 43417]

98 Greiff, F. Methangas-Erfahrungen und Folgerungen. Landtechnik 8:227-230. March 5, 1953. [CI]

99 ________ Methangas-Erfahrungen und Folgerungen. Landtechnik 8:124-126. March 15, 1953. [BA 17 57191]

100 Gussoni, L. [Agricultural set-up for production of methane.] (It) Cent. di Studi per l'Ingegn. Agr. Mem. ed Atti 8:37-44. July/Aug. 1953. [BA 18 26957]

101 ________. [The Allerhop plant for biologic methane] (It.) Cent. di Studi per l'Ingegn. Agr. Mem. Ed Atti 8:64-65. Nov/Dec. 1953. [BA 18 53492]

102 Happold, F.H. Power and humus from waste: methane and fertiliser from controlled fermentation. Times Rev. Industry 8:24-25. 1954. [SL]

103 Huisman, L.L. [Manufacture of gas from manure. I.] (Dutch) Friesch Landbbl. 49:495. Aug. 29, 1952. [BA 17 17602]

104 Intérêts et moyens d'une installation de gaz de fumier. [Interest and means of effecting a manure-gas installtion.] Technique Agricole No. 63:16-21. 1952. [CBS 29, CI]

Gas containing 35-55% of methane is produced by fermenting vine prunings with HCl-neutralized liquid manure. The artificial manure thus produced is richer in minerals than that from wheat straw. Production of gas from farmyard manure and plant residues is described with details of installation and method.

105 Isman, M. Une etude sur les modes d'utilisation pratiques des appareils à gaz de fumier. Elevage et Culture 21. 1951. [414]

106 Lord Iveagh. Gas production on the farm. Power Fmr. 7:87. 1951. [CBS 31]

A letter explaining that a plant was made in 1918 for collecting the methane given off when straw or farmyard manure was left in a closed container.

107 Jacobsen, A. P. [Gas from manure.] (Danish) Dansk Landbr. 70:511. Nov. 8, 1951. [BA 16 25561]

108 Jenisch, K.H. Mistgas als Energiequelle der Landwirtschaft. Deut. Agrartech. 3(5):137-139. May 1953. [BA 17 81310, DL]

109 Jones, J.L. Power from farm waste. Farmer's Wk. [London] 41(10):90-91. Sept. 3, 1954. [BA 18 96863]

110 Joppich, Wolfgang. Betriebswirtschaftliche Untersuchungen über die Biogas-erzeugung. Dissertation, Göttingen. 1955. 157 p. [Jahresverzeichnis Der Deutschen Hochschulschriften 1955. V. 71. 1958.]

111 Kar, J. Neuzeitliche Abwasser- und Abfallstoffverwertung. [Modern utilisation of sewage and refuse.] Bodenkultur 4:518-520. 1952. [CI]

Gas production from domestic, garden, and slaughter-house waste and from farmyard manure is briefly discussed, and the remaining materials are claimed to be superior to those decayed naturally or by other fermentation processes.

112 Kellner. Der heutige Stand der Biogas-gewinnung. Landmasch.-Rundschau 5:248-249. Sept. 1953. [BA 18 23333]

113 Kemmler, Georg. Über Veränderungen in der Stofflichen Zusammensetzung des Stallmistes bei der biologischen Gaserzeugung. Dissertation, Göttingen. 1952. [Jahresverzeichnis Der Deutschen Hochschulschriften 1952. V. 69. 1956.]

114 Kertscher, F. Biogasgewinnung. Wissenschaftliche Zeitschrift der Universität Rostock der Reihe Mathematik und Naturwissenschaften [Rostock] 2(3):209. 1953. [DL]

115 Kind, W. [Plant gas: the self-sufficient agricultural fuel.] (Ge) Elektrizitat 1954:14-16. [SL]

116 Kosmack, K. Mistgaserzeugung in der landwirtschaft. Unser Milchvieh. 4(11):2. Nov. 1952. [BA 17 27265]

117 Krüger, Kurt. Die Arbeitswirtschaft im Tieflaufstall. ALB-Schriftenreihe [Düsseldorf] 1953(3):21. [DL]

118 Laffitte, CH., and J. Gaudrōn. Le Fumier Artificiel. La Maison Rustique, Paris. 1953. [CI]

119 Landwirtschaftliche Energieträger. Landtechnik 8(9):276- . 1953. [DL]

120 Leroux, D. Engrais et amendemants. Gauthier-Villars, Paris. 1951. [CI]

121 Lesage, E. & P. Abiet, Gaz De Fumier; Dernières Techniques De Production Et d'Utilisation. Soissons, Duffusion Nouvelle du Livre, 1952. 132 p. [BA 18 17069]

122 Luther, H. Biogas in der Landwirtschaft - eine Ergänzung. Deut. Agrartech. 3(7):214. July 1953. [BA 17 90381, DL]

123 Manninger, Ernö. Gas from agricultural wastes. Oil Eng. Gas Turb. 22:21. 1954. [SL]

124 ________. [Gas analysis of stable manures fermented by various methods.] (Hu., en.) Agrokém. és. Talajtan 3:113-116. July 1954. [BA 19 13492]

125 Marini, P. [Methane for the aid of the country] (It.) Gior. di Agr. 62:159. May 25, 1952. [BA 16 69487]

Manufacture from manure.

126 Martin-Leake, H. Methane production from farm wastes. Intl. Sugar J. 54(644):208-209. 1952.

M-L stresses the economics of scale which would justify the wider use of biogas; the collection of village waste and night soil to be used with other organic wastes in community systems. He suggests that sugar cane trash and bagasse be stored, to be fermented with animal wastes and excess molasses at the sugar factory.

127 ________. Methane gas on farm and plantation. Intl. Sugar J.54(648): 321-323. Dec. 1952.

It is proposed that cooperative gas plants intermediate in size between individual farm and city plants be composed of a number of batch digesters. The gas would be used for a variety of purposes, and the effluent be used in the production of compost on the site.

128 ________, and L.E. Howard. Methane gas from farmyard manure. Publs. Albert Howard Fdn. Org. Husb., No. 9. 1952. [SL]

129 ________. Power from sewage could finance composting; compressed gas is stored in Germany and used to run tractors and other machinery. Farmer's Wk. [Bloemfontien] 88:53. March 9, 1955 [BA 19 54997]

130 Massaux, Léonard. Procédé de fermentation de matiéres organiques et appareils pour sa mise en oeuvre. French patent 1,017,119. 2 Dec. 1952. [DL]

131 "Matepa" Maatschappij Tot Exploiteeren van Octrooien en Licenties N.V., and K.P. Kalis. Method of producing methane. British patent 721,823. 1955. [SL]

By dry fermentation of organic wastes.

132 Mattei, F. [Manures as a source of methane] (It.) Gior di Agr. 65:261. July 31, 1955. [BA 19 90732]

133 Methane from manure as tractor fuel: not promising on a small farm scale. World Crops 4(1):40. Jan. 1952.

In a paper read at the Institue of British Agricultural Engineers, Gerhard Rosenberg reported on a German batch digester built in 1947, which was filled with grain crops, waste vegetables, waste potato haulms, chaffed straw, and solid and liquid manure. The contents were heated by means of a hot water cylinder and closed coil and mixed by pumping slurry from the bottom and jetting it at the top. After two or three weeks of digestion the tank is emptied, the contents having produced 0.8 - 0.9 volumes gas per tank volume. I assume that Rosenberg is referring to the Schmidt/Eggersglüss Bihugas system.

134 Miège, E. Le gaz de fumier, possibilitiés et prix de revient. Inform. Marocaine 601:1,4. July 19, 1952. [BA 16 86488]

135 Mignotte, F. Une richesse trop peu exploitée: le gaz de fumier. Agriculture [Paris] 16: 51,53, 55-56. Feb. 1952. [BA 16 53359]

136 ________ , and R. Pitot. Gaz de Fumier à la Ferme. Paris, Maison Rustique, 1952. 84 p. [BA 16 86489]

137 ________. Le gaz de fumier au service de l'agriculteur. Culture 37: 14-16. July/Aug. 1952. [BA 17 17603]

138 Milquet, F. Installations brevetées pour la production de gaz méthane et d'engrais naturels. [Patented installations for the production of methane and natural manures.] Rev. de l'Agr. 4(12):1621-1633. Dec. 1951. [BA 16 40973, CI]

Current processes are reviewed and a new technique is described which maintains economically a constant temperature of 40°C in the tanks by complete isolation in winter as in summer and periodic reheating of the mass. The tanks were buried underground and had double metal walls with low density cellular concrete between them. The covers were of thick cork, permanantly fixed, and coated with an impermeable substance. Reheating was necessary only once during the fermentation, whereas with tanks above ground it had to be carried out more often and more vigorously. Straw was the raw material and the products were highly profitable quantities of methane and artificial manure.

139 Mori, A.D. [Studies & plants for the production of biological methane in Italy] (It) Genio Rur. 17:825-829. Sept. 1954. [BA 19 17347]

140 Müller, Martin. Untersuchungen über die biologische Gaserzeugung bei der Methangarung von Stallmist und Stroh. Dissertation, Landwirtschaftlichen Hochschule Hohenheim. May 1955. 96 p.

Batch digestion studies were conducted using a 0.4 m^3 heated digester which had provision for mixing. Stable manure was digested and rye straw was digested with the addition of seed, and $CO(NH_2)_2$, $(NH_4)_2SO_4$, NH_4NO_3, or $NaNO_3$ and water.

141 Narayanan, E.K. Cowdung gas & community projects. Indian J. Med. Res. 43:355-357. April 1955 [BA 19 82232]

142 Neuling, S. Der Wärmeaufwand für den Betrieb von Biogasanlagen. Deutsche Agrartech. 5(6):203-205. 1955. [DL]

143 Noack, W. Die bedeutung der biogasanlagen für die landwirtschaft. Übersicht 5:139-146. March 1954. [BA 18 62153]

144 ________. Biogas in der Landwirtschaft. Elsner, Darmstadt, 111p. 1955. [414]

145 Olsen, E. [Biological manufacture of gas and liquid manure] (Da) Jydsk Landbr. 35:256-259. Apr. 16, 1953. [BA 17 62657]

146 Paglia, G. [Methane from agricultural waste.] (It) Macch. e Motori Agr. 10:1001-1006. Oct. 1952. [BA 17 17604]

147 ________. [Biological methane on farms.](It) Genio Rur. 17:66-72. Jan. 1954. [BA 18 49899]

148 Patel, J.J. Digestion of waste organic matter for production of methane gas and organic fertiliser & a new economic apparatus for small scale digestion (Gramlaxmi). Poona Agr. Col. Mag. 42:150-159. Nov. 1951. [BA 16 40975]

149 Paulick, S. Beheizung von Trocknungsanlagen. Deutsche Landw. Presse 76:12. 1953. [DL]

150 Peyaud, Raymond C. and Société Centrale Technique Francaise. Methane. French patent 1,004,994. Apr. 4, 1955. [CA 51 7446f]

In the production of CH_4 by fermentation of manure, fat peat and sump water, optionally together with purine, are added to the starting materials; the fermentation is thereby accelerated. Fredrich Epstein

151 Pickard, H. Efficient utilization of cattle manure - design for a miniature gas producer. Indian Dairyman 5:169. Sept. 1953. [BA 18 17070]

152 Pietrabissa, E. [Methane in agricultural motors] (It) Terra e Sole 122: 332-333. Oct. 1952. [BA 17 17500]

153 Pizon, L.G. Le Gaz de Fumier. Paris, Foulon, 1953. 72 p. Thèse - Ecole Nationale Vétérinaire, Alfort. [BA 18 67130]

154 Poch, Martin. Biogas; wege zur zusältzlichen Energiegewinnung in der Landwirtschaft bei gleichzeitiger Verbesserung der Humuswirtschaft. Deutscher Bauernverlag, Berlin. 1953. 48 p. [BA 18 75882]

155 ________ Biogas. Deutsche Akademie der Landwirtschaftswissenschaften z. Berlin, Institut für Versuchs- u. Untersuchungswesen. Jena-Zwätzen, 1954. [241 Stauss]

156 ________. Methangewinnung aus Stalldung. Chem. Tech. [Berlin] 7:227-230. Apr. 1955.

A brief description of the methane-bacteria is given, their classification, biochemistry, and ecology, and a table of gas production expected

from a dozen waste materials. Descriptions of three fermentation systems are given. The Ducellier-Isman, Massaux consists of 2 or 3 tanks of 6 - 14 m^3 capacity which daily produces 5 - 17 m^3 gas. Rotted manure is placed in the tanks, covered with water and liquid manure, and allowed to ferment for 3 months. The older tanks are unmixed, but the newest have provision for breaking the scum layer. Gas production virtually ceases during the winter, much manual labor is involved, and high losses of organic matter are caused by use of already rotted manure.

The Darmstadt system, developed by Reinhold and similar to the systems of Harnisch and Müller, consists of a 15 m^3 covered pit into which farm wastes and household wastes are fed through piping. The tank is heated and stirred, solids making their way from one end of the tank to the outlet in a matter of weeks, from which they are shoveled and stacked. Gas production is 0.3 - 0.5 m^3 gas/m^3 tank daily. A good deal of manual labor is involved, and losses of nutrients occur after the solids are extracted from the tank and piled.

A fully mechanized Schmidt-Egersglüss system, the Biological Humus Gasworks (Bihugas), consists of heated (30° - 35°), mixed tanks, gas compressor, gas storage tank, and effluent storage tank. Three m^3 tank capacity are required per head of cattle and gas production is 2 - 2.5 m^3/livestock unit/day. Straw is stored to be ready for use as fermentation feedstock when the cattle are in the fields. The length of digestion in the process is 18 - 20 days.

157 ________. Spülentmistung im Stall mit und ohne Biogasgewinnung. Deutsche Agrartech. 5(4):136-137. 1955. [DL]

158 ________. Gas for nothing. Chem. Age, London 73: 652. 1955. [SL]

Gas from farm wastes in the Tyrol.

159 ________. Zur frage der energiebilanz bei landwirtschaftlichen biogasanlagen und der dabei zu berücksichtigenden faktoren. [The heat balance in agricultural "biogas" installations and the factors to be taken into account.] Chem. Tech. [Berlin] 7:549-552. Sept. 1955. [CA 50 14173c, BA 20 7491]

The installations described are those which agricultural wastes, e.g. stable manure, are digested by fermentation to yield combustible gas (e.g., 58% CH_4) and humus. Two kinds of fermentation are discussed, mesophil (M) with a working temp. of 30° and a thermophil (T) with a working temp. of 50°. Construction of the containers based on the desired output is discussed and the method of calcn. of the thickness of insulating material is illustrated. Parameters for the calcns. of heat balance are drawn from published data on actual installations, largely municipal disposal plants, some in the U.S. Of several possible methods, it is preferred to heat the fermenters by injecting low-pressure steam obtained by burning some of the gas. The efficiency of such a heating device is expected to be 80%. Heat losses included bringing new charges of stable manure or other wastes up to operating temp., make-up for radiation losses, and power requirements for chopping, pumping, and the like. These are calcd. to use roughly 1/3 of the CH_4 produced. The sample computation gave 66.85% theoretical recovery of the thermal energy of the CH_4 produced in the M process and 68.67% in the T.

E. L. Green

160 ________. Zur Frage des Eigenenergiebedarfes von landwirtschaftlichen Biogasanlagen. Deutsche Agrartech. 5(10):424-425. 1955. [DL]

161 Pöpel, F. [Decomposition sludge and decomposition gas for agricultural use.] (Ge) Mitt. Dtsch. Land. Ges. 69:756-757. 1954. [CBS 17]

Agricultural gas containing CH_4 and CO_2 is produced by anaerobic fermentation of wastes. The decomposed material is a valuable fertilizer which, by means of aerobic composting with refuse or peat, can be converted into a true humus substance. The operation of a small-scale plant for processing agricultural wastes is described.

162 La production de gaz méthane (gaz de fumier) à la ferme. Rev. Agr. Bruxelles 6(12):1765-1771. Dec. 1953. [CI]

Research relative to the influence of aerobic fermentation, the role of agitation of the mass, and the action of cyanamide on the production of methane.

163 Reinhold, F. Neuzeitliche Abwasser- und Abfallstoffverwertung. VDI-Zeitschrift 98(29):917-920. 1951. [DL]

164 ________ Gasgewinnung in der Landwirtschaft nach dem System "Darmstadt". Landtechnik 7(2):33-37. 1952. [DL]

165 ________ Biogas. Wärmtechnik No. 2, Feb. 1953. [241 Stauss]

166 ________ Faulgas aus organischen Stoffen. Gas- und Wasserfach 96(6):176-177. 1955. [DL]

167 Rocasolano, C. El gas de estiércol. Cult. Mod. 36:204. June 1953. [BA 17 90373]

168 Roig Miro, J. El biogás y el desarrollo de la agricultura. Reus Avic. 21:7,9. Jan. 1951. [BA 15 36192]

169 Rosegger, S. Neue Wege in der Stallentmistung. Deutsche Agrartech. 5(6):200-202. 1955. [DL]

170 ________ Energetische Fragen bei der biologischen Gaserzeugung in der Landwirtschaft. Deutsche Agrartech. 5(10):383-393. 1955. [DL]

171 Rosenberg, Gerhard. Power from biological sources. Farm Mechanization 3:425-428. Nov. 1951.

The installations of Ferdinand Schmidt and Waldemar Harnisch, of Allerhop and Heidelberg, are described. Scmidt's installation consists of three fermentation silos with a total capacity of 158 m^3 , a 28.3 m^3 gas-holder, 113 m^3 silo which holds effluent, compressor, and gas tanks which store the gas at 300 atm. Scum formation is prevented by the operation of a moveable jet three times daily for 15 minutes. Schmidt recycles the liquid portion of the effluent and thereby adds no additional water to the system. The digesters are above ground, cylindrical reinforced concrete, insulated, and heated to 30°-32°C. One disabled man is employed fulltime to operate the £ 6000 plant which daily produces an amount of gas equal to the volume of the digesters from the wastes of cattle, pigs, chickens and chaffed straw.

Harnisch's smaller continuous digester consists of a horizontal cylindrical tank which is enclosed within a greenhouse type structure in order to maintain the temperature at 30°C. The contents are mixed by a wind-powered agitator.

At the conclusion of the article the editor comments upon the work done by the Earl of Iveagh and Dr. Hannaford Richards at Lord Iveagh's estate, Pyrford Court, Surrey. The heated digester of 125 m^3 capacity had been in operation since 1929. The tank was charged with manure, straw and water , the initial filling being supplemented twice yearly by the addition of a quantity of waste equal to 10% of the initial charge.

172 ________. Methane production from farm wastes as a source of tractor fuel. Oil Eng. Gas Turb. 19:305. 1951. [SL]

173 ________. Methane production from farm wastes as a source of tractor fuel. Inst. Brit. Agr. Engin. J. 8(3):3-17. Jan. 1952. [BA 16 69497]

174 ________. Methane production from farm wastes as a source of tractor fuel. Agriculture; The Journal of the Ministry of Agriculture 58 (10): 487-494. 1952.

Rosenberg reports on German experiences with digestion of agricultural wastes. The firm of Defu from Verden constructed a plant at Allerhop, which is undoubtedly the Schmidt plant. The tank is of unspecified size (though large), heated to 30°-32°C by 76° water coils and is daily fed unspecified ratios of quantities of "green crops, waste vegetables, weeds, potato haulms, chaffed straw, solid and liquid manure..." without additional water. A recirculating pump and movable nozzle break the scum by operating 15 minutes/day. After 2-3 weeks the entire contents are removed and spread on land. He culls some particulars from an article by Dr. Eggersglüss in Defu Mitteilungen, No. 9, Jan. 1951.

- 0.8 to 0.9 tank volumes of gas per day
- 16 grams waste added per liter volume of tank
- 29 to 48 ml gas (60% CH_4) produced per gram cow dung
- 48 to 78 ml gas produced per gram pig manure

There is a short section on the fertilizing value of the sludge and some economics of operation from German experience.

175 ________. Methane production from farm wastes as a source of tractor fuel. Soil Assoc. Inform. B & Adv. Serv. 50:1-10. Apr. 1952. [BA 16 78682]

176 Sauerlandt, W. Über die Wirkung des Bihudungs in Feldversuchen. Mitteilungen der Deutschen Landwirtschafts-Gesellschaft 68(2):31. 1955. [DL]

177 Schachl, M. Biogas aus Stallmist. Bauer 6(28):2-3. July 11, 1953. [BA 17 90374]

178 Schäffer, K. Elektrische Energie aus Stallmist. Landtechnik. 9(1):11. Jan. 15, 1954. [BA 18 35762, DL]

179 Scheffer, F. and G. Kemmler. Biologische Gasgewinnung aus Stallmist. [Biological production of gas from farmyard manure.] Deut. Landwirt. - Gesell. Mitt. 68:27-29. Jan. 8, 1953. [CBS 22, BA 17 42995]

Under anaerobic conditions of farmyard-manure storage, the products include organic acids from which methane is formed. The Schmidt-Eggersglüss method is described, in which 5-7m^3, of gas is formed per 100kg of fresh manure, without loss of N,P,K or Ca from the residual sludge which is of high nutrient content. Large N losses occur if the sludge comes long in contact with atmosphere.

180 ________ E. Welte, and G. Kemmler. Über Veränderungen der stofflichen Zusammensetzung des Stallmistes bei der biologischen Gaserzeugung. Landwirtsch. Forsch., Sonderheft No. 4:61-68. 1953. [CA 48 3611c, CI]

The advantages of the "Bihugas" method, Schmidt-Eggersglüss system, are discussed. The losses of org. matter and of C are about 33% for a gas output of 270 l. per kg. of org. matter, but 55% of the C of the decompn. products is utilized as mixed gas (about 60% as methane). The gas output amounts to 3-7 cu. M. per 100 kg. fresh manure. The max. heating value of the mixed gas is 5700 kcal. The loss of N is only 1% of the total N; no P,K, and Ca are lost. No formation of humus was observed. The av. compn. of fermented manure was dry matter 10.56, org. matter 6.9, C 3.47, N 0.36, ammonia N in percentage of total N 38, K_2O 0.27, CaO 0.18, and P_2O_5 0.13%. The process, compared with the conventional handling of manure, decreases losses in N from 18.5% to 1%, and those in C from 38% to 7.3%.

181 ________, A. Kloke, and H. Gerken. Die vernichung der keimfähigkeit von unkrautsamen bei der biologischen gaserzeugung. Landwirt. Forsch. 7:200-203. 1955. English summary. [BA 20 2803]

182 ________, and H. Brüne. Über die bedeutung des stickstoffs beim abbau verschiedener organischer stoffe im bihugasverfahren. [The importance of nitrogen in the decomposition of various organic substances in the Bihugas process.] Landwirt. Forsh. 8(2): 126-132. 1955. English summary. [CBS 13, BA 20 39690]

About 30% of the organic matter is decomposed during the fermentation process, 20-25% of the organic N being mineralized to NH_3. Trials with straw, sisal, peat, etc. showed that additional mineral N promotes the fermentation process of substances which decompose rapidly or are poor in easily available N compounds, except potato starch which decomposes without any notable fixation of N. Results did not confirm claims on the beneficial effects of hormone preparations and on killing of pathogenic typhus-enteritis bacteria during fermentation.

183 Schmidt, F. Development of the Bihugas Plant Allerhop. Deutsche Bihugas G.m.b.H., Verden (Aller), West Germany. 1951. [319]

184 ________ (Ed.) Defu-Mitteilungen. Deutsche Futterkonservierungsges., Verden, No. 9. 1951. [140, 414]

F. Schmidt. Entwicklung der Bihugasanlage Allerhop, ihre Leistung und betriebswirtschaftliche Auswirkung. p. 5
W. Eggersglüss. Erfahrungen beim Betrieb und Betrachtungen über die Wirtschaftlichkeit der Bihugasanlage Allerhop. p. 19
W. Sauerlandt. Bericht über die Düngungsversuche. p. 42
E. Welte. Vorläufiger Bericht über den Stoffkreislauf. p. 45
R. Kloss. Bihugas als Kraftstoff. p. 50

185 ________ and W. Eggersglüss. Das biologische Humusgaswerk Allerhop. Wirtschaftlichkeit von Bihugaswerken. Z. Mitt. DLG 68:30. 1953. [140]

186 ________, and W. Egersglüss. Gas from agricultural waste. Gas Journal [London] 279 (4757):286. Aug. 4, 1954

An abstract of a paper presented at the Sectional Meeting of the World Power Conference, Rio de Janeiro, July 25 to August 10, year unspecified. Schmidt and Eggersglüss report that there were a number of Bihugas (biological humus) plants operating in Germany, the largest being 722 m^3 and averaging a gas production of 650 m^3/day. The gas averages 62% CH_4 and 32% CO_2. At the larger installations the gas is scrubbed of CO_2, the calorific value thereby being increased to 3.7×10^7 joules/m^3. It is stored at 350 kg/cm^2 and used to fuel tractors at 200 kg/cm^2. Gas production equals 0.351 m^3/cow day. E.P. Taiganides et al (Anaerobic digestion of hog wastes. J. Agr. Eng. Res. 8(4):333. 1963.) present the full title of the paper as "Production of high powered gas from agricultural wastes or other organic matter" and confirm the year as 1954.

187 ________, and W. Egersglüss. Hochwertiges Gas aus landwirtschaftlichen Abfällen und anderen organischen Stoffen. Brennstoff-Warme-Kraft 7:249. 1954. [414]

188 Schwarz, M. [Biogas-inexhaustable source of energy for our field crop farming] (Czech). Za Socialist. Zemedel. 5:1487 - 1493. Dec. 1955. [BA 20 52534]

189 Seifert, A. Bisherige Erfahrungen mit Bihugas als Kraftstoff für Motoren und Ackerschlepper. Landbauforschung Völkenrode 4(4):82. Oct. 1954. [DL, BA 19 35965]

190 ________. Biogas als Kraftstoff für Motoren und Ackerschlepper. Landtechnik 10(2):29-31. 1955. [DL]

191 Sers, J. Que peut-on espérer du gaz de fumier? Rustica 24:545,571. June 17-24, 1951. [BA 15 86743]

192 Stallmist und Biogas. Landtechnik 10(23/24):839. 1955. [DL]

193 Stauss, W. Biogas-anlagen. ALB Mitt. 43-45. May/June 1952. [BA 17 17606]

194 ________ Biogas schafft Wärme und Energie. Entwicklung und Stand der Biogaserzeugung in landwirtschaftlichen Betrieben. Landtechnik 7(12):360-366. June 30, 1952. [DL, CI]

195 ________ Neue Probleme der Humus- und Energiewirtschaft. Mitt. DLG 67(38):671-672. Sept. 1952. [Bibliography "Biogas-Literatur", kindly provided by Cord Tietjen]

196 ________ Bio-gas installations in Western Germany. FATIS Review 6:21. Nov./Dec. 1954. [BA 19 72801]

197 ________ Der heutige Stand der Entwicklung von Biogasanlagen. Landw. Woche, Bayr. Landw. Verl. München, 1954. [140]

198 Stifel, W. Kraftmittel durch "Dorfgas"! aus Mist und anderen Abfallstoffen wird Heizgas und Treibstoff erzeugt. Bauern Ztg. 4(3):5-6. Jan. 19, 1951. [BA 15 31377]

199 Strell, M., and G. Götz. Die Biogaserzeugung aus Abfallstoffen mit natürlichen Feuchtigkeitsgehalt. Z. Gesundheits-Ing. 73(13/14):229. 1952. [140, 241 Stauss]

200 Tietjen, Cord. Methan aus Stalldünger. [Methane and farmyard manure.] Lanbauforsch. Völkenrode 4(4):80-81. Oct. 1954. [DL, CBS 18]

A brief historical account of methane production from manure.

201 ________. Stallmist und Biogas. Deutsche Landwirtschaftliche Presse [Hamburg] 77(22):311. 1954. [DL]

202 Vadè S. Une tonne de paille + 3 tonnes de fumier = 1 5000 000 calories. Vie á la Campagne 40: 108-110. March 1951. [BA 15 69632]

203 Velberg, A.M. [The manufacture of gas from manure. II] (Dutch) Friesch. Landbbl. 49:719. Nov. 28, 1952. [BA 17 43001]

204 Welte, E. and G. Kemmler. Uber die Stofferteilung in den Faulschlamm-behaltern der Bihugas-Anlage Allerhop. Landwirt. Forsch. 5:201-206. 1953. [BA 19 6870]

205 Wibratte. Les gaz biologiques ruraux. Renaissance Agr. 76(123): 2-5. Oct. 1954. [BA 19 27240]

1956–1960

206 Acharya, C.N. Your home needs a gas plant. Indian Farming (n.s.) 6(2): 27-30. May 1956.

Acharya describes a gas plant which daily receives 45.5 kg of cow manure mixed with an equal amount of water, producing on the average 2.83 m^3 gas/day. A design and parts list for the construction of the plant are given. The tank is sunk 3.65 m into the ground, being 1.72 meters diameter in the upper portion and 1.47 meters in diameter for the lower 2.43 meters, built of brick. A counter-weighted sheet metal gasholder covers the top of the tank. Fresh manure is gravity fed near the bottom of the tank, spent slurry overflows, and gas is removed through a fixed pipe which enters through the wall of the tank and rises into the gasholder.

207 ________. With this change the cow-dung gas plant works better. Indian Farming (n.s.) 6(9):10-11,13. Dec. 1956.

The digester described by Acharya in the May 1956 issue of Indian Farming is modified by replacing the fixed gas outlet pipe with an outlet at the top of the gasholder which consists of flexible tubing capable of moving with the gasholder.

208 ________. Preparation of fuel gas and manure by anaerobic fermentation of organic materials. Indian Coun. Agr. Res., Res. Ser. No. 15. 1957. 58 p. [BA 23 11667]

209 Ananiashvili, G.D. [Utilization of farm waste materials for the production of power.] (Ru) Mekhaniz. Élektrif. sots. sel! Khoz. 1954(4):50 - 53. [SL]

210 ___________. [Biogas - a cheap source of energy.] (Ru) Priroda [Moscow] 46(7):87-89. July 1957. [BA 22 36676]

211 ________. [On the possibility of utilizing livestock manure for heat and power needs in collective farm production] (Ru) Vsesoiuzn. Akad. Sel'skokhoz. Nauk im. V.I. Lenina. Dok. 22(1):42-48. 1957. [BA 21 78562]

212 Anttila, A. [Also fuel from fields.] (Finnish, en.) Teho 2:106-108. 1956. [BA 20 58645]

213 Boratyński, K. [A note on anaerobic fermentation of farmyard manure.] (Po) Prace Dział Zyw. Rośl.Nawoz. 1951-1955, No. 1, 48-66. 1956. [CBS 8]

A detailed account of methane production during farmyard-manure fermentation is given.

214 Brunotte, R., and A. Gac. Etude des installations de production de méthane bilogique en République Féderale Allemande. Bull. Techn. Génie Rural 45. 1958. [414]

215 Cala, H. El gaso metano. Rev. Nac. de Agr. 54(664):8-13. Aug. 1960. [BA 25 14974]

216 Cibrian, S. [Methane gas produced from manure and wastes.] (Sp) Spain. Inst. Nac. de Invest. Agron. B. 20(43):319-327. Dec. 1960. [BA 26 21753]

217 Dhital, B.P. Fuel from cattle dung. Poona Agr. Coll. Mag. 50:166-168. 1959. [CA 55 22775g]

218 Ducellier, G. Note sur la biogénèse du méthane. Soc. d'Hist. Nat. de l'Afrique du Nord. B. 49 (5/6):254-263. May/June 1958. [BA 23 84613]

219 Féraud, L. & Zedet, E. Le méthane biologique source d'énergie fermière. Agr. Prat. 120:497-502. Nov. 1956. [BA 21 24978]

220 ________. Nouvelles observations sur le dévelopment des installations productrices de méthane biologique. Acad. d'Agr. de France. Compt. Rend. 42(16):762-766. 1956. [BA 21 50530]

221 ________. De la nécessité d'une politique en matière de fermentation anaérobie du fumier. Acad. d'Agr. de France. Compt. Rend. 45(15): 758-762. 1959. [BA 24 33533]

222 Galibin, IU. M. [Methane production installation.] (Ru) Udobr. i Urozhai 1958 (8):49-56. Aug. 1958. [BA 24 87742]

223 Gärtner, Annaliese, and S.D. Ikonomoff. Faulraum (Gasanlage) "System München". Städthygiene 7:110-113. 1956. [DL]

224 Gates, Charles D. Treatment of Long Island Duck Farm Wastes. New York State Department of Health, New York State Water Pollution Control Board Research Report No. 4, 1959. 76p.

Duck farm wastes were treated by chlorination and by anaerobic digestion in separate experiments. The wastes, consisting primarily of duck droppings, sand, and a small amount of grain, were subjected to digestion in 4 l. flasks in batches, the duration of digestion averaging one month. The variables were: (1) temperature, ambient (25-29°C) and 35°C.; (2) total solids concentration, 2 to 20%; (3) amount of seed solids, none to a one-to-one ratio with fresh solids, on a volatile matter basis; (4) frequency and amount of lime added. It was not possible to get active digestion started in unseeded sludge even with the aid of liming. Percent volatile matter destroyed in the batch studies ranged from zero to 95.4, the majority being above 50. The figures for gas production, in terms of ml/g volatile solids destroyed, clustered from 500 to 800 with a maximum of 1150.

Continuous, daily feed experiments were also conducted, varying: (1) temperature, ambient (25°-29°C) and 35°C; (2) loading rate, 0.8-3.0 g VS/l/day. The bottles were batch loaded and seeded at the start. On the third day daily loading was started. The operation was successful in the range of 0.8 to 1.6 g VS/l/day at a detention time of 10 days. Gas production averaged slightly over 600 ml/g VS destroyed under those conditions.

225 Gerngross, O. & C. Isiksalan. Versuche zur Verwertung von Gerbmittel-Extraktionsrückständen für die Gewinnung von Methangas und Dünger durch anaerobe Fermentierung. Leder 9(12):312-313. Dec. 1958. [BA 23 42664]

226 Gisiger, L. Neue Bestrebungen in der Herstellung der Stalldünger. Grüne 87(25): 768-774. June 19, 1959. [BA 23 73343]

Storage & handling for methane manufacture.

227 Gotaas, Harold B. Composting: Sanitary Disposal and Reclamation of Organic Wastes. World Health Organization Monograph Series No. 31. Geneva, 1956. 205p.

Gotaas devotes chapter 9 (p. 171-193), "Manure & night-soil digesters for methane recovery on farms and in villages," to the construction and operation of biogas plants. Several detailed plans of batch digesters are presented, although their capacities in terms of livestock units waste treated are omitted. He suggests the construction of several concrete, masonry, or steel batch digesters, to be sequentially loaded in order to maintain relatively uniform gas production. For cool climates it is suggested that fresh compost be placed around the digester to a thickness of one meter in order to generate heat, and that loops of tubing might be placed through the wall of the tank into the mass of the compost through which the slurry would circulate. He also suggests placing oil one centimeter thick on the surface of the liquid to prevent the formation of ice during cold snaps.

228 Götz, W. Die Biogas-Anlage im bäuerlichen Betrieb. Tech u. Landwirt. 11(7): 161-163. April 10, 1959. [BA 23 84614]

229 Guttfeld, S.P. [Gas from manure.] (Hebrew) Hassadeh 37(8):694-695. May 1957. [BA 21 78573]

230 Hart, S.A. Sludge digestion tests of livestock manures. Agricultural Engineering Dept., University of California, Davis. Mimeo. 1960. [321]

Digestion of poultry wastes in 3.78 liter bottle digesters, maintained at 35°C with no mixing, yielded 668 ml gas/gram volatile matter destroyed. About 52% of the volatile matter of the manure was destroyed.

231 Household gas from farm manure. Power Farming Austral. & New Zeal. & Better Farming Digest 66(8): 29, 31, 33, 35, 37, 39. Aug. 1957. [BA 22 8409]

232 Hutchinson, Timothy H. Gas production. Brit. patent 812, 616. April 29, 1959. [CA 53 14472h]

A digester silo is described for the production of CH_4 by the anaerobic fermentation or decompn. of vegetable metter mixed with animal or artificial manure.

Nathan Berman

233 Idnani, M.A. and O.P. Chowla. The cow-dung gas plant is in the news again. Indian Farming (n.s.) 9(4):9-11. July 1959.

Several improvements in the IARI gas plant design are noted. The feeding pipe diameter was increased from 6.4 to 15cm to ease the introduction of leaves and straw. An "L" shaped stick is passed between the wall of the tank and the floating gasholder in order to break the scum manually. The gas can be enriched by bubbling it through a trap containing gasoline or light oil. The mass and cost of the supports alligning the gas cover were reduced and the counterweights dispensed with, at a cost of 10-15% reduction in gas yield due to the increased pressure.

234 Isman, M. Quelques precisions sur la production et l'utilisation du gaz de fumier. Chambres d'Agr. 28(125/126, equip.-agr.):3-11. June 1/15, 1957. [BA 21 78575]

235 Jones, Sir Henry. Efforts to make gas from materials other than carbonisation coals. Br. Powr. Engng. 1(5):32-36. 1960. [SL]

236 Joppich. Das neue wirtschaftsdüngemittel bihusclamm. Deut. Landwirt. - Gesell. Mitt. 71:559-560. June 7, 1956. [BA 20 76651]

237 Joppich, Wolfgang. Verkürzung der stallmistkette durch das bihugasverfahren. Tech. u. Landwirt. 9(3):54-55. Feb. 10, 1957. [BA 21 59091]

238 ________ German farms too use fuel gas plants. Indian Farming (N.S.) 6(11):35-37, 39-40. Feb. 1957.

Three German digester systems (Schmidt-Eggersglüss, Weber, and Kronseder) are described and compared to the Indian Agricultural Research Institute designs. The German plants had in common the fact that they were fed cattle dung and straw while Indian plants were designed only for manure at the time, and the German tanks were insulated. The simple Kronseder design, consisting of an open unheated tank with floating cover, is recommended for Indian experimentation.

239 Lasseur, J. Le gaz de fumier. (Abs.) Chambres d'Agr. 27(94):21 Feb. 15, 1956. [BA 20 52532]

240 ________. Le gaz de fumier a la ferme. Chambres d'Agr. 27(98, Equip. Agr.):3-8. April 15, 1956. [BA 20 71291]

241 Liebmann, H. (Ed.) Gewinnung und Verwertung von Methan aus Klärschlamm und Mist. Müncher Beitrage zur Abwasser-, Fischerei-, und Flussbiologie Vol. 3. 1956.

H. Liebmann. Der neueste Stand der Kenntnisse über die Biologie der Methanbakterien. p. 9
G. Brunner. Die Widerstandsfähigkeit von Gärtnerbakterien (Salmonella enteritidis) gegen die Klärschlammfäulnis in einem beheitzen Faulraum. p. 23
W. Hoppe. Entwicklung und Stand der Klärgasgewinnung und Klärgasverwertung in Deutschland. p. 33
W. Hoppe. Laubzusatz als Mittel zur Steigerung der Wirtschaftlichkeit der Faulgasgewinnung in zweistöckigen Absetzbecken. p. 101
F. Kiess. Die wirtschaftlichen Möglichkeiten der Klärgasverwertung. p. 130.

W. Stauss. Der heutige Stand der Biogasgewinnung aus Landwirtschaftlichen organischen Stoffen. p. 216

Stauss surveys the status of biogas research and experience in Germany at some length and more briefly describes the work performed in France, Italy, and England. The German installations described are: (1) The five digesters constructed by Schmidt's firm Deutsche Bihugas of 140 to 720 m^3 capacity which yield 0.76 to 0.85 digester volumes of gas per day. The plants all consist of two or more heated tanks which have rotating and swivelling nozzles within which circulate the contents. The digesters are daily fed 3-4 kg of organic mass per m^3 tank volume, the material consisting of urine, dung, and straw. The operations of the tanks are staggered so that after three weeks of daily loading two-thirds of the contents of a tank is removed and daily loading begins anew. (2) A digester installed on the farm of Mr. Weber in Untersontheim of 50 m^3 capacity, heated, fed daily, which yields 75 m^3 gas per day. (3) Two below ground, fixed cover trench digesters are described. The first, "System Darmstadt", is 3-4 m long, 2 m wide, and 2.2 m deep. It is mixed and heated, accepting the wastes of 7 livestock units which are twice daily scraped into one end of the chamber and manually removed from the other. The second installation was constructed by Deutscher Landwirtschaftsring and was 17 m long, 2.8 m wide, 2.9 m deep, with a net capacity of 240 m^3. The wastes of 50 livestock units generate 0.3 to 0.4 digester volumes of gas per day. (4) The "System Berlin" consists of silos 5-6 meters in diameter and 3.5 meters high. Gas production is a low 0.27 digester volumes per day.

F. Reinhold and W. Noak. Laboratoriumsversuche über die Gasgewinnung aus landwirtschaftlichen Stoffen. p. 252
Numerous wastes were placed in heated flasks in the laboratory, seeded, and allowed to ferment up to 123 days. The characteristics of the liquid seed and the solid wastes, the characteristics of the fermented mass, and the gas production rates are presented in six pages of tables which are followed by short commentaries on the wastes. The wastes included horse, swine, and cattle manures; stable wastes of cattle; oat, rye, barley, wheat, and rape straw; chopped straw of 0.0 to 0.5 mm and 3 cm lengths; rye, barley, wheat, and oat chaff; turnip tops, sugar beet tops, potato plants, maize stalks, clover, and grass.

G. Götz. Die Biogaserzeugung ohne Schwimmdecke "System München". p. 269.
A patented system is described which is unique to German practice in that wastes are digested without the addition of water. The heated digester yields 0.7 to 0.8 tank volumes of gas per day.

F. Feldmann. Die wirtschaftlichen und energetischen Grundlagen der landwirtschaftlichen Biogasgewinnung. p. 279
Feldmann assumes the construction of digesters of unspecified design which would be heated to 30°C and would produce 0.75 tank volumes of gas per day. He calculates the net energy available from various sizes of digesters and relates the value of the gas to the price of the fuels for which it might be substituted, thereby determining the maximum cost permissible for the construction of digesters on farms of 5 to more than 200 ha.

W. Sauerlandt and E. Groetzner. Eigenschaften und Wirkungen der bei der biologischen Gasgewinnung aus Stallmist anfallenden organischen Dünger. p. 306
The results of field experiments at Völkenrode and at Allerhop are

presented. Manures in different forms which had been subjected to differing treatments and storage techniques were used in the experiments and the results compared to the results achieved with digester effluent.

H. Liebmann. Folgerungen für die Praxis aus den Ausfuhrungen über die Gewinnung und Verwertung von Methan aus Klärschlamm und aus Mist. p. 337-341.

242 _________. [Biogas, an energy source of agriculture.] (Hu) Budapest. Magyar Tudo. Akad. Agrtudo. Osztályának. Közlem. 18(1/2):179-188. 1960. [BA 25 43479]

243 Manninger, Ernö. [Gas analysis of manure fermented with synthetic fertilizers and bentonite.] (Hu) Magy. Tudom. Akad. Agrártud. Osztál Közl. 13:51-56. 1957. [SL]

244 ________, and F. Zoltai. [Laboratory examination of fermenting of barnyard manure with kòla phosphate.] (Fr) Acta Agron. Hung. 8:171-185. 1958. [SL]

245 Nanna, S. [Use of wastes for methane production and its use in agriculture.] (It) Metano 10:309-11. 1956. [SL]

246 ________. [New observations on development of biological methane producing plant.] (Fr.) C.R. hebd. Séanc. Acad. Agric. Fr. 1956(16): 762 - 767. [SL]

247 Naszalyi, L. Premiers résultats d'exploitation d'une importante installation réalisée en Hongrie pour la production du gaz de fumier. Acad d'Agr. de France. Compt. Rend. 42:718-719. 1956. [BA 21 33203]

248 Neuling, S. Untersuchungen zur wirtschaftlichen Speicherung von Biogas. Deutsche Agrartech. 6(2):64-66. 1956. [DL]

249 ________. Zur Frage des Wärmeaufwandes für den Betrieb von Biogas-anlagen. Deutsche Agrartech. 6(2):83-84. 1956. [DL]

250 ________. Wiggins-Behälter - eine neue Scheibengasbehälterkon-struktion. Energietechnik 7(10):471. 1957. [DL]

251 ________. Gestaltungsmöglichkeiten für den Bau von landwirtschaft-lichen Biogasanlagen. Deutsche Agrartech. 7(10):467-471, 479. Oct. 1957. [BA 22 27560]

252 Pasteur, F. Production du méthane. Agr. Prat. 122(1):25-29. Jan. 1958. [BA 22 36678]

253 Perrard, P. La production de méthane biologique "conduite" en toute saisson. Agriculture [Paris] 19:135-139. May 1956. [BA 20 80048]

254 Pietura, K. & Z. Rauszer : Über die anwendung von Biogasen in der Landwirt-schaft. (Po) Mech. Roln. 4(12):8-13. Dec. 1957. [BA 22 55001]

255 Robles, C.R. Un procedimiento revolucionario. AGA (ser.2)5:15, 20-22. Oct. 1958. [BA 23 39382]

Bioabono, a compost & fuel gas produced in a single process from agricultural wastes.

256 Romashkevich, I.F. [Methane fermentation of manure](Ru) U dobr. i Urozhai 1(8):62-64. Aug. 1956. [BA 21 38715]

257 Rosegger, S. & S. Neuling. Wege zur berechnung von landwirtschaftlichen biogasanlagen. Dresden. Tech. Hochsch. Wiss. Z. 5(5):865-868. 1955/1956. [BA 21 59095]

258 ________, and S. Neuling. Die Versuchsanlage zur Humus- und biologischen Gasgewinnung an der TH Dresden. Deutsche Agrartech. 6(4):147-149. 1956. [DL]

259 ________, and S. Neuling. Wege zur berechnung von landwirtschaftlichen biogasanlagen. Deut. Agrartech. 7(1):14-17. Jan. 1957. [BA 21 41877]

260 ________. Der Entwicklungsstand von Biogasanlangen und Perspektiven für die landwirtschaftliche Praxis. Deut. Agrartech. 7(12):545-552. Dec. 1957. [BA 22 46303]

Also in Dresden. Tech. Hochsch. Wiss. Z. 6(3): 511-518. 1956/1957.

261 Rowan, D.M. Gas from manure & farm wastes. Veldtrust 17(8):16-17,22. August 1956. [BA 21 33204]

262 Sansone - Capogrosso, A. ["Biological" methane and how to use it.] (It) Gior. di Agr. 68(30):281. July 27, 1958. [BA 22 90586]

263 Schmidt, Ferdinand, and Walter Eggersglüss. Vorichtung für Sammelbehalter oder Speichersilos von Schwemmentmistungsanlagen. Gebrauchsmuster Nr. 1,724,625; Kl. 45 h/1. 21 June 1956. [DL]

264 ________, and W. Eggersglüss. Method and apparatus for the processing of organic waste material. Canadian patent 540,755; filed Dec. 30, 1954; issued May 14, 1957. [United States. Office of Solid Waste Management Programs. Patent Abstracts; International Solid Waste Management, 1945-1969. U.S. Environmental Protection Agency Solid Waste Management Series SW-78c.]

This apparatus subjects stable manure that is in a semiliquid or pulpy condition, to a rotting process resulting in continuous gas recovery. Inside a tank, the waste material encompasses a vertical, liquid supply pipe. The pipe contains ports which allow the passage of liquid for dispersing scum on the waste material, and allow the permeation of liquid through the waste material at predetermined levels. A cover that can move axially along the pipe retains and is supported by the gas produced by the rotting waste material.

265 Société Anonyme Immobilière Canadienne Francaise. Methane production by fermentation of organic wastes. Fr. patent 1,213,721. 1960. [SL]

266 Solodenikov, V.N. [Biogas installations.] (Ru) Traktory i Sel'khozmash. 1958 (7):31-35. July 1958. [BA 23 84617]

267 Srivastava, S.N. & R.H. Richharia. Utility of cow-dung gas plants. Bihar Acad. Agr. Sci. Proc. 6/7:104-107. 1957/1958, pub. 1959. [BA 24 95188]

268 Stauss, W. Wie steht es um die Klein-Biogasanlage? Deutsche Landtechnische Zeitschrift 7(3):69-70. March 1956. [BA 20 62273, DL]

269 ________. Biogas 1957 noch interessant? Deut. Landwirt. - Gesell. Mitt. 72(2):29-31. Jan. 10, 1957. [BA 21 41878]

270 ________. Biogas. DLZ-Deut. Landtech. Z. 8(5):167-168. May 1957. [BA 21 88375]

271 Sun, Y.H. Methane gas for rural power. China Reconstr. 8(5):7-9. May 1959. [BA 23 68663]

272 Szekeres, L. [On the problems connected with biogas.] (Hu) Agrártudomány 10(1):55-57. Jan. 1958. [BA 22 74057]

273 ________. [Problems in biogas production.] (Hu, ge.) Gödöllö. Agrártudo Egyetem. Mezögazdásagtudo. Kar. Közlem. 1959:153-163. [BA 25 6867]

274 ________. [Problems connected with the introduction of biogas methods.] (Hu) Gödöllö. Agrártud. Egyetem. Tud. Tájékoztató 1(1) 40-45. June 1960. [BA 26 21759]

As energy source in agriculture.

275 ________, Laszlo G. Molnár, and Géza Láng. [Experiments on manure fermentation in the laboratory. I.] (Hu.) Agrartud. Egyet. Mezögtud. Kar. Közl., Gödöllö. 1960:245-258. [SL]

276 Tietjen, C. Bilanzuntersuchungen bei stallmistaufbereitung in biogasanlagen. [Decomposition of stable manure in biogas apparatus.] Z. f. Pflanzenernähr. Düngung, Bodenk. 77(3):198-212. 1957. [CBS 7, CA 53 3567d, BA 21 88376]

Three types of digesters were tested for three weeks. The Schmidt-Eggersglüss design produced the greatest amount of gas and retained the most plant nutrients in the effluent, being a total gas production of 130 l. CH_4/100 kg. organic matter and the retention of 89, 100, and 94% of the initial N,P, and K. respectively. The Rheinhold and Ducellier-Isman designs, which use aerobic treatment of the fermented manure, produced 1/3 to 1/2 as much gas and lost 30 - 50% of the nutrients.

277 ________. Biogas, Schwemmist und Abwasserschlamm. Mitt. der Deut. Landwirt. - Gesell. 75(12):362,364. March 24, 1960. [BA 24 56829]

278 Trapp, F. Gaswerk bauernhof; die methangasgewinnung - mit mikroskop beobachtet. Ubersicht 8(1):25-28. Jan. 1957. [BA 21 50534]

279 Ugolini, P. [Riches in the barn.] (It) Agricoltura 6(7):30-39 July, 1957. [BA 22 18207]

280 Voloshchik, D.P. [Manure gas: a review of the Soviet & foreign literature.] (Ru) Zhivotnovodstvo 21(8):90-96. Aug. 1959. [BA 23 91828]

281 Wick, Hermann. Die Stoffbilanz bei Stalldünger nach Lagerung und nach Faulgärung mit Vegetationsversuchen über die Düngerwirkung der gewonnenen Rotteprodukte. Dissertation, Universität Hohenheim. 1960. [Jahresverzeichnis Der Deutschen Hochschulschriften V. 76, 1960, p. 401.]

282 Winters, P.C. The production of methane gas from farm manure & wastes. Power Farming Austral. & New Zeal. & Better Farming Digest 66(9): 29-31, 33, 35. Sept. 1957. [BA 22 18208]

283 ________. What happens to the manure. Fmrs.Wkly S. Afr. 95:18-19. July 2, 1958. [CBS 6]

The processing of manures to give good methane production is discussed.

284 Zaruba, J. and J. Souhrada. [Suggestion for an experimental bioenergetical research station.] (Czech., en.) Ceskoslov. Akad. Zemedel. Ved. Sborn. Rada Mech. a Elektrif. Zemedel. 29(6):367-374. Dec. 1956. [BA 21 88377]

285 Zunker, Ferdinand. Methane fermentation of manure. German patent 942,034. April 26, 1965 (Cl. 16,9). Addn. to Ger. 936,691. [CA 52 13169i]

An app. is described in which CH_4-contg. gas and fertilizer are obtained from manure and other rottable substances by fermentation in the absence of air. The fertilizer is free of anaerobic bacteria and the CH_4 yield is improved. Kurt Mann

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286 Barth, H. [How far is it from the manure pit to the biogas plant?] (Ge) Tech u. Landwirt. 16(6):136-138. Mar. 25, 1964. [BA 28 64699]

287 ________. [Biogas for the small farm.] (Ge) Tech. u. Landwirt. 17(3): 68-69. Feb. 10, 1965. [BA 29 64764]

288 Commonwealth Bureau of Soils. Bibliography on Manure Gas (1941-1963). Commonwealth Bureau of Soils bibliography no. 874. 1965. 5p.

289 Das, R. Gobar gas and potential for its utilization. Allahabad Farmer 36(1):17-21. Jan 1962. [BA 27 74462]

290 ________. The cowdung gas plant gets popular in U.P. Indian Farming 12(9): 7-9,31. Dec. 1962.

Work at the Planning Research and Action Institute, Lucknow, was confined from 1957 to 1959 to constructing gas plants of 2.83 m^3 gas production capacity per day. A deomonstration plant on the premises produced gas for lighting and cooking. Successful research at Chinhat demonstrated that small gasoline and kerosene engines could be run on the gas through carburettor modifications. Since 1960 workers at the gobar-gas research center at Ajitmal have developed at two-stage digester system of combined volume of 63.8 m^3 with a 35.5 m^3 gasholder. The primary digester is heated and mixed, gravity fed, and passes the slurry through a siphon to the secondary digester. Work continues on the conversion of diesel engines to biogas, the use of the gas for welding, development of stoves on which to bake flatbread, and more efficient use of the effluent.

291 Doaso, M. [Combustible gas obtained from manure.] (Sp) Rev. Cafetal. (ser. 4) 1(5):37-38. Jan. 1962. [BA 27 74472]

292 Ducellier, G. [Manure gas & the efficient treatment of composts, manures, and sewage.] (Fr) Algeria. Dir.de l'Agr. et des Forets. Agr. Algerienne 3(15):47-53. Feb. 1962. [BA 26 83295]

293 Farm effluent plant produces gas for domestic heat and power. Wat.Waste Treat. J. 9:434. 1963. [WPA 38 1166]

A plant for treating farm waste waters, developed by Wright Rain Ltd. and based on a prototype plant invented by Fry, J., which has been in continuous use for 5 years on a pig farm at Rietvlei, Johannesburg, is described. Manure is pumped into one end of the digestion tank about one-third of the way up the tank, and anaerobic decomposition occurs at a controlled temperature (optimum 35°C); the gas rises to the top and is collected in gas holders to be utilized for domestic heat and and power, while an outlet near the bottom of the tank allows decomposed matter to be drawn off for spreading. Results with pig manure suggest that a digestion tank should be planned for a 60-day cycle. Cow and pig manure can be digested without difficulty, but it would be necessary to add water to chicken manure for successful digestion.

294 Feraud, L. [Anaerobic fermentation of fertilizers: manure, humus, methane and electricity.] (Fr) Agr. Prat. 125(6):249,251-253. June 1961. [BA 26 5905]

295 Gornovesov, G. [Manure fermentation for producing of methane.] (Ru) Tekh. v Sel'sk. Khoz. 1:28-32. Jan. 1965. [BA 29 64767]

296 Habel, F. [Gas-fuel for the rural household.] (Ge) Ubersicht 14(5):278-281. May 10, 1963. [BA 27 74463]

297 Hart, Samuel A. Digestion tests of livestock wastes. J. Water Poll Cont. Fed. 35(6):748-757. June 1963.

In this 8 1/2 week duration laboratory study eight 3.4 l digesters were operated at temperatures of 23° and 35°C with detention times of approximately 25 days. Four of the digesters were fed chicken manure at loading rates of 2.76 to 4.89 g VS/l/day and the remaining four were fed dairy cow feces and urine at 2.11 to 3.44 g VS/l/day. The tops of the digesters were removed twice weekly for feeding and the digesters were stirred twice daily. The destruction of volatile matter in the dairy units was low (10-16%) but the amount of gas produced was 700 to 1000 ml/g VS destroyed. The digesters which operated on chicken manure suffered from incipient souring, the cause of which remained unexplained. Tables and graphs present figures for COD and BOD, pH, alkalinity and volatile acids concentrations, nitrogen, and gas production.

298 Ho-A-Shoo, John A.R. Methane generator. Brit. pat. 925, 891. May 15, 1963. Appl. Dec. 29, 1961. 3pp. [CA 59 11241f]

299 Huge, P. [Methane fermentation and its application to the farm.] (Fr) Rev. de l'Agr. 14 (10):1307-1336. Oct. 1961.

The methane fermentation found in nature first described. A second, lengthier section describes the biochemistry, microbiology, and ecology of the process as studied in the laboratory. The last section describes the technology of the process as applied on the farm and the conclusion is drawn that the gas would cost 1.80 - 2.50 Belgian francs/m^3, depending upon the quantity of necessary equipment already on the farm which could be modified, and upon the concentration of the waste.

300 Hutchinson, T.H. Methane farming in Kenya. Mother Earth [London] 12(3): 296-298. July 1962. [BA 26 89689]

See 375

301 Idnani, M.A. and Jai Singh. Some improvements in the bio-gas plant. Indian Farming 12(11):24-25. Feb. 1963.

No account of improvement to the plant itself is given. However, means of gas use are described. The gas can be enriched by passing it through gasoline before its use in lighting. Gasoline engines can be run on the gas by (1) passing the gas through a 0.635 cm tube into the intake manifold, with variable gas supply; (2) supplying the gas above the carburettor and fabricating an air valve for control air supply; (3) passing the gas through the carburettor gasoline line (which previously ran to the fuel tank) and removing the float and other internal impediments to gas flow.

302 ________, and C.N. Acharya. Bio-Gas Plants; their installation, operation maintenance and use. Indian Council of Agricultural Research Farm Bulletin No. 1 (New Series). New Delhi, 1963. 24p.

This pamphlet is a compilation of IARI work which had previously appeared as separate articles in Indian Farming, with little new information put forward. A description, detailed diagram and parts list for the prototypical IARI bio-gas plant are presented; ie. 1.7 m dia. bricked tank 3.65 m deep, gravity fed, floating and counterweighted gasholder, effluent overflow design which yields 2.83 m^3 gas/day from 45.5 kg manure added daily. Note that the 16 gauge galvanized mild steel gasholder comprises 45% of the total installed cost while the labor of erection amounts to less than 6%. Several other designs are briefly described and sketched; viz. rectangular trench design with floating gas collectors which are bled to a central gasholder, batteries of continuous feed digester yielding gas to a common gasholder, a night-soil (human waste) plant, and battery digesters for the batch production of gas from cellulosic materials. Short sections on the operation and maintenance of the gas plant and the use of the gas follow. The concluding section on economics shows that by the savings in nitrogen fertilizer costs and in kerosene for lighting alone 22% of the initial cost can be recovered yearly.

303 ________, and O.P. Chawla. Bio-gas plant slurry is now easier to dispose of. Indian Farming 13(11):6. Feb. 1964.

Separation of the solids of the digester effluent is effected by draining the slurry on a bed of leaves. The liquid portion is recycled with fresh waste, while the accumulation of solids and leaves are composted.

304 ________. Why bio-gas plant has not caught on with farmers. Indian Farming 14(3):14,25,31. June 1964.

Idnani concludes that the isolated farmer operating a biogas plant must fight the weight of tradition and that the plants will only gain in favor when they are clustered in villages in order to amass public acceptance proportionate to their density.

305 Jeffrey, Edgar A., Wm. C. Blackman, Jr., and Ralph L. Ricketts. Aerobic and anaerobic digestion characteristics of livestock waste. University of Missouri Engineering Experiment Station Bull. No. 57. 1963. 106 p.

Pages 18-34 of the bulletin encompass the studies of anaerobic digestion of hog, dairy cow, and sheep waste. In all cases the contents of eight liter digesters were maintained at 35°C and fed daily. No mention is given of the presence or absence of mixing. In all cases, too, the digester feed was gradually changed from sewage sludge to animal waste during an acclimation period.

Hog manure was digested at a 20 day detention time with incremental increases in loading from 2.4 to 3.2 g VS/l/day. It was found that:
- raw hog manure had a volatile solids concentration of 84 to 89% TS.
- the critical loading rate was 2.4 to 2.7 g VS/l/day. At 3.2 g VS/l/day the volatile acids concentration increased and gas production fell.
- volatile solids reduction was about 50%
- gas production was about 530 ml/day gram VS added or 810 ml/g VS destroyed
- the gas contained approximately 32% CO_2

Dairy cow waste was digested at a detention time which decreased from 20 days to 16.6 days, and at loading rates which were reduced from 2.9 to 2.4 g VS/l/day and then increased gradually to 3.49 g VS/l/day. It was found that:
- raw cow manure had a volatile solids concentration of 87-89% of TS.
- the maximum loading rate is probably in excess of that attained in this study.
- volatile solids reduction was about 50%.
- gas production averaged 160 ml/day/g VS added or about 320 ml/g VS destroyed.
- the gas contained approximately 35% CO_2.

Sheep manure was digested at a 20 day detention time with the loading rate increasing from 2.4 to 2.82 g VS/l/day. Conclusions:
- raw sheep manure had a volatile solids concentration of 90% of TS.
- higher loading rates are possible.
- volatile solids reduction varied from 38 to 33% for a volatile loading of 2.4 to 2.82 g VS/l/day.
- gas production varied from 120 to 220 ml/g VS added. The higher the loading rate the lower the gas production became. 370 to 560 ml gas were produced/gram VS destroyed.
- the gas contained approximately 36.5% CO_2.

Graphs of pH, gas production, volatile acids concentration, and loading rates through time are presented, along with summary tables of those data and total and volatile solids concentrations.

306 ________, Wm. Blackman, Jr. and Ralph L. Ricketts. Treatment of livestock waste; a laboratory study. Trans. Am. Soc. Agr. Eng. 8(1):113-117,126.1965.

This paper is a brief summary, lacking utility, of the results of the study presented in the previous citation. Their procedure is explicated, yet only a graph of hog manure digestion results is presented, neglecting the summarization of the figures. The cow and sheep manure digestion studies are nearly totally neglected, with no results reported.

307 Klawenek, A. and A. Pentkowski. [Methane fermentation of manure.] (Po) Zesyty Nauk. Szkoly Glownej Gospodarst. Wiejskiego Warsawie, Rolnictwo 5:103-119. 1962. [CA 61 16735c]

Gas evolution during the fermentation of manure at 35-40° was uniform, while at 48-52° an initial outburst was observed. Compn. of the gas (CH_4 48-53%; CO_2 44-47; H 2-5) as well as its heat value (4300-4600 kcal./m^3) did not depend upon the temp. of fermentation. Gas production was increased by water diln. of the manure. K. Belzecka

308 Kuan, S.S. & Chou, J.C. Methane gas production-anaerobic fermentation of hog droppings and agricultural waste materials. Taiwan Sugar 10(4): 17-20. Oct./Dec. 1963. [BA 28 50060]

As fertilizers in sugarcane culture.

309 Manninger, E. [Biogas production from swine manures mixed with agricultural waste.]. (Hu., ge.) Agrokém. és Talajtan 10(4):505-510. Dec. 1961. [BA 26 65040]

310 Nation, H.J. Report on a visit to Germany and Holland II. Farm methane production. Nation. Inst. Agric. Engin., Brit. Soc. Res. Agric. Engin. 18p. 1961. [414]

311 Pathak, B.N., D.N. Kulkarni, J.M. Dave, and G.J. Mohanrao. Effect of gas recirculation in a pilot-scale cow-dung digester. J. Envir. Hlth. [India], 7:208-212. 1965. [WPA 40 109]

Laboratory experiments showed that if, during anaerobic digestion of cow manure, the contents of the digestion vessel are mixed by recirculating gas, nearly twice as much gas is produced, and there is less variation in the temperature of the digesting liquor, the pH value, the carbon-dioxide content of the gas, and the reduction in volatile matter. Results of experiments during which gas was recirculated for periods ranging from 0-4 hours, are tabulated.

312 Roa, E.G.K. Advantages of bio-gas. Indian Farming 12(12):13-14. March 1963.

The ease of plant operation, utility and cleanliness of the gas, and the manurial value of the effluent are described. It is calculated that the value of the effluent as a fertilizer alone could nearly repay the initial cost of the plant within a year.

313 Rocasolano, C. [Obtainment and use of biological methane.] (Sp.) Cult. Mod. 48(2):45-46. Feb. 1965. [BA 29 64771]

314 Sandor, I. [Agriculture as a source of engine-fuel gas energy.] (Hu.,en.) Jarmuvek, Mezogazdasagi Gepek 12(3):107-109. March 1965. [BA 29 64772]

315 Spillman, Charles K. Characteristics and Anaerobic Digestion of Swine Waste. M.Sc. thesis. University of Illinois, Urbana. 1963.

Swine waste was diluted with water to varied concentrations and placed in small digesters at ambient (16°C) temperature. The digesters were unseeded and remained unmixed. At the end of six weeks time several of the digesters were seeded with municipal sludge and/or limed. The experimental methodology employed exhibits a lack of control of variables and presents analysis and summarization extremely difficult.

316 Suthipolpaiboon, S. [Utility of CH_4 gas from cattle dung] (Siamese, en.) Kasikorn 37(6):493-503. Nov. 1964. [BA 29 43143]

317 Taiganides, Eliseos Paul. Characteristics and Treatment of Wastes from a Confinement Hog Production Unit. PhD dissertation, Iowa State University of Science and Technology, Ames, 1963.

Taiganides assayed the volume and chemical composition of wastes produced by growing hogs and related waste quantity and composition to the following factors: the daily quantity and composition of the feed intake, water intake, the size of the hog, and the air temperature within the confinement unit.

Studies of the anerobic digestion of the wastes were undertaken in six laboratory digesters which were heated to 35°C, continuously mixed, and fed daily. Loading rates, detention times, and solids concentrations of the feeds varied widely between the digesters and through time within each digester. Maxima and minima are as follows:

Loading rate	0.40-3.89 g VS/1/day
Detention time	7.9-80 days
Total solids in feed	0.84-8.5%
Volatile solids destruction	low mean of 34% to max. 79%
Gas production (ml/g VS added, mean)	484 to 630

He concluded that:

(1) At 35°C hog manure can be satisfactorily digested at a loading rate of 3.2 g VS/1/day with a volatile solids concentration of 3%, fed daily, and operating at a detention time of 10 days;

(2) Copper content of the manure limited the digestion process at 36 ppm, necessitating the reduction of total solids to below 3.6% by the addition of water;

(3) The daily gas yield per gram volatile matter fed was approximately 600 ml. The gas was approximately 59% CH_4 and had a heating value of 2.1×10^7 joules/m^3;

(4) On the basis of the above criteria and the manure production figures presented in the thesis, approximately 1.06 m^3 of digester volume is required per pig.

318 ________. Digestion of farm poultry wastes. Proceedings First National Symposium on Poultry Industry Waste Management. Nebraska Center for Continuing Education, Lincoln, Nebraska, May 13-15, 1963. [319]

319 ________, E. Robert Baumann and Thamon E. Hazen. Sludge digestion of farm animal wastes. Compost Science 4:26-28. Summer 1963.

Digester loading rates of 1.6 to 4.8 g VS/l/day at 7 to 10% total solids with detention time of 10 to 30 days are recommended for a mixed digester operating at 35°C. Tables of physical proerties of animal wastes and expected gas yields are presented. It is calculated that the total initial cost of a digester which would handle the waste of 100 dairy cattle or 1000 hogs would range from $9000 to $15 000, the digester yielding gas worth $700 yearly.

320 ________ E.R. Baumann, H.P. Johnson, and T.E. Hazen. Anaerobic digestion of hog wastes. J. Agr. Eng. Res. 8(4): 327-333. 1963

A short history, a list of advantages and limitations, and a short introduction to the principles of the process of anaerobic digestion are given. Six five gallon bottle digesters were daily fed hog manure, maintained at 35°C, and constantly agitated. Satisfactory operation was assured at 3.2 g VS/l/day with a detention time of 10 days, yielding 490-643 ml gas/g VS/day with a CH_4 content of 59% (2.1 x 10^7 joules/m^3). A figure and discussion portray the interrelationships of loading rate, solids concentration and detention time. They estimate that a marginal profit might be obtained by the operation of a heated digester handling the wastes of 10,000 hogs.

321 ________. Anaerobic digestion of poultry manure. World's Poultry Sci. J. 19(4):252-261. Oct./Dec. 1963.

The process is described and the parameters to be optimised are noted. A design similar to a municipal heated, mixed,fixed cover digester is presented. It is calculated that at a loading rate of 3.2 g VS/l/day and a 23 day detention time that the digester capacity required per hen is 10.5 liters. A 20,000 hen flock would require a digester with 210 m^3 capacity, costing from $11,000 to $25,000. The income from using the gas produced at 150 m^3/day would be between $900 and $1200 per year.

322 Vishnoi, S.L. and S.P. Bose. Effect of educational exposures on the acceptance of cow dung gas plants by farmers. Indian J. Agron. 5(4): 284-291. June 1961.

Eighty farmers, literate and illiterate, of many ages, and with annual incomes of from two times to over three times the initial cost of the IARI gas plant were exposed to an operating gas plant and accompanying talk three times. A pretest and three posttests after the exposures revealed correlations of acceptance with education and economic status. Two among the 80 farmers were willing to enter a 50-50 cost-sharing agreement with the government to construct small digesters.

1966–1970

323 Agnew, R.W. and R.C. Loehr. Cattle-manure treatment techniques. In: Management of Farm Animal Wastes; Proceedings National Symposium on Animal Waste Management, May 5-7, 1966, Michigan State University, East Lansing. American Society of Agricultural Engineers publication no. SP-0366. p. 81-84.

Five brief paragraphs and a table describe the performance of four digesters loaded at 1.6, 3.2, 4.8, and 6.4 g VS/l/day which were mixed, fed daily, heated to 35°C, and operated at a 10 day retention time. Problems with low pH were corrected during startup by the addition of sodium bicarbonate. Total solids reduction was greatest in the lightly loaded digesters (42-55%), while BOD_5 reduction and percent CH_4 in the gas produced were in the fiftieth percentile range for all digesters. Gas production was 547 to 743 ml/g VS added.

324 Baines, Selwyn. Anaerobic treatment of farm wastes. In: Symposium on Farm Wastes, University of Newcastle-upon-Tyne, 1970. London, 1970. Paper No. 18, p. 132-137.

A description of the operation of municipal waste treatment digesters is given, and a résumé of works by Hart and Taiganides. Baines describes a digestion installation at The West of Scotland Agricultural College which accepts the wastes of 1600-1700 laying hens. The digester has a capacity of 24.92 m^3, is insulated, heated to 35°C, and at the time of the presentation of this paper was unmixed. The hens produce 0.15 kg waste each per day which is diluted by 0.272 kg water/hen day to yield a slurry of 8% solids. The capacity of the digester/hen is 0.0156 to 0.0147 m^3 and the detention time is 28 to 30 days. It was assumed that the daily introduction of feed and convection caused by heating coils within the tank would prevent the formation of scum. Such was not the case; some form of agitation being necessary. Gas production was 14 liters/hen/day. Insufficient information was available at the time of the symposium for such figures to be presented.

325 Cassell, E. Alan, and Arthur Anthonisen. Studies on Chicken Manure Disposal: Part I, Laboratory Studies. New York State Department of Health Research Report No. 12 Part 1. April 1966.

Pages 65 to 79 comprise an introduction and historical review of anaerobic digestion. Pages 80 to 102 recount an experiment in which three laboratory digesters were seeded with digester sludge, with one digester continuing on sewage sludge and the other two gradually converted to operation on chicken manure. One of the later two digesters was fed sodium chloride with the manure to serve as an antagonist to ammonia. They concluded that: (1) High ammonia nitrogen concentration appears toxic to the anaerobic digestion of chicken manure; (2) The addition of NaCl to a digester with high ammonia concentrations appears to promote the digestion of chicken manure; (3) The following conditions appear to provide an environment under which chicken manure can be anaerobicly digested: pH of 7.4, volatile acids of 1,500 mg/l or above, alkalinity of 10,000-12,000 mg/l, ammonia nitrogen concentrations of 1,500 mg/l, detention time 20 days, loading rate of 1.4 g VS/l/day, 35°C, and sodium concentration of 0.018 molar. The third section (p. 103-128) presents a kinetic model for high-rate anaerobic digestion.

326 Cross, O.E. and Alvaro Duran. Anaerobic decomposition of swine excrement. Trans. Am. Soc. Agr. Eng. 13(3):320-322, 325, May/June 1970.

Nine laboratory digesters were operated in a matrix of various temperatures (10°, 21°, 32°C) and loading rates (0.8, 1.6, 3.2 g VS/l/day);fed and mixed daily. The digesters were initially charged with digesting sludge and were daily fed an amount which displaced 1/25 the volume of the digester. The experiment lasted but 15 days, and the authors acknowledge that "the duration of run was not sufficient" for the digesters to reach equilibrium under the regime they had prescribed. They nonetheless conclude from an analysis of volatile solids reduction that the digesters which operated at higher temperatures and lower loading rates were at or approaching equilibrium, that at the higher loading rates and lower temperatures the digesters were approaching failure, and were unsure of the success of the digesters which were operated in the middle region.

327 Cute, E., E. Mambet, E. Juriari, and C. Murgoci. [Investigations on the treatment of waste waters from pig breeding.] (Rumanian, en.). Studii Prot. Epur. Apel. [Bucharest] 9:305-328. 1967. [WPA 41 865]

The introduction of intensive methods of pig breeding has caused changes in the characteristics, particularly the strength, of the piggeries waste waters; analytical data are tabulated for waste waters from 3 pig - breeding farms and 1 large pig-breeding combine in Romania. At older piggeries, waste waters are treated by sedimentation and sludge digestion in Imhoff tanks. In more recent establishments, treatment comprises primary sedimentation followed by storage of the settled waste waters in ponds to be used for irrigation, and separate digestion of sludge in open tanks. Experiments showed that precautions are necessary to prevent blocking of the sewerage system by easily-settleable material before reaching the sedimentation tanks; sedimentation is more efficient in horizontal sedimentation tanks than in the older Imhoff tanks; biological treatment is possible without addition of nutrients, but the waste waters must be diluted; and digestion requires a longer period than that for sewage sludge, difficulties being caused by the presence of coarse suspended particles of waste feeding stuffs.

328 Dalrymple, Waite and Donald E. Proctor. Feasibility of dairy manure stabilization by anaerobic digestion. Water and Sewage Works 114(9):361-364. Sept. 1967.

Four laboratory digesters were operated within the matrix of variables of loading rates (1.6 and 2.9 g VS/l/day) and detention times (12 and 20 days) All digesters were maintained at 35°C and mixed for 15 minutes every two hours. The digesters were initially charged with digester sludge from a municipal plant and fed dairy manure at the given rates during a three week acclimation period; the experiment continuing 41 days beyond that time. The results were: (1) Only slightly less that 120 ml gas was produced per g VS destroyed; (2) Destruction of volatile solids ranged from 37.8 to 53.3%, the shortest detention time digesters showing a greater reduction; (3) The gas contained 74-79% CH_4; (4) The alkalinities more than counterbalanced the volatile acids; pH was 7.4 to 7.5.

329 Farag, F.A., Esaad H. Bedaiwi, and M. Abou El-Fadl. Production of methane gas from poultry droppings. Ag. Res. Rev. 48(2): 98-106. 1970. [CA 76 57710e]

It was possible to produce flammable gases through anaerobic fermentation of poultry droppings. The remaining residues were available for use as manure. Periods of active fermentation varied widely according to the chemical compn. of the droppings with beddings. Active production was max. for the first 10 weeks with clay loam bedding and the first 6 weeks with sawdust bedding. A study was made, through 16 weeks fermentation of the production of CH_4 from 2 types of poultry droppings mixed with day loam soil and sawdust beddings. Total gas of 66.7% cm^3 contg. 43.1 cm^3 flammable gases were produced on an av. from each g. dry matter oxidized during the period of fermentation. The avs. during the active periods, of the first 10 weeks of droppings with soil and the first 6 weeks with sawdust,were 63.4 cm^3 total gases contg. 40.5 cm^3 flammable gases.

330 Gramms, L.C. Anaerobic Decomposition of Animal and Poultry Manure Under Laboratory Conditions. MSc. Thesis. University of Wisconsin, Madison, May 1967. [C.G. Golueke. Solid Waste Management: Abstracts and Excerpts from Literature, Vols. 1 and 2. US Dept. of Health, Education and Welfare, Environmental Health Service, Bureau of Solid Waste Management. Public Health Service Publication No. 2038. 1970. p. 284.]

See 368

331 ________, L.B. Polkowski, and S.A. Witzel. Anaerobic digestion of farm animal wastes (dairy bull, swine and poultry). Paper No. 69-472, American Society of Agricultural Engineers, St. Joseph Mich. 1969. 29pp.

See 368

332 Lee, Yong Bin, and Chong Saeng Park. [Production of methane as a fuel from the feces of swine, fowl, and cattle.] (Korean) Soul Taehakkyo Nonmunjip, Chayon Kwahak, Saengnongge 1970, 21, 35-40. [CA 76 131196k]

These studies were made to det. the CH_4 production with feces of fowl, swine, and cattle, and the seasonal variation in methane gas produced with swine feces. Fowl feces produced more CH_4 than the feces of swine or cattle. Daily CH_4 production, energy, and combustion time with 10 to 20 kg feces were 1.86 m^3, 5285 kcal, and 342 min with fowl feces, and 1.54 m^3, 4569 kcal, and 295 min with cattle feces, and 1.68 m^3, 4977 kcal, and 319 min with swine feces resp. CH_4 production increased in proportion to the amt. of feces used. Av. CO_2 content was 17.7% in the fuel gas and there were no significant differences in CO_2 content between these feces. Great seasonal variation in CH_4 production was found. Daily CH_4 production, energy, and combustion time with 20 kg. of swine feces were 1.80 m^3, 5198 kcal, and 335 min. in the summer, and 0.59 m^3, 1704 kcal, and 110 min. in the winter. More CH_4 was produced in the fall than in the spring. It appears possible that 20 kg. of swine feces a day produce enough fuel for cooking for a 5 member family, except in the winter.

333 Loehr, Raymond C. and Robert W. Agnew. Cattle wastes - pollution and potential treatment. J. San. Eng. Div., Am. Soc. Civil Eng. 93(SA 4):55-72. Aug. 1967.

Laboratory digesters were operated at loading rates of 1.6, 3.2, 0.3, and 6.4 g VS/1/day. All digesters were mixed, heated to 35°C, fed daily, and had detention time of 10 days. Total solids reduction and percent CH_4 in the gas produced were higher in the two digesters with the lower loading rates; 41.9 to 55.2% reduction and 58-57% CH_4. Five day BOD reduction was 52.4 to 57.0%. Gas production was 547 to 743 ml/g VS destroyed.

334 London Science Museum Science Library. Some post-war references to "biogas". Science Library bibliography series no. 794. Oct. 1968. 2 p. 31 references.

335 Maree, W.S. Methane gas from farm and animal waste. Farming So. Afr. 41(12):6-7,9. March 1966. [BA 30 60284]

336 Meenaghan, G.F., D.M. Wells, R.C. Albin, and W. Grub. Gas production from beef cattle wastes. Paper presented at the winter meeting of the Am. Soc. Agr. Eng., Chicago, December 8-11 1970. ASAE Vol. 70 No. 907. 15 p.

The wastes of three steers which grew from 225 to 350 kg during the course of the experiment, were diluted with 150-180 liters of water daily. 23 liters of the slurry were daily fed to the first stage of a two-stage digester. Both tanks were of 114 liter capacity, continuously mixed by pumps, and heated to 36°C by electrical heating units which were side-mounted on the tanks. Detention time in each stage was five days, giving a total detention time of 10 days. The results obtained were as follows:

	Stage I	Stage 2
Gas production (digester volumes/day)	4.3	2.82
% CH_4 in gas	53	72
pH	6.3	7.1
Volatile acids (mg/1)	2990	1030
Alkalinity (mg/1)	3750	4700

BOD_5 reduction was 56.5% and COD reduction was 40%.

337 Poch, M., and L. Hänske. Die biologisch-thermische Desinfektion von Gülle mit Hilfe der thermophilen Methangärung. Z. Hygiene u. Grenzgebiet 14:553. 1968. [414]

338 Prasad, C. Popularizing biogas (gobar gas) production. Khadi Gramodyog 12(10) 661-663. July 1966. [BA 31 46105]

339 Prasad, C.R., K.C. Gulati and M.A. Idnani. Changes in biochemical constituent [sic] of some organic waste materials under anaerobic methane fermentation. Indian J. Agr. Sci. 40(10):921-924. Oct. 1970.

Changes in the percentage composition of holocellulose, cellulose, hemicellulose, lignin, pentosans and methoxyl contents of organic materials after fermentation of various systems like cowdung alone, cowdung-gum arabic, cowdung-wheat straw, cowdung-groundnut shells and cowdung-sugarcane bagasse by methane organisms indicated that the systems which had holocellulose: lignin in a ratio of 3:1 or less before fermentation showed a greater decrease of hemicellulose fraction than of cellulose fraction. The percentage of lignin (18.41-22.03) and pentosans (0.292-5.129) increased after fermentation, except in cowdung-gum arabic, which showed decrease of pentosans content.

Methoxyl contents also decreased after fermentation, indicating a positive role of methyl group of methoxyls in the formation of methane by methane-formers. Author's summary

340 Rajagopal, G., and B.N. Pathak. Effect of volatile and acid accumulation in dung digestion. Envir. Hlth. [India] 8:194-196. 1966. [WPA 40 992]

In continuation of laboratory experiments on the anaerobic digestion of cow dung experiments were carried out to determine the limiting concentrations of volatile acids and to investigate methods of regenerating digestion after failure. Volatile acids were increased by adding acetic acid to digesting dung slurry; digestion failed completely when volatile-acid concentration was 6194 mg per litre, at pH 4.4. Attempts were made to regenerate digestion by adding lime, after dilution with water, but although over a period the volatile-acid content was reduced from 5650 to 3730 mg per litre, and the pH value rose on average from 4.5 to 6.3, gas production remained at a low value until additional digested slurry was introduced, leading to resumption of normal digestion.

341 Rizk, S.G., F.A. Farag, M. Kh. El Mofty, M. Abou El-Fadl. Production of methane gas from organic wastes under anaerobic conditions. I. Important factors influencing formation of combustible gases. Agr. Res. Rev. [UAR] 46(2):53-66. 1968. [CA 71 53297z]

As a 1st step in producing CH_4 on a com. scale, lab expts. were carried out to ferment, under restricted O conditions rice straw, corn stalks, cotton stalks, and buffalo dung. Factors affecting gas yield viz., $CaCo_3$ and $(NH_4)_2SO_4$, variation in incubation temp., ratio between materials and aq. soln. in fermentors, and changes in pH were studied. The max. rate of CH_4 formation occurs in environments of neutral pH; there is little activity below pH 6.0. Addn. to the substrate of buffering materials such as $CaCO_3$ to neutralize the acids formed would favor CH_4 production. CH_4- producing organisms flourish at 30° thus raising the incubation temp. to 37° or 60° would depress gas yields. It appears logical that fragmentation of org. wastes in the CH_4 fermentors favors production of gas yields compared to powdering. Philip Jacobson

342 Schmid, Lawrence A. and Ralph I. Lipper. Swine wastes, characterization and anerobic digestion. In: Animal Waste Management. Cornell University Conference on Agricultural Waste Management, Syracuse, New York, Jan. 13-15 1969. p. 50-57.

The authors analyzed the waste characteristics of swine and related waste quantity and composition to the live weight of the swine; percentage of components of waste remaining relatively constant over the course of finish feeding. In digestion experiments at loading rates of 3.2 and 6.4 g VS/1/day, detention times of 10 and 20 days, and temperatures of 20° and 30°C difficulties were encountered with ammonia concentrations. Resultant gas production was less than 60 ml/g VS added, methane concentration in the gas was less than 18%, and there was poor solids reduction. They concluded that "conventional anaerobic digestion cannot be practiced on raw undiluted hog wastes which include urine" because of resultant ammonia toxicity. A 10 day retention time at 20°C was as effective in liquifying the waste as were longer detention times and higher temperatures.

343 [The solution to the poultry manure problem. 1-2.] (It) G. Pollicoltori 17(6):60-64, 66-70, 72-93, 98, 100, 103, 105. June 1967. [BA 32 71266]

Conversion to methane and use as fertilizer; includes reports by T. Favali, C. Soprani, A. Rigoni, G. De Stanchina, and V. Tranquillini.

344 Taiganides, E. Paul. Farm-waste management in Europe and India. Agr. Eng. 48 (12):710-713. Dec. 1967.

Taiganides states that most of the post WWII digesters in Germany are no longer operational because of both technical and economic problems, and asserts that "they were never really economically feasible and many maintainance problems are associated with their operation." He reports that about 2,000 digesters were in India, with the construction of an additional 9000 planned for the following four years.

345 Werthmuller, E. Farm power from manure. New Zeal. Tobacco Grower's J. Jan. 1966:12-13. [BA 31 54733]

346 Witzel, S.A., E. McCoy, O.J. Attoe, L.B. Polkowski, and Koby Crabtree. Research Project Technical Completion Report, December 1969. OSW Project No. UI-00556-01 to 04. Project title: Farm Animal Waste Disposal. 37 p. mimeo.

The results of studies on the anaerobic digestion of dairy bull, swine, and poultry wastes are presented on pages eight and nine of this report. They concluded from observation of temperature controlled anaerobic digesters at 10 and 15 day detention times with loading rates of 1.9 and 4.0 g VS/1/day that: (1) Anaerobic digesters for dairy bull waste may be loaded at rates of 3.8 g VS/1/day with detention times as short as 10 days without indication of digester failure; (2) Digesters for swine waste may be loaded at rates of 3.8 g VS/1/day with detention times between 10 and 15 days for good reductions in volatile solids and COD; (3) Poultry waste digesters should not be loaded at rates greater than 2.9 g VS/1/day with detention times between 10 and 15 days; (4) The effluents require additional treatment before they may be introduced into a watercourse, anaerobic-aerobic sequences being suggested. An alternative disposal method is long-term storage of digester effluent and field spreading.

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347 Abeles, T.P. and P. Atkinson. Economics and energy considerations for anaerobic digestion of farm waste. Paper presented at the 7th National Agricultural Waste Management Conference - Energy, Agriculture, and Waste Management, April 16-18, 1975, Syracuse, New York. In press.

348 Anaerobic digestion plant for pig waste. Agric. Environ. 1(2):202-204. Aug. 1974. [CAIN]

349 Another recycling venture. Calf News 11(4):15-16. April 1973. [Ramsey et al. 1975]

Hamilton Standard initiated an experiment in December 1970 to determine the feasibility of converting animal wastes into usable by products by anaerobic fermentation. At the time of this report, two twenty-liter fermenters had been used for 1 1/2 years. The operating temperature was in the thermophilic range and the feed material was animal waste obtained from cattle fed a high concentrate ration. Tank volumes of only 1/3 that of municipal systems were deemed practical. The system utilized very thick waste concentrations, operated with high process loading rates and small fermenter volumes, had low power requirements and generated its own fuel. Advantages of the process were: (1) It produced two products (fuel and animal ingredients) which could be used in the feedlot operation. (2) It would accept all of the solid wastes in the form available. (3) It had no discharges of liquid, solid or gaseous pollutants. This study showed the anaerobic process to require two-thirds of the capital investment and one-half the annual operating expense compared to the aerobic process. (Lee-East Central)

See 356

350 Anthonisen, A.C., and E.A. Cassell. Methane recovery from poultry waste. North Atlantic Region of Am. Soc. Agr. Eng. paper no. NA74-108. 1974. 28p. [352]

351 Bell, C. Anaerobic digestion of dairy farm slurry. Effl. and Water Trt. J. [G.B.] 13(4):232-233. April 1973. [S. Ghosh and J.R. Conrad. Anaerobic processes. J. Wat. Poll. Cont. Fed. 46(6):1156. June 1974]

Bell described the intermittent operation of a pilot-scale anaerobic digester receiving dilute dairy farm slurry. A 65 to 75 percent reduction of the 'permanganate (COD) value' could be obtained at 35° and a 60 day detention time. Methane content of the gases ranged between 40 and 70 percent.

352 Belyea, David. A., Awatif El-Domiaty Hassan, and H. Moustafa Hassan. Characterization of methane production from poultry manure. Paper presented at the 3rd International Symposium on Livestock Wastes, 21-24 April 1975, Urbana-Champaign. In press.

Laboratory and field demonstration plant studies were undertaken, studying the effects of temperature (25° - 50°C), solids concentration (1.5-18%), inoculum size (0-50%), and exogenous carbon sources (sawdust and potato processing wastes) on the production of methane by batch fermentation of chicken manure. The optimum temperature for gas production was found to be 35°C. After 110 days of digestion at 25°C the greatest gas production (129-149 l CH_4/kg solids) and solids reduction (34-45%) were found in digesters which were initially charged with 4.6 to 7.6% solids. The rate of gas production was proportional to the size of the inoculum used. The addition of 2-4% sawdust increased the amount of gas produced, but at 8% sawdust gas production was "significantly lower." The field digester of 2.63 m^3 capacity was charged at a 7% solids concentration, the temperature controlled at 35°C, and recharged at 21 day intervals by removing 25% of the tank contents and replacing it with fresh waste slurry. The contents were mixed by recirculation and a rotating scum breaker was installed. Methane production of 133-161 l/kg dry manure and a net output of 3489 to 4187 kJ/kg dry manure were obtained.

353 Berthelsen, L. Alternative energikilder. 3. Biogas - eller godningsgas. [Alternative energy sources. 3. Biogas or manure gas.] Ugeskr. Agron. 3(21):427-429. May 23, 1974. [CAIN]

354 Boyd, J.C. Anaerobic treatment of animal waste: a survey. Montana Agricultural Experiment Station, Montana State University, Bozeman, Research Report 65. Dec. 1974. 13 p.

A survey sent to the 50 state agricultural experiment stations or to the state university departments of agricultural engineering or animal science yielded knowledge of only one commercial animal production unit using an anaerobic digester in a waste management program and another digester under construction at another commercial unit. Only four small family-type digesters were reported. Twenty states reported research or anticipated research in the area, and brief descriptions of the research were included.

355 Cassell, E.A., R.N. Downer, J.C. Oppenlander, and J.H. Corazzini. Energy analysis of anaerobic digestion of dairy cow manure. Symp. on Use of Agric. Wastes, Regina, Sask. 1974. In press. [383]

356 Coe, Warren B., and Michael Turk. Processing animal waste by anaerobic fermentation. In: George E. Inglett (Ed.). Symposium: Processing Agricultural and Municipal wastes. AVI, Westport Conn. 1973. p. 29-31.

These workers at Hamilton Standard were pleased with the stability of two laboratory digesters which had operated in the thermophilic range, fed steer manure, for one and one-half years. They envision a system which would use a digester to concentrate waste and solve disposal problems, and refeeding the effluent solids to steers at up to 10% of the diet. The effluent supernatant would be recycled as makeup water. Their research indicated no problems in the buildup of salts or minerals in the digesters, and no problems which would be caused by the concentration of undigested substances through refeeding. They conclude that a feedlot in the 5000-7000 head range could economically operate such a system.

357 Converse, James C., and Robert E. Graves. Facts on methane production from animal manure. University of Wisconsin, Madison, Extension Fact Sheet A2636. July 1974. 4p.

This fine little sheet poses 26 questions which might be typically asked of extension agents ("What equipment is required to produce biogas?", "How much bio-gas is produced?", "How many cows would it take to supply enough bio-gas to heat my home?", "Is it practical to run large tractors on methane?") and proceeds to answer them simply and accurately.

358 Dohne, E., and M. Brenndorfer. Wie akteullist heute biogas? [How current is biogas today?] Landtechnik 29(7):302-307. July 15, 1974. [CAIN]

359 Dugan, G.L., C.G. Golueke, and W.J. Oswald. Recycling system for poultry wastes. J. Wat. Poll. Cont. Fed. 44(3) [part one]:432-440. March 1972.

A system is described in which the wastes of 112-140 birds are flushed to a sedimentation tank, the solids passed to an anaerobic digester, the sedimentation tank supernatant and digester supernatant pumped to an algae pond, algae fed to the chickens, and the pondwater used to flush the wastes. At loading rates of 0.64 to 0.87 g VS/1/day and an average detention time of 23 days gas production amounted to 750 ml/g volatile matter added. CH_4 content of the gas rose from 13% to 45% during the course of the study. The digester did not reach stable peak operation during the study.

360 Ecotope Group and Parametrix Inc. Process Feasibility Study: The Anaerobic Digestion of Dairy Cow Manure at the State Reformatory Honor Farm, Monroe, Wash. Ecotope Group, Box 618, Snohomish, Wash. 1975. 119 p.

The residents of the state reformatory are constructing a digestion system capable of handling the wastes of the 400 head dairy herd housed on the farm. The system is comprised of two Harvestore tanks of 378 m^3 capacity (loaded at 3.5 g VS/1/day at a 17 day detention time), manure holding pits, effluent storage, gas compressor, propane tanks to hold the compressed gas (a half-day's output at 1.7 x 10^5 kg/m^2), and heat exchangers between effluent and influent lines and in the gas recirculation system. Total estimated cost, using a maximum amount of "free" labor and donated or reduced-cost equipment, is estimated to be $71,040, which can be repaid in ten years through savings in fuel and fertilizer costs (calculated using contemporary fuel and fertilizer costs, and an interest rate of 7%).

This summary skeleton is fleshed out in the book by a welcome literature review, design calculations, and tabulations of costs in dollars and energy. The calculations and substantiations of the reasoning cover the events from the point the waste hits the gutter to the time the effluent is spread on the farm fields. This eight dollar book presents a clear and substantiated engineering design study which, although the particulars are tied to the situation at the reformatory farm, gives the figures, calculations, and design process which would be informative and educational to others considering construction of such a system.

361 Fischer, J.R., and D.M. Sievers, and C.D. Fulhage. Anaerobic digestion of swine manure. Paper presented at the 7th National Agricultural Waste Management Conference - Energy, Agriculture, and Waste Management, April 16-18 1975, Syracuse, New York. In press.

362 Fong, W. Methane Production from Animal Wastes by Anaerobic Decomposition. M.Sc. thesis, University of Manitoba. 1973.

Laboratory digesters were fed hog waste and dairy cattle waste slurries of 10% total solids (by weight) arranged in a matrix of variables as follows: loading rates of 2.4, 3.2, and 4.0 g VS/l/day, detention times of 10 and 15 days, and temperature increased by 5° increments from 32°C to 52°C, allowing digestion equilibration at each step. The digester contents were mixed thrice daily weekdays and once on Sunday.

Fong concluded that "based on the results obtained, digesters operating at a temperature range of 37° to 42°C is recommended. The rate of volatile solids reduction and gas production at 42°C were, respectively, 30% and 200% greater than at 32°C in hog waste digestion... Simiar results were also observed in dairy cattle waste digestion... Although the quality of the gas in terms of methane content and the quality of effluent sludge was better at 52°C than at mesophilic temperatures, in both wastes digestion, the amount of heat energy required to maintain the digester at that temperature is not considered economically feasible.

"Results also indicated that anaerobic digesters for dairy cattle waste may be loaded at rates of 0.25 lb VS/ft^3/day (4.0 g VS/l/day) with retention times as short as 10 days without indication of digester failure. However, anaerobic digesters of hog manure should not be loaded at rates greater than 0.25 lb VS/ft^3/day (4.0 g VS/l/day) and should have a retention between 15 to 18 days for good reduction of volatile solids and COD. Higher loading rates may result in accumulation of ammonia which is detrimental to the digestion process.

363 Fry, L. John and Richard Merrill. Methane Digesters for Fuel Gas and Fertilizer. New Alchemy Institute West Newsletter No. 3. Spring 1973. 45 p.

This short paperbound newsletter, for all of its shortcomings, must, I think, be judged the most comprehensive and available treatise on the subject. Other publications which may best it are either available only with difficulty, in a foreign language, or the cost of procurement exceeds the $3 demanded for this primer. The book gives a fair introduction to the microbiology and ecology of the anaerobic fermentation process, to the composition of animal waste, and to digester design. However, the calculations are too often poor, incomplete, or incorrect, and the treatment of digester design and operation is limited. The latter half of the book describes a digester made of truck or tractor tire inner tubes, bicycle tire inner tubes, and liberal amounts of plastic, designed to fill the needs and desires of the people of the developing nations. The Indian Agricultural Research Institute has demonstrated the efficacy of using low-cost indigenous construction materials (granting that mild steel is but domestically manufactured and not of the same class as sun-dried brick), and the necessity and wisdom of using high-technology petrochemical products in a low-cost design is questionable. The last pages recount the work of L. John Fry with a digester accepting the wastes of 1000 hogs in South Africa.

364 _______. Practical Building of Methane Power Plants. L. John Fry, 1223 North Nopal St., Santa Barbara, CA. 1974.

Twelve dollars secures "the first practical book on how to design and build your own displacement-type methane-generating plant, complete with charts, diagrams and photos... authored by the pioneer and innovator of the first, continuously-operated displacement digester methane plant ... disclosing a never-before-revealed solution to the scum removal problem before it becomes a problem... Revealing plans for a Power Plant of the Future, 100 feet long, 25 feet in diameter and yielding 50,000 cubic feet of gas daily from 5 tons (dry weight) of manure." [Emphasis in the original advance notice of publication.]

365 Gaddy, J.L., E.L. Park, and E.B. Rapp. Kinetics and economics of anaerobic digestion of animal waste. Water, Air, and Soil Pollution 3(2):161-169. June 1974.

The initial excursion into kinetics was made to calculate the necessary detention time required in a two-stage digestion system which would reduce steer manure of BOD_5 15,000 mg/l to 1,000 mg/l, the effluent to be treated in an aerated lagoon. The authors conclude that a system which would treat the wastes from 100,000 cattle would require an initial investment of $520,000 and yield an annual revenue of $1,020,000 before taxes by the sale of the gas produced. Only the slightest substantiation of their calculations is given.

366 Gobel, W. Biogas in der landwirtschaft. [Biologically produced gas in agriculture.] Schweiz Landtech. Dtsch. Ausg. 36(12):745-746. Sept. 1974. [CAIN]

367 Gosi, Pal. [Technical and economic problems of appliances producing sewer gas and biogas.] (Hung.) Energiagazdalkodas 13(6):275-280. 1972. [CA 77 155946b]

A review with 10 references. The biogas is composed of methane and carbon dioxide produced from the fermentation of silage and manure. M.M. Benarie.

368 Gramms, L.C., L.B. Polkowski, and S.A. Witzel. Anaerobic digestion of farm animal wastes (dairy bull, swine and poultry). Trans. Am. Soc. Agr. Eng. 14(1):7-11, 13. 1971

Dairy bull, swine, and poultry wastes were digested at loading rates of 1.9 and 3.8 g VS/l/day with detention times of 10 and 15 days. All digesters were maintained at 32°C and mixed twice daily weekdays and daily on weekends. The authors concluded that: (1) Anaerobic digesters for dairy bull waste may be loaded at rates of 3.8 g VS/l/day with detention times as short as 10 days. Volatile solids reduction and COD reduction were low at both loading rates and both detention times; (2) Anaerobic digesters for swine waste may be loaded at rates of 3.8 g VS/l/day with detention times between 10 and 15 days for good reduction in volatile solids and COD; (3) Anaerobic digesters for poultry waste should not be loaded at rates greater than 2.9 g VS/l/day with detention times between 10 and 15 days because of ammonia toxicity at higher loading rates; (4) The COD can be reduced considerably by solids-liquid separation utilizing gravity settling. However, the COD of the supernatants all exceeded 2650 mg/l and may require additional treatment; (5) Although substantial reductions may be achieved in volatile solids and COD the ultimate disposal of the wastes would still be a problem; (6) Of the three wastes studied the specific resistance of the poultry waste was the only value that was similar to the specific resistance of anaerobically digested domestic sludge.

369 Halderson, James Lee. Dynamic Response of an Anaerobic Digester with Dairy Cow Manure Substrate. PhD. thesis, Purdue University, Jan. 1972. 129 p.

Laboratory digesters were daily loaded with increasing amounts of manure (1.6 rising to 8.0 g VS/l/day) while the detention time remained at 15 days, temperature at 35°C, and the digester contents continuously mixed. The digesters were acclimated for seven weeks prior to the loading rate increases, and 15 days were allowed between increses. Among Halderson's conclusions were: (1) A maximum loading had not been achieved even at 8.0 g VS/l/day, where digester design and foaming determined the limit; (2) Constant loading rates for 15 days and one detention time does not appear to allow complete microbial stabilization time after a step change in loading rates; (3) A step change in loading rate of 100% did not cause instability in the biodegradation system for loading rates of approximately 1.6 to 8.0 g VS/l/day; (4) "All of the measured parameters responded in a similar manner to that of a municipal sewage sludge digester...it appears that time allocated to characterization of farm animal manures would yield a greater amount of usable information than would an equal amount of time on anaerobic digestion studies."

370 Halderson, James L., Alvin C. Dale, and Edwin J. Kirsch. Anaerobic digester response with dairy cow manure substrate. Paper No. 73-4532 presented at the 1973 Winter Meeting Am. Soc. Agr. Eng., Chicago, 11-14 December.

371 Harper, Judson M., and David W. Seckler. Engineering and economic aspects of manure utilization. Paper presented at the 3rd International Symposium on Livestock Wastes, 21-24 April 1975, Urbana-Champaign, Illinois. In press.

There are three possible uses of manure: (1) refeeding; (2) as a fuel; and (3) as fertilizer.

To compare accurately these varying manure utilization alternatives, an engineering evaluation of the capital requirements and operating costs associated with each of the alternatives are developed using a 10,000 head confinement feed lot as the basis of comparison. Common to all these systems is a manure collection system. Each then require various additional capital costs to allow utilization in the manners outlined. Therefore, capital and operating costs vary widely between systems. An economic analysis was run using the capital and operating cost estimates to determine the production costs of the products of each of the utilization methods. These production costs were then compared to current and projected prices for feed, energy and fertilizer to determine the economic viability to the alternatives. Based on this analysis, it appears that processes producing refeedable products show considerable economic potential. Any process which fractionates the manure to produce feeds of varying energy and protein levels potentially offers the greatest number of utilization alternatives and therefore economic advantages. Unless anaerobic fermentation processes can be sped up, thereby reducing capital requirements and the value of methane increases substantially, methane production appears to be a poor alternative to refeeding manure as a method of utilization. Utilization of manure as fertilizer depends on circumstances such as distance and availability of disposal sites. Costs increase rapidly as distances increase.
Excerpted from authors' abstract.

372 Hobson, P.N., and B.G. Shaw. The role of strict anaerobes in the digestion of organic material. In: G. Sykes and F. Skinner (Eds.) Microbial Aspects of Pollution. Academic Press, 1971. p. 103-121.

Laboratory digesters were fed daily, mixed by 80 rpm paddle-stirrers, and maintained at 35°C. When digestion was attempted by feeding undiluted pig manure of 10-15% total solids the process failed due to high volatile acids concentration. Feeding was resumed with 2% total solids slurry at 0.21 g VS/1/day and detention time of 37.5 days. The following reductions, in percent, were obtained: whole sample BOD5, 76; whole sample COD, 39; total solids, 38; suspended solids, 44. The loading was gradually increased to 2.2 g VS/1/day ("Probably not the maximum capacity of the digestion") and the detention time reduced to 14 days. The following reductions, in percent, were obtained: whole sample BOD_5, 56; whole sample COD, 31; total solids, 26; suspended solids, 24. No gas production figures are given.

373 ________, and B.G. Shaw. The anaerobic digestion of waste from an intensive pig unit. Water Res. 7(3):437-449. March 1973.

Use was made of heated (35°C), stirred, and daily fed laboratory digesters. It was found that digestion of undiluted feces-urine was impossible, but balanced digestion could be obtained in digesters originally seeded from a working domestic anaerobic digester or in digesters filled with water into which small amounts of waste were regularly added. The results from running two digesters for over 80 weeks at loading rates of 0.5 to 3.2 g VS/1/day at detention times of 37.5 to 14 days are given. Above a loading rate of about 2.6 g VS/1/day, at a detention time of 14 days, performance in terms of percentage reduction in solids, BOD and COD began to fall. Maximum BOD reduction of 80-90% was found at that loading rate. Volatile acids and ammonia remained below inhibitory levels. It was postulated that there was an upper limit of total solids of about 4.5% above which satisfactory performance cannot be expected.

374 ________, and B.G. Shaw. The bacterial population of piggery-waste anaerobic digesters. Water Res. 8(8):507-516. Aug. 1974.

A survey was made of the anaerobic and facultatively anaerobic bacteria present in piggery waste, digesting piggery waste and domestic anaerobic sludge used to start a piggery waste digester. An influence of the input waste was shown in that streptococci, the predominant facultatively anaerobic bacteria in the piggery waste, were the predominant bacteria in the digesting waste, and they replaced Entrobacter, predominant in the domestic sludge, when a piggery waste digestion had been established from this latter material. Cellulolytic or methanogenic bacteria could not be detected in the piggery waste but populations of these, and other hydrolytic bacteria, became established at different times during the build-up of digestion by gradual addition of piggery waste to water. The bacteria concerned in degradation of the waste constituents were all anaerobes. Production of methane from H_2/CO_2, formate and butyrate could be detected in mixed cultures from dilutions of digester contents, but the only methanogenic bacterium that could be isolated in pure culture was Methanobacterium formicicum, which uses H_2/CO_2 or formate only. Authors' abstract.

375 Hutchinson, T.H. Methane farming in Kenya. Compost Sci. 13(6):30-31. Nov./Dec. 1972.

In this short reprint from Mother Earth (July, 1962) Hutchinson describes the effect of digester effluent and compost on tropical crops. He does write that his firm, Tunnel Co. Ltd. (Tunnel Estate, Fort Ternan, Kenya) was manufacturing and marketing three different types of "methane plants" which "are designed to operate from (a)grass,straw, coffee pulp and other organic material mixed with manure, and (b) manure mixed with water to make it into a liquid sludge. The difference between them is that type (a) consists of a series of compartments which are filled and emptied in rotation, and which produces compost and liquid manure. and type (b) is one large compartment that is topped up daily with fresh manure. This displaces an equal quantity of digested sludge, and so the fermentation is continuous."

A 1962 catalog which we have bears a summary of the three digester designs:

"There are now three types of the Hutchinson Methane Plant. Briefly the Mark I [batch type] is designed to operate from all the normal farm wastes such as bedding, grass, straw, coffee pulp, etc. The Mark II and Mark III Plants [continuous type] both operate from dung and water only--no other organic matter being put through these Plants. The Mark I and Mark II Plants both consist of two separate units--the DIGESTER SILO where the gas is stored prior to being used. Each of these units is built in stone or brick on a concrete base by the farmer himself. The Mark III is a small self contained Plant that requires no building. On this Plant the GAS HOLDER and DIGESTER SILO are combined into one unit. [Capitalization in the original.]

376 Jewell, William J. Energy from agricultural waste - methane generation. New York Agricultural Experiment Station, Cornell, Agricultural Engineering Extension Bull 397. Jan. 1974. 13p.

A series of commonly asked questions and non-technical responses, a tabulation of the advantages and disadvantages of the process, a table of operational limitations (detention time, loading rate, pH, solids concentration, temperature, and so on), and a listing of livestock waste production rates and possible gas production from the wastes are given. The concluding advice is that "although the technology exists to enable an individual to adopt such a system, it is not in a readily utilizable form. If the energy crisis continues and this approach is clearly shown to be a feasible alternative to energy generation, it can be anticipated that private business will quickly develop reliable systems for various agricultural operations."

377 Johnson, Glenn E., L.M. Kumka, W.A. Decker, and A.J. Forney. The production of methane by the anaerobic decomposition of garbage and waste materials. 163d National Meeting ACS, Boston, Mass., April 10-14, 1972, Preprints, 16(4):70-78. [Rita D. Sylvester (compiler). List of Bureau of Mines Publications and Articles Jan. 1 to December 31, 1972, with subject and Author Index. U.S. Dept. Int., Bureau of Mines Special publication, 1973. p. 64, OP 72-72.]

378 Kamata, S., and K. Uchida. [Studies on livestock excreta disposal by methane fermentation. I. Base experiments on conditions of fermentation.] (Ja., en.) Nippon Vet. Zootech. Coll. Bull. 21:79-83. Nov. 1972. [CAIN]

379 ________, and K. Uchida. [Studies on livestock excreta disposal by methane fermentation. II. Optimum load and comparison between mesophilic and thermophilic fermentation.] (Ja., en.) Nippon. Vet. Zootech. Coll. Bull. 21:84-92. Nov. 1972. [CAIN]

380 ________, and K. Uchida. [Studies on livestock excreta disposal by methane fermentation. III. Optimum load and comparison between mosophilic and thermophilic fermentation by addition of enzyme.] (Ja., en.) Bull. Nipon. Vet. Zootech. Coll. 22:54-61. Nov. 1973. [CAIN]

381 ________, and K. Uchida. [Studies on livestock excreta disposal by methane fermentation. IV. Basic experiment on condition of methane fermentation digestive fluid disposal by activated sludge method.] (Ja., en.) Bull. Nippon. Vet. Zootech. Coll. 22:62-66. Nov. 1973. [CAIN]

382 Kiker, J.T. Anaerobic digestion. University of California Ag. Ext. Service Agric. Nat. Resour. Pam. Ser. PM 74-2, 6pp. 1974. [CAIN]

383 Kroeker, E.J., H.M. Lapp, D.D. Schulte, and A.B. Sparling. Cold weather energy recovery from anaerobic digestion of swine manure. Paper presented at

the 7th National Agricultural Waste Management Conference - Energy, Agriculture and Waste Management, April 16-18. 1975, Syracuse, New York. In press.

Theoretical and actual energy expenditures for winter operation of digesters are compared. The 3194 liter digesters at Manitoba's Glenlea Research Station were constructed of fiberglass, insulated with 1.5 in. urethane foam, maintained at 35°C, and the contents continuously mixed. Air temperatures outside the digesters were maintained at 7°C as the digesters were loaded at 1.3 and 2.7 g VS/1/day at detention times of 30 and 15 days respectively. The total energy consumption in the plant was found to be approximately twice the energy recoverd. The energy required to heat the incoming manure from 0°C, without a heat exchanger, and to maintain digester temperature was approximately equal to the energy recovery rate of the digesters. Energy requirements for the continuous mixed liquor agitation proved to be a significant component of total energy consumption in the plant. Theoretical heat-loss calculations showed a satisfactory fit to the results of actual operation.

384 Lane, J.B. The Anaerobic Digestion of Cattle Manure. M.Sc. Thesis, Univ. of Minn., 1971.

Lane conducted three batch digestion experiments with cattle manure and urine mixes, an experiment designed to assess the effects of application of digester effluent upon soil, and presented a design for a small geodesic dome digester.

In the first experiment 15% (by weight) urine was added to cattle manure and that quantity diluted to 10% total solids. In an unseeded, insulated laboratory digester, the pH fell from 6.8 to 5.2 within 12 days. No heat was produced by the digestion process.

The second batch experiment was designed to determine the effect of added nutrients on anaerobic digestion. To a diluted urine-manure slurry (15% urine to manure by weight, diluted with water to 12.5% total solids) was added 2% by weight Bactopeptone. In unseeded digesters held at 32°C the gas production of the experimental digester was 25% greater than the control and produced 40% more CH_4, total; yet, the concentration of CH_4 in the gas was consistently lower.

The gas production from digesters which contained aerobically pre-treated substrates suffered by comparison to controls in the third batch experiment. The methane content of the gas was less than 20%, and after falling pH values were raised by the addition of lime, gas production resumed at a slow rate with extremely low percentages of methane in the gas and high percentages of N_2.

385 Lapp, H.M., A.B. Sparling, D.D. Schulte, and L.C. Buchanan. Methane production from animal wastes. I. Fundamental considerations. Paper presented at the annual meeting of the Canadian Society of Agricultural Engineering, Laval University, Ste. Foy, Quebec, 4-8 Aug. 1974. Paper No. 74-213. 27p.

Factors affecting digestion, several methods of gas purification, and methods of gas use are reviewed. A pilot-plant under construction at the Glenlea Research Station capable of handling the wastes of 75 hogs was described and a schematic drawing of the installation presented.

386 ________, D.D. Schulte, and L.C. Buchanan. Methane gas production from animal wastes. Canada Department of Agriculture (Ottawa) publication 1528. 1974. 9p.

A brief description is given of a dual-stage digestion system operating at the Glenlea Research Station, University of Manitoba. Two fiberglass tanks 2.4 m dia. by 3 m height, equipped with mechanical paddle stirrers and internal hot water coils (35°C), hold 5.13 m^3 slurry which is fed at 1.6 g VS/1/day with 20 day detention. The digesters yield gas of 60-69% CH_4 but fall below expectations of 2 m^3 gas/hog day. The loading rate will be increased to 2.4 g VS/1/day. The digesters are stable and operating generally as expected.

387 __________, D.D. Schulte, L.C. Buchanan, A.B. Sparling, and E.J. Krocker. Production and utilization of methane from swine wastes in Canada. Paper presented at the 3rd International Symposium on Livestock Wastes, 21-24 April 1975, Urbana-Champaign, Illinois. In press.

Bench-scale digesters were operated at 32° and 52°C with respective loading rates of 2.4 and 4.0 g VS/1/day. Detention time was 10 and 15 days respectively. Volatile solids reduction ranged from 26 to 76% while gas production varied between 480 and 1050 liters per gram volatile solids added. The methane content of the digester gas ranged from 57 to 60 percent.
A pilot plant containing four 2850 liter digesters installed in an insulated and electrically serviced building has been constructed at the Faculty of Agriculture's Glenlea Research Station, University of Manitoba. Initial gas production from the pilot plant operation in 1973 was lower than that of the bench scale digesters. Total gas production in the first month of pilot studies ranged from 170 to 260 ml/gram volatile solids added.
Results of bench-scale, initial and recent winter operation of the pilot plant are discussed. Problems associated with purification, handling, and storage of methane together with experience gained in the operation of a one-half ton pick-up truck equipped to operate on methane are outlined. Excerpted from author's abstract.

388 ________, D.D. Schulte, E.J. Kroeker, A.B. Sparling, and B.H. Topnik. Start-up of pilot scale swine manure digesters for methane production. Paper presented at the 3rd International Symposium on Livestock Wastes, 21-24 April 1975, Urbana-Champaign, Illinois. In press.

During the start-up of four single-stage 3194 liter digesters, problems were encountered with falling gas production and high alkalinity and volatile acids and ammonia concentrations. The loading rate was reduced and feeding was eventually discontinued during a 47 day recovery period. Loading was resumed and gradually increased over a 37 day period of reacclimation, after which the digesters were operating at a loading rate of 1.3 g VS/1/day at a detention time of 30 days, and at a loading rate of 2.7 g VS/1/day with a detention time of 15 days.

The authors conclude that swine manure may be digested successfully at ammonia levels in excess of 3000mg/1 if the methane forming bacteria are acclimated for time periods exceeding those normally reported for animal manure digestion, but also suspect that cation antagonism (introduced in the brackish makeup water) may account for the abnormal tolerance to ammonia found in the study.

389 Laura, M.D., and M.A. Idnani. Increased production of biogas from cowdung by adding other agricultural waste materials. J. Sci. Food Agr. 22(4):164-167. April 1971.

It was found that the addition of nitrogenous materials, such as casein, urea or urine, increased the extent of decomposition of cowdung, resulting in higher gas production. The effect appears to be due to the maintenance of pH 7 during fermentation. With the addition of urea or $CaCO_3$, materials such as dry leaves and cane sugar have yielded higher proportions of methane in the gas mixtures and these additions also increased the rate of gas production by promoting anaerobic conditions in the medium. Addition of cellulose also increased the rate but the gas mixture obtained had a lower methane content. - Authors' abstract.

390 Lawrence, Alonzo Wm. Anaerobic biological waste treatment systems. In; Agricultural Wastes: Principles and Guidelines for Practical Solutions. Cornell University Conference on Agricultural Waste Management, Syracuse, New York, 10-12 Feb. 1971. Cornell University. p. 79-92.

Process fundamentals, applications, process design, and process operation and control are reviewed by reference to municipal slude digestion. A short review of agricultural applications from the literature, both anaerobic digesters and lagoons, concludes the paper.

391 Lorimor, J.C., and S.W. Melvin. Methane generation from livestock wastes. Iowa State University, Ames, Extension Service Publication Pm-593. July 1974.

In four pages the authors discuss the advantages and disadvantages of anaerobic digesters on farms as part of a waste treatment process, treat the basics of the anaerobic process (temperature, pH, ammonia concentration problems), present figures for tank sizes per 1000 pounds livestock weight at various detention times, and describe anticipated gas production. Some few paragraphs are taken in emphasizing the fact that the digester effluent needs further treatment or judicious land application.

392 Morris, G.R., W.J. Jewell, and G.L. Casler. Alternative animal wastes anaerobic fermentation designs and their costs. Paper presented at the 7th National Agricultural Waste Management Conference - Energy, Agriculture, and Waste Management, April 16-18, 1975, Syracuse, New York. In press.

393 Ngoddy, P.O., J.P. Harper, P.K. Collins, G.D. Wells, and F.A. Heidan. Closed System Waste Management for Livestock. Environmental Protection Agency Water Pollution Control Research Series 13040 DKP 06/71. 1971.

The results of studies of the anaerobic digestion of the liquid portion of a liquid-solids separation of cattle and swine waste are reported pages 77 to 87. Laboratory digesters, which were mixed and maintained at 35°C, were fed the liquid portion of swine wastes at 1.84, 2.6, and 5.4 g VS/1/day, and the supernatant of cattle wastes at 2.64, 4.8, and 9.8 g VS/1/day. The purported detention times were from 10 to 15 days, but the description of the study leads one to believe that those figures actually describe the duration of the experiments at the indicated loading rates of livestock wastes. Predicted detention times required for 50% COD removal for the wastes are, from lowest to highest loading rates: swine - 6.5, 15, and 7 days; cattle - 12, 14, and 12 days.

394 Parker, R., F. Humenik, R. Holmes, and M. Overcash. Methane production from swine waste with a mesophilic solar and thermophilic reactor. Paper No. 74-3033 presented at the Annual Meeting Am. Soc. Agr. Eng., Oklahoma State University, Stillwater, 23-26 June 1974.

Two quite dissimilar digesters are described. The first consists of a 1.22 meter cubed steel tank (1900 liters) which was surrounded by 15 cm of styrofoam insulation and solely heated by the provision of a plexiglass and glass top cover which was set at 20° from the horizontal, facing south. Into it was introduced, "three times per week ...50 gallons [190 liters] of swine waste having an average COD of 40,000 mg/1, TOC of 12,000 mg/1, and volatile solids of 20,000 mg/1." The contents were mixed 15 seconds every 15 minutes. The temperature varied from 24° to 35°C through the year. From 250 to 1700 ml gas were produced per gram volatile solids destroyed. At 29°C the digester yielded 1200 liters gas per day. The gas consisted of 60% CH_4 and 30% CO_2, as they report it. COD reduction was 25%.

The second digester had a capacity of 1140 liters, was heated by electric water heating elements to 54°C, mixed, and three times a week fed 114 liters of the same slurry as the first digester. Maximum gas production was 600 liters per day and ranged from 500 to 870 ml/g VS destroyed. When the temperature was raised to 60°C gas production and CH_4 content dropped sharply.

395 Po, Chung. Production of methane gas from manure. In: Proceedings International Biomass Energy Conference, 13-15 May 1973, Winnipeg. Biomass Energy Institute, Winnipeg. 1973. p. XVI-1 - XVI-16.

A two stage digester capable of accepting the wastes of 20 hogs is described The digesters are constructed of brick or block laid in an excavation and plastered with a waterproofing. The first stage is approximately 1.2 meters on a side and 1.8 meters deep, and the second stage approximately 1.5 m by 2.4 m and 1.8 meters deep. Wastes are gravity fed into the first stage and displaced into the second eventually being displaced into a holding pit. Both tanks have floating gasholders constructed of mild steel sheet and provision for mixing by hand or by the action of the moving gasholders. It is reported that 7500 digesters are operating in Taiwan.

396 ________. Small methane generator for waste disposal. Paper presented at the 3rd International Symposium on Livestock Wastes, 21-24 April, Urbana-Champaign, Illinois. In press.

Small, simple $300 methane generators have been developed in Taiwan. The generator consists of an excavated brick digester of 1.5 X 1.5 X

1.8 m and an inverted steel gasholder 1.8 X 1.8 X 0.9 m resting in the water seal. The digester is connected to the pigsty by a cement pipe through which the wastes and sewage of 10-15 hogs are fed daily, and the production of gas is continuous. The gas contains 63-67% CH_4, 27-33% CO_2 and 1.7% H_2S. The hydraulic retention time is estimated at 5-10 days. Under the subtropical conditions, the gas produced is about 3,000 liters a day.

Experiments are underway to find alternative construction materials, such as rubber bag, PVC-impregnated mud plate and fiber glass gas holder to lower the cost so that the digesters can be commercialized. Oxidation ditches are also built beside the digester for further disposal of swine wastes. excerpted from author's abstract

397 Prasad, C.R., K.K. Prasad, and A.K.N. Reddy. Biogas-Plants; Prospects, Problems, Tasks. Indian Institute of Science, Bangalore. Mimeo. 50p. 1974. [414]

398 Produktion af biogas fra svinegodning. [Production of biogas from swine manure.] Det Nye Dan Landbrug 5(4):14- . April 1974. [CAIN]

399 Robertson, A.M., J.J. Clark and S.H. Baxter. The treatment of pig waste in a two stage anaerobic/aerobic system. C.I.G.R. 2nd Section 8th International Congress of Agricultural Engineering. Flevohof, The Netherlands. 1974. [401]

400 ________, G.A. Burnett, Sheila Bousfield, P.N. Hobson, and R. Summers. Anaerobic digestion of piggery wastes. Paper presented at the 3rd International Symposium on Livestock Wastes, 21-24 April 1975. Urbana-Champaign, Illinois. In press.

A farm scale plant was designed to give a low maintenance, efficient continuous digester of defined performance. The plant consists of a 13600 litre digester with feed and overflow tanks, feed pump and gas holder. Temperature control (at 35°C) is provided by circulating the digester contents through an external heat exchanger heated by a digester-gas boiler or a stand-by oil fired boiler. After initial seeding with domestic digester sludge, loading of piggery wastes was gradually increased to 450 litre/day at approximately 4% TS and eventually a retention time of 10 days with waste containing higher solids concentrations should be achieved. During the first six months of running results showed that a stable digestio had been attained; reductions in the pollutional load of the whole unsettled waste were on average BOD 91% TS 49% VFA 92% COD 50% with ammonia generally unchanged.

Stirring by heat exchanger flow proved inadequate over long periods; an impermeable crust developed which reformed after breaking. Other methods of stirring are being investigated; at present a twin-disc, slow speed turbine is being tested for optimum speed and time of intermittent stirring.

Digester loading has been stopped with and without heating for days or weeks during over twelve months experimentation. Digestion has always returned to normal soon after loading restarts. Ingress of small amounts of air does not retard digestion but nitrogen appears in the gas. Leakage of large amounts of air eventually stopped digestion; oxygen appeared in the gas but before this nitrogen dilution had stopped gas combustion.
Authors' abstract

401 ________, G.A. Burnett, P.N. Hobson, Sheila Bousfield, and R. Summers. Bioengineering aspects of anaerobic digestion of piggery wastes. Photostatic copy, n.d. (ca. 1975), 16 p.

This paper could well be an alternate form of the paper presented at the International Symposium on Livestock Wastes, Urbana-Champaign, 1975. The performance of digesters scaled from an initial 15 liters, to 100 liters, to a field unit of 13,620 liters is described. The detention time of the intermediate digester was reduced from 20 days to 7 days "without seriously increasing levels of total solids, volatile fatty acids, ammonia, BOD_5 or COD in the effluent." The performance of the heated (35°C), mixed, and daily fed field unit was similar to that of the laboratory units, achieving reductions of total solids, BOD_5, and COD of 44.87%, 83.7%, and 53.1%, respectively, at 15 day detention time of waste introduced at 4.9% solids. The digester was insulated with 50 mm fiberglass (U-valve 0.67 $W/m^2°C$) and operated without the exchange of heat from the effluent to the influent. It was found that "at 30 days the gross energy produced exceeds the heat requirements of the digester above an ambient temperature of 7.2°C, whilst at a 20 day retention time gas production provides sufficient energy for all the heat requirements of the digester." The use of at least twice the amount of insulation was felt justified, and work continues at increasing solids concentrations and shorter detention times. A short calculation of the economics of the system is given.

402 Roll, John L. Odor Control and Anaerobic **Degradation** of Swine Manure Mixed with Digester Sludge. M.Sc. thesis, University of Illinois, Urbana-Champaign, 1973. [403]

403 ________, Donald L. Day, and John T. Pfeffer. Anaerobic degradation of swine manure mixed with municipal digester sludge. Paper No. 73-4521 presented at the 1973 Winter Meeting Am. Soc. Agr. Eng., Chicago, 11-14 Dec. 1973.

Non-lagooned municipal digester sludge was added to liquid swine manure in five ratios. Excellent anaerobic digestion was exhibited by the five digestion was exhibited by the five digesters, and an odor panel indicated that adding digester sludge to manure aided in odor control. -- Authors' summary.

404 Sagar, Budhi, and N.S. Grewal. Anaerobic digestion of animal wastes in small size plants in India. Paper presented at the 3rd International Symposium on Livestock Wastes, 21-24 April 1975, Urbana-Champaign, Illinois. In press.

Because livestock are more dispersed in India than the developed countries only small digestion plants are constructed (1.7-5.6 m^3 gas/day). The plants suffer from: (1) Reduction or cessation of gas production during the winter; (2) Slow rates of gas production under normal conditions, and (3) Safe disposal of effluent from the digester. Experiments were conducted to find an economic method of heating the digester in the winter, to accelerate gas production by stirring the contents of the digester, and use of drying beds for the disposal of effluent. The results are reported.

405 Savery, William C., and D.C. Cruzan. Methane recovery from chicken manure digestion. J. Wat. Poll. Cont. Fed. 44(12):2349-2354. Dec. 1972.

Five 8-9 day experiments were conducted using a 351. heated digester. The digester was batch loaded with 2.8 kg. fresh chicken manure. The unmixed, unseeded, heated (51°C) batch yielded 130 1 gas/kg wet manure, consisting of 69% CH_4. The second batch study differed in that 3.1 kg. fresh manure was digested at 29°C, giving 92 1. gas/kg wet manure at 50% CH_4.

The remaining three experiments were attempts to feed the heated (51°C) digester daily at detention times of 4,5, and 6.7 days. No figures are given from which loading rates might be calculated. Volatile acids concentrations and pH, among other parameters, were not monitored. All digesters failed.

406 Schmid, L.A., R.I. Lipper, J.K. Koelliker, C.A. Cate, and J.V. Daber. Swine waste digestion enhancement with nutrient separation. Paper presented at the 3rd International Symposium on Livestock Wastes, 21-24 April 1975, Urbana-Champaign, Illinois. In press.

Total confined feeding of livestock results in the capture of all wastes, urine and feces, resulting in a very high nitrogen waste. Anaerobic digestion and biological stabilization has been hampered in the past due to the toxicity caused by the ammonium buildup. This has resulted in the need to add dilution water, increasing the waste volume and consequently the disposal costs.

This project was designed to explore a novel method of waste treatment that would reduce the toxic ammonium, increase waste stabilization and methane gas production, eliminate the need for dilution water, reduce the volume for ultimate disposal to the land and produce a clean liquid fertilizer in the form of ammonium phosphate.

The test facility consists of an eight foot cubed anaerobic digester serving 120 head of swine with gutter collection. Sealed gas blowers collect the gas from the digester and pass it through a phosphoric acid column for removal of ammonia and conversion to ammonium phosphate. It then passes through a potassium hydroxide column for removal of carbon dioxide. The cleaned methane gas is recycled to the digester for further mixing and gas stripping with the excess clean gas burned and used for digester heating. Carbon dioxide must be removed to maintain the digester equilibrium pH near 8. Because of digester detention times of 15 to 20 days ammonia can be reduced at these pH values. Gas recirculation is at the rate of approximately 50 cfm. per 1000 cu. ft. of digester volume.

Design and operational recommendations, with seven months of field data are presented along with the proposed economics of a large scale system.

Authors' abstract.

407 Shaw, B.G. A Practical And Bacteriological Study Of The Anaerobic Digestion Of Waste From An Intensive Pig Unit. PhD thesis, University of Aberdeen. 1971. [Index To Thesis Accepted For Higher Degrees By The Universities of Great Britain And Ireland And The Council For National Academic Awards V. XXI, 1970-71]

408 Singh, Ram Bux. Some Experiments With Bio-Gas. Gobar-Gas Research Station, Ajitmal, Etawah (U.P.) India. 1971. 30p.

This booklet appears to consist of four papers which were consolidated without editing, leading to excessive repetition of statements concerning the advantages of gas production from manure viz. reduction of fly breeding potential, cleanliness of biogas compared to burning dried cow dung, and the preservation of the fertilizing value of the waste. Designs for above and below-ground, heated and unheated, insulated and uninsulated, batch and continuous digesters are given, without comment as to their proven performance. An appendix detailing seasonal atmospheric and soil temperatures and gas production is included.

409 ________. Bio-Gas Plant: Generating Methane From Organic Wastes. Gobar Gas Research Station, Ajitmal, Etawah (U.P.). India. 1971. 70p.

A short review of Indian experience with digesters is given, along with an introduction to the basics of the process and explanation of the parameters which are controlled. Five standard designs have been developed which yield from 2.8 to 71 m^3 gas per day, having the following characteristics in common: the feed consists of equal parts of waste and water (giving a slurry of 7-9% solids) which has a retention time of a month or more. Nearly 60 ml gas are produced per gram of manure at an ambient temperature of 24°C. Designs of several digesters, both above and below ground, unheated or heated by internal hot water coils, single and dual stage, are given without comment concerning their performance in operational tests.

410 Slane, Thomas C., and Robert L. Christensen, Cleve E. Willis, and Robert G. Light. An economic analysis of methane generation feasibility on commercial egg farms. Paper presented at the 3rd International Symposium on Livestock Wastes, 21-24 April 1975, Urbana-Champaign, Illinois. In Press.

The study focused on determination of net costs associated with adoption of a methane generation system by commercial egg production units of 20,000, 40,000 and 80,000 birds in a cage housing system. The methane generated was used to fuel an engine-generator(s). The engine-generator was assumed to run continuously and provide supplementary electrical power.

The fixed and variable costs of the system were estimated for the three benchmark operations by identifying the fixed and variable factors associate with the system, estimating input requirements, and budgeting costs for each unit. In order of increasing flock size, these annual costs were \$6,475, \$10,020 and \$16,930. However, since the methane is used to generate electricity for the farms' lighting and ventilation requirements, a credit or costs reduction accrues. Based on a commercial rate of 2.3 cents per kilowatt-hour, the cost reductions were estimated as \$1,575, \$3,155 and \$6,310 annually for the 20,000 40,000 and 80,000 bird flocks respectively. The net annual costs of the system ranged from about \$5,000 for the 20,000 bird flock to \$10,600 for the 80,000 bird flock. The net cost per dozen eggs, therefore, ranged from 1.3 cents on the smallest flock to 0.7 cents on the largest flock considered. Economies of scale were found to exist.

The results indicate that the system studied was not economically feasible at present. This conclusion is directly related to the assumed cost of commercial power. For the smallest flock size a commercial electrical cost of nearly 10 cents per kilowatt-hour would be a "breakeven" while for the largest size the "breakeven" is about 6 cents per kilowatt-hour. It is conceivable that commercial electricity prices might reach such levels within the next decade.

Condensed from the authors' abstract

411 Smith, R. J. The anaerobic digestion of livestock wastes and the prospects for methane production. Paper presented at the Midwest Livestock Waste Management Conference, 27-28 Nov. 1973. 30p.

The first third of this paper comprises a review of the chemical and biological fundamentals of the process. The middle section of the paper tabulates the operating parameters and performance (loading, temperature, detention, volatile solids reduction, COD reduction, total nitrogen, volatile acids concentration, alkalinity, pH, gas production, and CH_4 fraction) of digesters in the experiments of Cross and Duran, Gramms et al., Hart, Jeffrey et al., Loehr and Agnew, Meenaghen et al., Ngoddy et al., Schmid and Lipper, and Taiganides. In the concluding section are presented tentative guidelines for maximum loading rates of heated mixed anaerobic digesters, and a most refreshingly detailed sample design calculation of the energy and dollar costs of construction and operation of a mixed and heated digester which would accept the waste of 10,000 beef animals.

412 Srinivasan, H.R. Gobar-gas plants promises and problems. Indian Farming 23(11): 29, 31, 33. Feb. 1974.

By obtaining cooking gas from manure through anaerobic digestion, rather than directly burning the manure, the health of women (whose lot is to cook over the burning dung) is improved at the same time as the fertilizing qualities of the manure are retained. The process might also be used to dispose of human wastes in villages, to which end the Khadi and Village Industries Commission has constructed several community latrines. The Commission has also installed over 6,500 gas plants and plans to build tens of thousands more in coming years.

413 Thaer, R., R. Ahlers, and K. Grabbe. Untersuchungen zum prozessverlauf und stoffumsatz bei der fermentation von rinderflussigmist bei erhohten temperaturen. [Investigations on the technological equipment, procedure and turnover of organic matter with hot fermentation of liquid cattle manure.] (Ge., en.) Landbauforsch. Volkenrode 23[?](2):117-126. Dec. 1973. [CAIN]

414 Tietjen, C. From biodung to biogas - historical review of European experience. Paper presented at the 7th National Agricultural Waste Management Conference - Energy, Agriculture, and Waste Management, April 16-18, 1975, Syracuse, New York. In press.

Tietjen briefly describes nine post-WW II German digester designs: those of Strell, Götz, and Liebmann at München; Reinhold and Noack at Darmstadt; Schmidt and Eggersglüss at Allerhop; the "Hohenheim"; Gärtner and Ikonomoff, System "Berlin"; Pötsch at Völkenrode; Kertscher and Poch at Jena; Rosegger and Neuling at Dresden and Bornim; Schmallfuss and Fiedler at Halle. He recounts how "biogas" plants were rapidly converted (by omission of the heating system) to "biodung" storage tanks because of falling fuel prices and resultant diseconomies of the process, reaching a ratio of four bihudung plants to one biogas plant in Germany by 1956.

415 Wong-Chong, G.M. Dry anaerobic digestion. Paper presented at the 7th National Agricultural Waste Management Conference - Energy, Agriculture, and Waste Management, April 16-18, Syracuse, New York. In press.

416 Yokoyama, Morio. Production of methane gas from chicken excrement. Japan. Kokai 74 62,502 (Cl. 17 B7, 17 B01, 92(7)AO), June 18, 1974, Appl. 72 104, 905, Oct. 20, 1972. 3 pp. [CA 81 158466p]

Excrement, especially from chicken, is mixed with garbage, preferably at a ratio of 3:1, in an airtight tank and the mixture is agitated for gas formatin. The gas formed is successively passed through cold water, alkali solution, acidic solution, and grain water to recover relatively pure CH_4. The remaining mixture is dewatered, dried, and incinerated. The polluted water resulting from the dewatering of the remaining mixtures is treated by the activated sludge method.

APPENDIX I ANAEROBIC DIGESTION OF FARM-GENERATED CELLULOSIC MATERIALS

The contents of this section can only be taken as being indicative of works published concerning the anaerobic digestion of farm-generated cellulosic materials (straw, cornstalks, sawdust, and so on). A large and growing body of literature deals with the digestion of pure cellulose and other cellulosic materials; bagasse, canning wastes, paper mill waste and urban refuse are examples. This appendix resulted from the search of the literature relating to the anaerobic digestion of manures and bedding, and I feel that it merits inclusion because of the coincidental source of both livestock wastes and crop residues. Because of the ease of use of the Chemical Abstracts decennial indexes, and because a significant amount of research was conducted prior to 1946, several abstracts from Chemical Abstracts which appeared before that arbitrary early limit are included.

I 1 Boshoff, W.H. Methane gas production by batch and continuous fermentation methods. Trop. Sci. 5(3):155-165. 1963.

The paper considers methods of producing methane gas on many tropical farms where, in the absence of livestock dung is not available as the major material for fermentation; gas production from the three methods of fermentation considered suitable for use in the tropics proved to be predictable. Thus for ambient temperatures of between 20-22°C a mean gross gas production of the order of 0.26, 0.35, and 0.83 digester volumes per day could be expected respectively in 60-day batch fermentations in which dung was used as starter, 40-day batch fermentations in which residues of a previous fermentation were used as starter, and continuous fermentation.

Although the predicted performances were based on data obtained when elephant grass was the chief feeding material, indications are that many materials commonly found in the tropics, notably sweet potato tops, papyrus, sisal waste and plantain peelings, could equally successfully be used as feeding material.

Only in batch fermentations, when using dung as starter material, could a marked increase in gas production be expected with an increase of digester temperature above 20-22°C, which would involve artificial heating of digesters in the tropics. The alternative method of batch fermentation using residues as starter and operated under ambient temperature conditions may therefore be preferred. A continuous method of fermentation would, however, appear to be by far the most efficient method of gas production. It would require the smallest digester volume for a specific daily gas production, as compared to either of the batch methods. The weight of organic matter used in such an installation would, however, be as much as 35 per cent higher, and facilities for agitation of the fermenting material would be essential.

Author's Summary.

I 2 ________. The application of methane fermentation in the tropics. World Crops. 15:433-435. Dec. 1963.

The advantages of continuous digestion outweigh the disadvantages, and an unheated digester of such a design to operate in the tropics under ambient temperatures of 20°-23°C is suggested as practical. The continuous digester would produce 0.83 digester volumes of gas per day, compared to 0.26 volumes from batch digestion and 0.35 volumes by batch digestion with recycled effluent as "starter", thereby decreasing necessary tank size and cost. The labor of loading a continuous digester would be evenly distributed over time, whereas the other methods require periodic intervals of intense activity. Because the batch process more thoroughly converts the introduced waste to gas than the continuous process, less land would be needed to grow the material with which to feed the digester and less of that material transported to the installation; calculated as 0.6 hectares and 0.8 hectares to supply elephant grass which would produce 1.6 X 10^5 kJ/day by batch and continuous processes, respectively.

I 3 Decau, Jean. [Comparative variations of free amino acids in the course of aerobic and anaerobic fermentations of wheat straw.] Compt. Rend. 254:4530-4532. 1962. [CA 57 6444c]

In aerobic fermentation the content of free amino acids diminishes rapidly from the beginning. In anaerobic fermentation, if the content of free amino acids decreases at first, it increases again; this last variation is due to the increase in content of alanine of the anaerobic medium. C.W. Ackerson

I 4 Desart, M., and H. Scuflaire. Chamber for methane fermentation. Belg. patent 504,170. Oct. 16, 1951. [CA 48 4177a]

The construction of a chamber from concrete or metal for CH_4 fermentation from cellulosic substances is described. J. Van I.

I 5 Dopter, P., and H. Beerens. Étude expérimentale sur la fermentation méthanique de la paille. [Experimental study of methanic fermentation of straw.] Acad. d'Agr. de France. Compt. Rend. 38:745-750. Dec. 3/17, 1952. [BA 17 42982, CBS 24]

The amount of liquid manure obtainable was a limiting factor in methanic fermentation of wheat straw. An equal volume of 0.2% aqueous solution of Na formate could be substituted for 90% of the normal requirements of liquid manure. This shortened the preliminary stages of cellulosic fermentation when no methane was produced and slightly increased the subsequent yield of methane.

I 6 ________, and H. Beerens. Utilisation de la "bourre de tréfle" comme source de méthane par voie biologique. Acad. d'Agr. de France. Compt. Rend. 39(11):557-562. June 17/July 1, 1953. [BA 18 13690]

I 7 Ducellier, G., and M. Isman. [A specifically agricultural fuel: manure gas.] (Fr.) Progrès Agr. et Vit. 124:105-109. 1945. Chimie & Industrie 57:259. 1947. [CA 42 2086a]

By means of an appropriate succession of thermogenic, neutralizing, and CH_4-producing fermentations, 1 ton dry straw can produce up to 300 cu.m. of combustible gas contg. 60-70% CH_4 and 30-40% CO_2, and having a calorific value of 6000 cal. per cu.m. It has the advantage of being non-toxic, as it contains no CO, and of being only slightly explosive at ordinary pressure. Its advantages on the farm are briefly discussed.

A. Papineau-Couture

I 8 Goswami, K.P. & Choudhury, S. Farm wastes can yield fuel-gas and manure. Indian Farming 17(1):18-19. April 1967. [BA 32 106016]

Plant wastes used for manufacture of methane and composts.

I 9 Laurenty, François. Apparatus for continuous fermentation of pulverized vegetable matter. U.S. patent 2,655,434. Oct. 13, 1953. [CA 48 316a]

In the app. described, a mixing device proportions and stirs the vegetable material and liquid manure derived therefrom in an anaerobic fermentation vat. A fertilizer residue and a combustible gas are thereby produced. M.L.H.

I 10 Leroux, Henri. [Gas from waste materials] (Fr) J. Usine Gaz 67:26-28. 1943. [CA 40 6787[3]]

Various efforts to produce fuel gas from waste materials by fermentation are reviewed. Although the thermal yield appears to be attractive (60%) in the formation of CH_4 + CO_2 from cellulose the process requires very large equipment owing to the slowness of the reaction. From 1 ton of waste, a daily production of 1 cm. m. of gas (7700 cal.) is obtained for 50 days. B.J.C. von der Hoeven

I 11 Lucas - Girardville, Paul N. Methane. French patent 888,925. Dec. 27, 1943. [CA 48 348e]

CH_4 is manufd. by biol. fermentation of cellulosic vegetable materials. The fermentation is caused by the activity of Bacillus methanigénes, found in dung, dirty water, mud, fermented compost liquor, etc. K_2CO_3, $(NH_4)_2CO_3$, and $(NH_4)_2HPO_4$ are added to the fermentation mass. Straw, poplar sawdust, ferns,peat, paper-mill waste, etc., may be used. P.M.

I 12 ______. Methane. French patent 972,836. Feb. 5, 1951. [CA 46 9287e]

Cellulosic material, such as wood, twigs, leaves, and plants, are fermented in aq. media in app. similar to sewage-digesters. Wood, first reduced to small particles, or sawdust, or waste waters from paper mills contg. some cellulose is used. Undigested residues are dried and compressed to use as fuel. The CH_4 is added to town gas to raise its calorific value. G.D. Gillies

I 13 Milquet, F. [Patented installations for the production of methane gas and natural manures.] (Fr.) Rev. Agric. Bruxelles 4:1621-1633. 1951. [CBS 32]

Current process are reviewed and a new technique is described which maintains economically a constant temperature of 40°C in the tanks by complete isolation in winter as in summer and periodic reheating of the mass. The tanks were buried underground and had double metal walls with low-density cellular conrete between them. The covers were of thick cork, permanently fixed, and coated with an impermeable substance. Reheating was necessary only once during fermentation, whereas with tanks above ground it had to be carried out more often and more vigorously. Straw was the raw material and the products were highly profitable quantities of methane and artificial manure.

I 14 Mikkelsen, J.P. Alternative energikilder. 4. Omfremstilling af metangas frahalm og slam. [Alternative energy sources. 4. Production of methane gas from straw and sludge.] Ugeskr. Agron. 3(22):443-444. May 30, 1974. [CAIN]

I 15 Nath, B. Viswa. Report of the imperial agricultural chemist. Imp. Agr. Research Inst., New Delhi, Sci. Repts. Yr. Ending June 30, 1940, 81-93 (Pub. 1941). [CA 36 603[2]]

Decompn. of straw by anaerobic fermentation proceeded most rapidly at temps. of 38-50° and 85% of the C was converted into gas. The compn. of the gas and its calorific value were not greatly affected by differences in the compn. of the org. waste.

I 16 Nelson, G.H., Robert P. Straka, and Max Levine. Decomposition and gas production of cornstalks under anaerobic conditions at 28° to 30°. Iowa State Coll. J. Sci. 13:161-180. 1939. [CA 34 214[7]]

Chopped cornstalks and cornstalk flour were: (1) subjected to an active methane-producing seed and (2) sealed in tap water without inoculation. Sometimes daily but usually at the end of 3, of 5, of 10, of 20 and of 30 days analyses were made for: total solids, volatile solids, pentosans, cellulose, and lignin. The data are reported in 11 tables and 7 series of graphs. The flour fermented 43% more rapidly (gas production). The gas was 34-5% CO_2 and 55 - 9% methane. At the 3-, 20- and 30-day periods for the flour, loss of cellulose and pentosans accounted for 95% of the gas: for the chopped stalks only 75%. For the 5- and 10-day periods more cellulose and pentosans were decompd. than could be accounted for by the gas produced. The loss of cellulose and pentosan was greater in the flour and the loss of lignin greater in the chopped stalks. Incubation of corn stalks gives little promise of usefulness in pulp prepn. but fermentation with an active seed does give some promise.

F.L. Brown

I 17 ________, Robert P. Straka, and Max Levine. Effect of temperature of digestion, chemical composition and size of particles on production of fuel gas from farm wastes. J. Agr. Res. 58:273-287. 1939. [CA 33 4766[8]]

The rate and quantity of gas produced by the anaerobic decompn. of chopped cornstalks, chopped wheat straw, ground wheat straw, cornstalk flour, filter paper, seed flax straw, artichoke-top flour, cook liquor from wallboard manuf. and alkali lignin were detd. at 28-30° and 50-55°. The effect of temp. on the rate of anaerobic decompn. was different for the various fibrous farm wastes tested. The chem. compn. of the materials was almost identical, and compn. therefore cannot be used as a basis for predicting the probable influence of temp. on the rate of digestion is more marked with coarse materials, such as chopped corn stalks and chopped wheat straw, than with finer materials such as cornstalk flour and ground wheat straw. The lignin, cellulose and pentosans in fibrous wastes are not a dependable basis for evaluation of ease of anaerobic decompn. or of the rate and quantity of gas produced per unit wt. of material. Phys. factors also play an important role in the susceptibility of fibrous material to anaerobic microbial decompn. The rate and quantity of gas obtainable from a fibrous farm waste by this type of decompn. can only be detd. at present by a fermentation test under controlled conditions.

W.H. Ross

I 18 ________, R.P. Straka, and Max Levine. Anaerobic decomposition and gasification of cornstalks by thermophiles. Iowa State Coll. J. Sci. 14:233-251. 1940. [CA 34 6759[6]]

The thermophilic seed was developed from packing-house waste. The gas produced from cornstalks was 34-8% CO_2, 55-9% CH_4 and 1.3-1.5% H_2. Cornstalk flour (200 mesh) produced 43% more gas than chopped stalks (1/4-in. mesh) in a 10-day period. For the flour, cellulose and pentosan decomposition accounted for 98% of the gas produced in 3 days, 93% in 5 days and 87% in 10 days; for the chopped stalks the percentages were 83, 31 and 70. In 10 days, 1 g. of volatile solid in flour produced 508 cc. of gas; in chopped stalks, 355 cc. Only a small fraction of any of the major constituents was decomposed. The present results offer little promise that pulp can be prepd. by this process. The CH_4 and CO_2 might be useful. F.E. Brown

I 19 Procopio, M. [Methane from agricultural residues.] Chim. Ind. Agr. Biol. 16:470-472. 1940. [CA 35 4576[8]]

The production of CH_4 by microbiological transformation of agricultural residues is discussed. G.A. Bravo

Romashkevich, I.F. and G.N. Karelina. Methane and organic fertilizers from wood waste and manure fermentations. Mikrobiologiya 30(1):146-151. Jan/Feb 1961. [CA 55 19101h]

Fermentation of sawdust of foliate trees by mesophyllic microflora is feasible, producing CH_4; the yield of gas is 500 cu. m./ton, which surpasses that from manure and other agricultural wastes. Preliminary acid hydrolysis is unnecessary. At 5% org. matter, sawdust fermentation proceeds normally and with good yield, but 10% initial concn. of org. matter results in poor performance. Fermentation of common manure, that of sawdust and manure, or that of sawdust alone yields essentially the same gases. Fir sawdust does not ferment, but it does not stop manure or ash sawdust from fermenting if mixed with these. Fermented sawdust behaves like a fertilizer; it is beneficial to plants and crops. Nonfermented sawdust does not. Lupine N content is increased by both fermented and nonfermented sawdusts. P.A. Parent

I 21 Ruhemann, E. Production and uses of methane gas from waste vegetation. "The Times," Rev. of Ind. 2(12):47. 1948; Fuel Abstracts [N.S.] 3(5):70. 1948. [CA 43 5925c]

A comparatively simple process, resembling the production of CH_4 from sewage by fermentation, is described for treating the great abundance of herbaceous vegetation which is no economic value and may even be a charge on the economy of the country. Research directed to finding the best conditions for the production of methane from cellulose has shown that side-reactions lead to the production of certain fatty acids and alcs.; it appears that, given the right conditions, a very large amount of reasonably related compds. can be produced by bacterial action from cellulose. R.D.H.

I 22 Straka, Robert P. and G.H. Nelson. Effect of metal containers on the anaerobic fermentation of cornstalk flour by thermophiles. J. Agr. Research 64:19-31. 1942. [CA 36 1729[4]]

A study was made of the effect of metal containers, as compared with glass, on the continuous thermophilic anaerobic fermentation of cornstalk flour by repeated use of a CH_4-producing seed prepd. from sewage sludge. A stainless steel container was approx. as satisfactory as the glass container. Results obtained with a sheet-Fe container were erratic and not so satisfactory as those obtained with the stainless steel. Galvanized-Fe and Cu containers were unsatisfactory. W.H. Ross.

I 23 ________, G.H. Nelson, and Max Levine. Anaerobic decomposition of wheat straw by thermophiles and the quantity of gas produced. J. Agr. Res. 64:129-144. 1942. [CA 36 2409[a]]

Wheat straw flour (I) and chopped wheat straw (II) were fermented for 20 days at 50-55°. Percentage decomposition of cellulose and pentosans was high in the fermentation of I, and little difference in the percentage decompn. of these constituents was noted. Appreciable breakdown of lignin was observed during the later stages of the fermentation. The decompn. of cellulose and pentosans was much smaller in II than in I and only slight decompn. of lignin was noted throughout this fermentation. In both fermentations the formation of lignonitrogenous complexes was indicated. Approx. the same vols. of gas were obtained from I and II, although considerably greater quantities of the constituents of I were broken down during fermentation. The quantity of gas produced per unit wt. of raw material was less for II than was previously noted for cornstalks. Possibilities for the utilization of this type of anaerobic fermentation in the manuf. of paper pulp from wheat straw are not considered to be promising.

I 24 Tietjen, C. [The utilization of straw for Bihudung production.] (Ge) Landbau-Forsch. (Völkenrode) 5:86-87. 1955; Soils and Fertilizers 19, Abstr. No. 961 (1956). [CA 52 16724[b]]

Surplus straw unwanted for farmyard-manure prepn. is best utilized for the production of manure gas. In the German Bihugas process, anaerobic fermentation of wheat straw, alone or mixed with beet leaves, at 31° for 22-36 days produces about 15 cu. m. gas of 44-6% CO_2 content/100 kg. material. The decompn. product supplies an org. manure of favorable C/N ratio, generally <20:1. K.L.C.

I 25 ________ Bihudung aus Abwasserschlamm und Stroh. Landbauforschg. Völkenrode 6:75. 1956. [414]

APPENDIX II FERTILIZING QUALITIES OF DIGESTER EFFLUENT

The papers listed in this section pertain solely to the fertilizing qualities of effluent from digesters which were fed farm wastes. Undoubtedly, countless numbers of the papers in the main body of this bibliography describe the use of the effluent as fertilizer, judging the unseen by the papers which have been abstracted.

II 1 [Effectiveness of fertilizer from manure-gas installations.] (Fr.) Potasse 27:88. 1953. [CBS 21]

A summary is given of an article in Mitt. D.L.G. Jan. 1953 comparing yields of hay and potatoes with either K or NPK combined with farmyard manure, manure-gas residues or without organic fertilizer. The residue was applied at five times the rate of farmyard manure. It produced higher yields and higher increase in available soil P, particularly on plots receiving K instead of NPK. Residual action was similar with both organic forms.

II 2 Hutchinson, T.H. Methane farming in Kenya. Compost Sci. 13(6):30-31. Nov./Dec. 1972.

In this article, which is written in a popular vein, Hutchinson reports that the application of compost and digester effluent to coffee plants increased the crop yield over that which was previously obtained without the use of fertilizers.

II 3 Kuzelewski, Leszek, and Andrzej Pentkowski. [Fertilizing properties of farm manure submitted to methane fermentation, according to pot tests.] (Pol., ru., en.) Roczniki Nauk Rolniczych Ser. A. 82:715-737. 1962. [CA 57 8948 g, CBS 3]

In order to compare the fertilizing properties of the ordinary farm manure stored and fermented in dung hills with those of the manure submitted to CH_4 fermentation. pot tests with oats and potatoes were carried out. Investigation showed that: N losses taking place during CH_4 fermentation are much smaller than those from manure fermented in dung-hills. Because of different fermentation processes, the losses of solid matter in the CH_4 fermentation were greater than in manure fermented and stored in dung-hills. Although the manure submitted to CH_4 fermentation contained more N, its effect on crops was almost identical with the effect of ordinary manure. Expts. have shown that it is not necessary to cover with soil the manure submitted to the CH_4 fermentation after spreading it. Whether it was covered with soil or not, there was no difference in crop yield. Manure fermentating in O-free atm. may contain products harmful to plants, but they oxidize quickly on exposure to the atm. 53 references. T.M. Barzykowski.

II 4 ________, and Andrzej Pentkowski. [Effect of farmyard manure after methane fermentation in the light of field experiments.] (Pol., en.) Roczniki Nauk Rolniczych Ser. A 85(2):261-275. 1961. [CA 57 11595c, BA 26 70929]

Yard manure after CH_4 fermentation was compared with manure kept in a manure pit with respect to compn. and the effect on the crop, in both pot and field expts. CH_4 fermentation reduced N losses of fresh manure and made for more easily assimilable N compds. However, the first year and after-effects on crops of both types of manure were the same. No differences were noted for fermented manure due to ploughing over as compared to mere spreading on the soil. Alina S. Szczesniak.

II 5 Mehlich, A. A note on the effects of methane plant residue on soil fertility and nutrient content of coffee. Kenya Coffee 30 (359):495-496. Nov. 1965. [BA 30 36225]

Discussion of article by T.H. Hutchinson

II 6 Sauerlandt, W. Über die Wirkung des Bihudunges in Feldversuchen. Z. Mitt. DLG 68:31. 1953. [140]

II 7 _______ and C. Tietjen. Humuswirtschaft Des Ackerbaues. DLG-Verlag, Frankfurt (Main), 1970. "Flüssigdung", p. 204-219.

II 8 Scheffer, F., E. Welte, and G. Kemmler. Über Veränderungen in der stofflichen Zusammensetzung des Stallmistes bei der biologischen Gaserzeugung. Landwirtsch. Forschg. 4. Sonderheft 1953. [414]

II 9 Schmalfuss, K. Fragen der organischen Düngung. Deutsche Akademie d. Landwirtschaftswiss., Berlin, Sitzungsber. VII,3, 24p. 1957. [414]

II 10 Sen, A.; N.B. Paul; and R.B. Rewari. Effect of different phosphates on the manurial value of aerobically fermented cowdung in the production of combustible gas. Proc. Nat. Acad. Sci, India 25A: 360-368. 1956. [CBS 9]

N content of cowdung was increased by anaerobic fermentation (for combustible gas production), though to a lesser extent if phosphates were added. Rates of nitrification of the fermented manure in soil were low and were not improved by P additions; the manure consequently induced little response in rice, but it improved pea yields considerably.

II 11 Tietjen, Cord. Plant response to manure nutrients and processing of organic wastes. In: Management of Farm Animal Wastes; Proceedings National Symposium on Animal Waste Management, May 5,6, and 7, 1966, Michigan State University. American Society of Agricultural Engineers pub. no. SP-0366. p. 136-140.

Tietjen briefly describes the fertilizing qualities of stacked manure, liquid manures containing varied amounts of straw bedding, and digester effluent to synthetic fertilizers. The liquid manures retain more nutrients than the open-stored manure, and the digester effluent is favored by a narrowed C/N ratio.

II 12 _______ Anwendung von Flussigmist im Ackerbau. Landw. Forsch. 25/II. Sonderheft, 25. 1970. [414]

II 13 Veronesi, G. [Methane & fertilization.] (It) Riforma Agr. 3(8/9):15-16. Aug./Sept. 1955. [BA 20 30008]

APPENDIX III SEARCH METHODOLOGY AND LIMITATIONS

A full list of the categories and terms searched in Chemical Abstracts, the Bibliography of Agriculture, and Water Pollution Abstracts are presented herein and are indicative of the terms searched and the method of search in the remainder of the sources. The exclusion of a likely term is caused either by its absence in the bibliography searched (Chemical Abstracts has no "manure") or its irrelevane in context (picture the multiple meanings of "digestion").

Bibliography of Agriculture; 1946-1969

Manure gas
Methane

Bibliography of Agriculture computer search, CAIN; 1970-1975.

CAIN retrieves by words in titles only, yet our search of more than a score of terms should have reasonably covered its system. The printout was fraught with errors. Do not place full trust in the veracity of its products.

Chemical Abstracts; 1946-1974

Corn	cobs	Gas (Fuel)	corn
	combustion		fermentation
	fuel		manure
	gas		straw
	stalks	Methane	corncobs and stalks
Fermentation			fermentation
	cornstalks and cobs		formation
	manure		manufacture
	methane		manure
	straw		straw
Fertilizer, manure		Straw	fermentation
	fermentation		fuel
	fuel		gas
	gas		methane
	methane	Wastes	agricultural

Both the annual and cummulative (decennial and quinquennial) indexes were consulted for nearly the entire period. A number of entries, interestingly, were found by one approach and not by the other. I cannot but think that I missed perhaps five percent of the pertinent abstracts in this convoluted abstracting service.

Water Pollution Abstracts; 1964-1972

Cattle	Manure
Cowshed	Piggeries
Farm waste	Poultry
Livestock	

Comprehensive Dissertation Index 1861-1972

Civil, Industrial, and Chemical Engineering, Agriculture, Microbiology and Bacteriology, and the 1973 Engineering supplement were searched.

Commonwealth Bureau of Soils Annotated Bibliography No. 874, Manure Gas. 1965.

London Science Museum Science Library Bibliographical Series No. 794, Some Post-War References to "Bio-Gas." 1968.

J.B. McQuilty and E.M. Barber. An Annotated Bibliography of Farm Animal Wastes. Water Pollution Control Directorate, Environmental Protection Service, Canada, Report No. EPS 3-WP-72-1. Dec. 1972.

J. Ronald Miner and John R. Jordan. Bilbiography of Livestock Waste Management. Midwest Plan Service, Iowa State University, Ames. June 1972.

J. Ronald Miner et al. Bibliography of Livestock Waste Management. U.S. Environmental Protection Agency Office of Research and Monitoring. EPA-R2-72-101. Dec. 1972.

Ralph Ramsey et al. Livestock and the Enviornment: A Bibliography with Abstracts. U.S. Environmental Protection Agency Office of Research and Development.
Vol. I EPA-660/2-74-024 April 1974
Vol. II EPA-660/2-75-003 April 1975

J. Water Pollution Control Federation annual literature review; 1964-1974.

Anaerobic processes and agricultural waste.

Abstracts of Papers International Symposium on Livestock Wastes at the University of Illinois, Urbana-Champaign. April 21-24, 1975.

Seventh National Agricultural Waste Management Conference - Energy, Agriculture and Waste Management. April 16-18 1975. Syracuse, New York. Pre-program flyer.

Bibliographic Index; 1946-1973.

Dokumentation Landtechnik, Braunschweig - Völkenrode, bibliography Biogas. 1973.

Commission Internationale des Industries Agricoles, bibliography 2650: Bibliographie sur la production du gaz de methane par fermentation du fumier et des residus agricoles, en rue de son utilisation a' la ferme. 1955.

APPENDIX IV TABULAR SUMMARY OF RECENT LITERATURE PERTAINING TO CONTINUOUS-FEED DIGESTERS

The following tables, as nearly as possible, the figures are given by the authors of the works summarized. English units of measurement have been converted to SI units throughout, and gas production calculated as a function of volatile solids added. An attempt was made to retain significant digits during the conversions and calculations. Most of the figures are averages, either the authors' or us of digester performance over a period of time. Many of the authors stated that the wastes were without bedding, and we assume that to be true of the remainder of the studies, unless otherwise specified.

To convert	into	multiply by
lbs/ft^3	g/l or kg/m^3	16.02
ft^3/lb	l/g or m^3/kg	0.062427
g/l	lb/ft^3	0.062427
l/g	ft^3/lb	16.02

		Dalrymple and Proctor (328)				Meenaghan et al (336) two stages: I	II
Feed Source		FRESH COW MANURE - FROZEN STORAGE				WASTES FROM THREE CONFINED STEERS (growing from 225 to 350 kg) were daily diluted with 150 - 180 liters water. 23 liters were fed to the first stage of the digestor. Both stages were 114 liters.	
Loading rate (g VS/l/day)		1.6	1.6	2.9	2.9		
Detention time (days)		12	20	12	20	5	5
Temperature (°C)		ALL 35°C ⟶				36°C	36°C
Loading Schedule		ALL DAILY ⟶				Daily continuously	
Mixing method and schedule		MECHANICAL SHAFT WITH BLADES MIXED 15 Min. EVERY 2 HRS.				Mixed by pumps	
Duration of experiment		9 Weeks ⟶					
Average TS (%)	Inf:	2.39	3.97	4.34	7.22		
	Eff:						
Volatile solids	Inf:	ALL 80.1 ⟶					
(as % TS)	Eff:						
pH	Inf:	7.5	7.5	7.5	7.5	7.3	
	Eff:	7.43	7.46	7.55	7.40	6.3	7.1
Volatile acids conc. (mg/l as CH_3COOH)		92	160	533	605	2990	1030
Alkalinity	Inf:	650	1500	1650	2600	2100	
(mg/l as $CaCO_3$)	Eff:	5040	6090	6750	7550	3750	4700
Organic nitrogen	Inf:						
	Eff:						
Ammonia nitrogen	Inf:						
	Eff:						
Average BOD_5	Inf:	0.044 ⟶				6900	
(mg/l)	Eff:	*0.046	0.060	0.071	0.093		2900
Reduction in BOD_5	(%)	mg O2/mgVS				mg/1 13,000	
Average COD	Inf:						7800
	Eff:						
Reduction in COD	(%)						
VS conc. (mg/l)	Inf:						
Reduction in VS	(%)	45.3	44.7	53.3	37.8		
ml gas/g VS added		54.8	49.2	65.6	35.9		
ml gas/g VS destroyed		121	110	123	95	tank volumes of gas/day 4.3	2.82
CH_4 content (%)		77	79	74	77	53	72

Comments

Fong (362)

Feed Source			120 lbs. of dairy cattle manure were diluted and refrigerated									
Loading rate (gVS/l/day)			2.4 →					2.4 →				
Detention time (days)			10 →					15 →				
Temperature (°C)			32 →	37 →	42 →	47 →	52	32 →	37 →	42 →	47 →	52
Loading Schedule			DAILY					DAILY				
Mixing method and schedule			Mechanical - 3 times/day weekdays, once on Sunday					As at left				
Duration of experiment												
Average TS (%)	Inf:											
	Eff:											
Volatile solids	Inf:		81.42 →					81.42 →				
(as % TS)	Eff:											
pH	Inf:		6.7 →					6.6 →				
	Eff:		6.5	6.8	6.85	6.9	7.1	6.85	6.9	6.95	7.05	7.15
Volatile acids conc. (mg/l as CH_3COOH)			190	230	280	?	380	125	150	210	250	280
Alkalinity	Inf:		1340 →					2010 →				
(mg/l as $CaCO_3$)	Eff:		1750	2100	2400	3000	3250	2050	2500	2900	3250	3600
Organic nitrogen	Inf:	mg/l as N	712 →					712 →				
	Eff:		670	620	590	580	550	1030	990	990	950	840
Ammonia nitrogen	Inf:		44 →					44 →				
	Eff:		110	120	130	150	180	210	220	260	280	300
Average BOD_5	Inf:											
(mg/l)	Eff:											
Reduction in BOD_5 (%)												
Average COD	Inf:	mg/l	30584 →					45876 →				
	Eff:											
Reduction in COD (%)			10.5	13	15.5	16.3	18.5	11	14.3	16.3	17	20
VS conc. (mg/l)	Inf:		24000 →					36000 →				
Reduction in VS (%)			18	23	24.5	25.5	28	19.5	25	27	27.5	28
ml gas/gVS added			70	110	130	140	170	50	83	97	100	120
ml gas/gVS destroyed			390	480	530	540	590	260	330	360	380	430
CH_4 content (%)			63.5	65.5	67	67	69	63	65	66	65.5	67.5

Comments

Fogg (362) cont'd.

Feed Source				SEE FOGG I							
Loading rate (g VS/l/day)		3.2 →					3.2 →				
Detention time (days)		10 →					15 →				
Temperature (°C)		32 →	37 →	42 →	47 →	52	32 →	37 →	42 →	47 →	52
Loading Schedule				SEE FOGG I							
Mixing method and schedule											
Duration of experiment											
Average TS (%)	Inf:										
	Eff:										
Volatile solids	Inf:	81.42 →					81.42 →				
(as % TS)	Eff:										
pH	Inf:	6.5 →					6.5 →				
	Eff:	6.8	6.85	6.9	7	7.1	6.9	7.0	7.05	7.15	7.2
Volatile acids conc. (mg/l as CH_3COOH)		270	290	325	375	480	140	220	270	325	390
Alkalinity	Inf:	1787 →					2680				
(mg/l as $CaCO_3$)	Eff:	2700	3000	3200	3550	4000	3000	3100	3200	4000	4500
Organic nitrogen	Inf mg/l	949 →					1424 →				
	Eff: as	780	760	760	720	700	1420	1300	1220	1190	1080
Ammonia nitrogen	Inf: N	59 →					88 →				
	Eff:	150	170	220	270	310	250	280	?	330	350
Average BOD_5 (mg/l)	Inf:										
Reduction in BOD_5	(%)										
Average COD	Inf: mg/l	40778 →					61168 →				
	Eff:	10	12.5	14	15	16	10.5	13	14.7	15.3	17
Reduction in COD	(%)	32000 →					48000 →				
VS conc. (mg/l)	Inf:	17.5	22	23	23.5	24.5	19	22	23	23.5	25
Reduction in VS	(%)										
ml gas/g VS added		79	140	150	160	180	57	84	110	120	130
ml gas/g VS destroyed		450	620	670	690	750	300	380	460	500	530
CH_4 content (%)		62	64	66	66.5	67.5	61.5	62.5	64	64	65
Comments:											

Fong (362) cont'd.

Feed Source				SEE FONG I								
Loading rate (g VS/l/day)			4.0 →					4.0 →				
Detention time (days)			10 →					15 →				
Temperature (°C)												
Loading Schedule			32 →	37 →	42 →	47 →	52	32 →	37 →	42 →	47 →	52
Mixing method and schedule				SEE FONG I								
Duration of experiment												
Average TS (%)	Inf:											
	Eff:											
Volatile solids	Inf:		81.42 →					81.42 →				
(as % TS)	Eff:											
pH	Inf:		6.5 →					6.6 →				
	Eff:		6.9	6.95	7.0	7.1	7.2	7.0	7.05	7.1	7.2	7.3
Volatile acids conc.			290	340	390	450	520	200	260	325	375	475
(mg/l as CH_3COOH)												
Alkalinity	Inf:		2233 →					3350 →				
(mg/l as $CaCO_3$)	Eff:		3300	3550	4000	4300	4700	4000	4300	4800	5200	5700
Organic nitrogen	Inf:	mg/l	1186 →					1780 →				
	Eff:	as	950	910	880	820	740	1850	1750	1660	1570	1340
Ammonia nitrogen	Inf:	N	73 →					110 →				
	Eff:		280	310	320	350	400	420	430	480	520	570
Average BOD_5	Inf:											
(mg/l)												
Reduction in BOD_5	(%)											
Average COD	Inf:	mg/l	50,973 →					76,460 →				
	Eff:											
Reduction in COD	(%)		9.5	11.7	13	14	14.5	9.5	12	13.5	14	15
VS conc. (mg/l)	Inf:		40,000 →					60,000 →				
Reduction in VS	(%)		15.5	18	19	19.5	20.5	17	20.5	22	22.5	23
ml gas/g VS added			74	120	150	150	180	65	90	110	120	130
ml gas/g VS destroyed			480	680	780	790	900	380	440	500	530	570
CH_4 content (%)			60	62	63	63	65	58	59	62	61.5	63
Comments:												

		Halderson (369)									
Feed Source		Dairy Cow Manure Collected from Concrete Floor and Refrigerated									
Loading rate (g VS/l/day)		1.6 →	3.2 →	4.0 →	6.4 →	7.2	1.6 →	2.4 →	4.8 →	5.6 →	8.0
Detention time (days)		All 15 days									
Temperature (^{o}C)		All $35^{o}C$									
Loading Schedule		Daily									
Mixing method and schedule		Paddle stirrer: continuous mixing									
Duration of experiment	(days)		15	15	15	15		15	15	15	15
Average TS (%)	Inf:										9.77
	Eff:	1.34	1.87	2.61	3.41	4.15	1.30	1.70	2.58	3.40	4.40
Volatile solids	Inf:										
(as % TS)	Eff:	81.93	84.73	85.48	85.55	85.88	82.70	83.59	85.36	85.74	86.63
pH	Inf:	5.5 all →									
	Eff:	6.81	6.84	6.90	6.83	6.87	6.79	6.85	6.91	6.83	6.84
Volatile acids conc. (mg/l as CH_3COOH)		132	220	448	597	511	110	198	531	521	420
Alkalinity	Inf:										
(mg/l as $CaCO_3$)	Eff:	2662	2843	2555	2486	2912	2617	2874	2625	2335	2773
Organic nitrogen	Inf:										
	Eff:										
Ammonia nitrogen	Inf:										
	Eff:										
Average BOD_5 (mg/l)	Inf:										
Reduction in BOD_5	(%)										
Average COD	Inf:										
	Eff: mg/l	9300	17600	33900	37400	43600	8100	15600	29800	38300	44300
Reduction in COD	(%)										35.6
VS conc. (mg/l)	Inf:										
Reduction in VS	(%)										55
ml gas/g VS added		270	240	350	380	400	260	260	310	370	370
ml gas/g VS destroyed											
CH_4 content (%)		CH_4 content averaged 60% with minor variations; average 380 l. gas/kg VS added									
Comments:		7 week acclimation before loading rate was initially increased							TS reduction (%)		52

		Gramms et al (368)					Hart (297)			
Feed Source		Dairy Bull Waste - collected weekly from liquid manure holding tank					Dairy Cattle Urine and Feces			
Loading rate (g VS/l/day)		1.9	1.9	3.8	3.8		2.11	2.11	3.24	3.44
Detention time (days)		10	15	10	15		25.7	26.3	26.3	25.3
Temperature (^{o}C)		All 32.5					23	35	23	35
Loading Schedule		All Daily					All Twice Weekly			
Mixing method and schedule		Swirled by hand? Twice daily on week days, once/day weekends.					Bottles swirled by hand? Twice daily during work week, undisturbed on weekends.			
Duration of experiment		13 weeks					8.5 weeks			
Average TS (%)	Inf:						6	6	10.8	10.8
	Eff:						4.37	4.14	6.50	6.70
Volatile solids	Inf:	77.5 →					All 81.6% →			
(as % TS)	Eff:						70.7	68.1	77.0	77.0
pH	Inf:	7.3	7.3	7.3	7.3				6.8	6.8
	Eff:	6.91	6.98	6.93	7.09		7.5	8	7.5	8
Volatile acids conc. (mg/l as CH_3COOH)		142	152	216	177		2000	1000	1000	1000
Alkalinity	Inf:	1245	1900	2530	3800					
(mg/l as $CaCO_3$)	Eff:	1800	2680	3318	5160		8000	7000	9000	10000
Organic nitrogen	Inf:	584	798	1170	1600		76	76	76	76
	Eff: mg/l as N	575	828	1053	1482	as %	48	47	51	53
Ammonia nitrogen	Inf:	41.4	61.6	82.2	132.2	total N	24	24	24	24
	Eff:	120	197	206	376		52	53	49	47
Average BOD_5	Inf:						5940	5940	9900	9900
(mg/l)							3500	1100	4100	2300
Reduction in BOD_5	(%)									
Average COD	Inf:	22750	34000	45200	68270	mg O_2/	All 1.00 →			
	Eff:					mg VS	1.22	1.32	1.21	1.24
Reduction in COD	(%)	4.66	11.2	9.33	13.2					
VS conc. (mg/l)	Inf:	19200	28800	38400	57600					
Reduction in VS	(%)	21.8	26.7	19.4	17.7		11.2	15.4	10.4	16.3
ml gas/g VS added		65	85	77	97		76.9	156	105	146
ml gas/g VS destroyed		300	317	395	550		687	1010	1010	893
CH_4 content (%)		66	65	65	61		52	65	66 - 69	58
Comments:							N content (% TS) of feed was 3.67			
						N content of effluent % TS	4.57	4.21	3.90	3.70

		Jeffrey et al (305)			Loehr and Agnew (323,333)					Ngoddy et al (383)		
Feed Source		Uncontaminated Dairy Cattle Manure			Beef Cattle manure collected from concrete floor shortly after defecation					Cattle waste flushing slurry passed through #60 screen		
Loading rate (g VS/1/day)		2.4 →	3.49	TS	16	3.2	4.8	6.4		2.64	4.8	9.8
Detention time (days)		20 →	16.6		10	10	10	10				
Temperature (^oC)		36	36		35 ± 1					All 35		
Loading Schedule					All Daily					All Daily		
Mixing method and schedule					"Mixed"					Baffled-Impeller Mixing Assembly Schedule?		
Duration of experiment		29 days acclimation, 19 days thereafter –			Six months					-- 15 day acclimation		
Average TS (%)	Inf:	4.4	5.27	mg/1						15	10	10
	Eff:	3.75	3.8									
Volatile solids	Inf:	88.9	87		7190	18,640	33,340	41,170				
(as % TS)	Eff:	74.9	85		77.8	79.5	69.1	64.6	%TVS	65	31	21
pH	Inf:	5.7	6.4									
	Eff:	7.1	7.0		6.7	6.8	6.8	6.7		7 –	8	
Volatile acids conc. (mg/1 as CH_3COOH)		164	176		100	100	175	175				
Alkalinity	Inf:											
(mg/1 as $CaCO_3$)	Eff:				1500	2050	1800	1900				
Organic nitrogen	Inf:											
	Eff:											
Ammonia nitrogen	Inf:											
	Eff:											
Average BOD_5	Inf:											
(mg/1)	Eff:				1830	3310	5130	6740				
Reduction in BOD_5	(%)				52.4	57.0	55.5	56.2				
Average COD	Inf:			mg/1	11,725	21,980	32,750	41,160	ppm	8000	6000	2200
	Eff:				23.8	28.6	29.1	33.1				
Reduction in COD	(%)											
VS conc. (mg/1)	Inf:											
Reduction in VS	(%)	42	53.4							30	34	35
ml gas/g VS added		170	150		560	547	743	705				
ml gas/g VS destroyed		399	290									
CH_4 content (%)		65			58	57	52	53				
Comments:			TS reduction,%		52.2	41.9	30.7	35.8		12	14	12
					Added sodium bicarbonate to correct low pH values during start up					Predicted detention time for 50% COD removal, in days.		

			Cassell and Anthonisen (325)		
Feed Source			Municipal Sludge	Chicken Manure	
Loading rate (g VS/l/day)				1.41	1.41
Detention time (days)			20	20	20
Temperature (^oC)			All $35^a \pm 2^oC$		
Loading Schedule			Daily		
Mixing method and schedule			Manual Shaking		
Duration of experiment			Every twelve hours (43 days total)		
Average TS (%)	Inf:		3.6	4.16	4.16
	Eff:				
Volatile solids	Inf:				
(as % TS)	Eff:	%	8.3	68	68
pH	Inf:				
	Eff:		5.6 - 5.9	6.9	6.9
			7.1	7.4	7.4
Volatile acids conc. (mg/l as CH_3COOH)					
Alkalinity	Inf:		748 - 1788	9700 - 15300	
(mg/l as $CaCO_3$)	Eff:		200	1400 and rising	
Organic nitrogen	Inf:		700 - 1400	8500-9000	
	Eff:		4000	10,000	10,000
Ammonia nitrogen	Inf:	mg/l		1500	1500
	Eff:		500	1300	1500
Average BOD_5 (mg/l)	Inf:				
Reduction in BOD_5	(%)				
Average COD	Inf:				
	Eff:				
Reduction in COD	(%)				
VS conc. (mg/l)	Inf:				
Reduction in VS	(%)				
ml gas/g VS added					
ml gas/g VS destroyed					
CH_4 content (%)					
Comments:					0.018 molar Na+ (0.041%) fed with manure as NaCl

		Gramms et al (368)					Hart (297)			
Feed Source		Two-day collection of droppings which fell into pans containing water					Chicken Manure			
Loading rate (g VS/l/day)		1.9	1.9	3.8	3.8		2.76	2.77	4.47	4.89
Detention time (days)		10	15	10	15		25.2	26.1	25.0	22.5
Temperature (^oC)		All 32.5^oC					23	35	23	35
Loading Schedule		All Daily					Twice weekly			
Mixing method and schedule		Swirled by hand? Twice/day weekdays, once/day on weekends					Bottles swirled by hand twice daily during workweek, undisturbed weekends			
Duration of experiment		13 weeks					8.5 weeks ⟶		7.5 weeks ⟶	
Average TS (%)	Inf:						9	9	14.96	14.96
	Eff:						4.95	4.27	7.99	7.27
Volatile solids	Inf:	80.9 ⟶				%TS		⟵ 71.5 ⟶		
(as % TS)	Eff:						59.9	57.1	61.7	59.7
pH	Inf:	7.18	7.34	7.42	7.52				6.5–8.5	6.5 - 8.5
	Eff:	7.20	7.35	7.42	7.52		7	7.6	6.5	7.5
Volatile acids conc. (mg/l as CH_3COOH)		350.4	175.2				7000	5000	15000	13000
Alkalinity	Inf:	3760	5650	7530	11290		14000	14000	20000	22000
(mg/l as $CaCO_3$)	Eff:	1660	2490	3320	4980					
Organic nitrogen	Inf: mg/l	380	510	690	1020		29	31	31	31
	Eff: as	1280	1920	2560	3840	% total N				
Ammonia nitrogen	Inf: N	1020	1570	1860	3150		71	69	69	69
	Eff:									
Average BOD_5 (mg/l)	Inf:						17760	17760	29600	29600
Reduction in BOD_5	(%) mg/l	40580	60920	81200	121730		12600	7600	21700	19100
Average COD	Inf:							⟵	1.11	⟶
	Eff:	75.3	78.1	74.8	68.7	mgO_2/ mg Vs	1.32	1.26	1.36	1.30
Reduction in COD	(%)	19200	28800	38400	57600					
VS conc. (mg/l)	Inf:									
Reduction in VS	(%)	67.2	67.8	64.2	57.0		32.4	44.8	20.2	32.0
ml gas/g VS added		305	362	306	280		100	260	67	214
ml gas/g VS destroyed		454	534	477	490		320	590	330	668
CH_4 content (%)		58	58	50	50		23 - 32	11-48	27-22	36-49
Comments:						N content, %TS	8.37	8.45	9.54	8.26
							Influent N=5.14% of TS, and is 92% org., 8% ammonia			
									---- Went sour---	

		Gates (224)					
Feed Source		Duck droppings, sand and a small amount of grain					
Loading rate (g VS/l/day)		0.69	0,82	1.63	1.60	2,18	2.18
Detention time (days)		All identical, decreasing from 30 to 10 days.					
Temperature (^oC)		35	24 - 29	35	24 - 29	35	24 - 29
Loading Schedule		Daily					
Mixing method and schedule		Seem to be mixed daily					
Duration of experiment		46 days	33	46	46	36	36
Average TS (%)	Inf:	4	4	4	4	4	4
	Eff:	3.36	6.15	3.3	3.4	5.58	5.6
Volatile solids	Inf:	59.2	59.2	59.2	59.2	66.4	66.4
(as % TS)	Eff:	26.9	42.0	45.8	50.0	25	34.2
pH	Inf:						
	Eff:	6.9	7.0	7.0	6.8	7.0	6.8
Volatile acids conc. (mg/l as CH_3COOH)							
Alkalinity	Inf:						
(mg/l as $CaCO_3$)	Eff:						
Organic nitrogen	Inf:						
	Eff:						
Ammonia nitrogen	Inf:						
	Eff:						
Average BOD_5 (mg/l)	Inf:						
Reduction in BOD_5	(%)						
Average COD	Inf:						
	Eff:						
Reduction in COD	(%)						
VS conc. (mg/l)	Inf:						
Reduction in VS	(%)	77	43	79	74	79	75
ml gas/g VS added		527	453	440	426	436	304
ml gas/g VS destroyed		718	793	637	674	637	480
CH_4 content (%)							
Comments:	lime added; times X g:	0	1 X 2	0	1 X 2	0	0

		Jeffrey et al (305)	
Feed Source		Urine assumed mixed with feces in normal ratio	
Loading rate (g VS/l/day)		2.40	2.82
Detention time (days)		20	20
Temperature (^oC)		35	35
Loading Schedule		Daily	
Mixing method and schedule			
Duration of experiment		70 days 25 days	18 days
Average TS (%)	Inf:	6.4	6.3
	Eff:	4.1	4.5
Volatile solids	Inf:	80	90
(as % TS)	Eff:	74	82
pH	Inf:	5.5 - 6.8	
	Eff:		
Volatile acids conc. (mg/l as CH_3COOH)		100	105
Alkalinity	Inf:		
(mg/l as $CaCO_3$)	Eff:		
Organic nitrogen	Inf:		
	Eff:		
Ammonia nitrogen	Inf:		
	Eff:		
Average BOD_5 (mg/l)	Inf:		
Reduction in BOD_5	(%)		
Average COD	Inf:		
	Eff:		
Reduction in COD	(%)		
VS conc. (mg/l)	Inf:		
Reduction in VS	(%)	37	33
ml gas/g VS added		220	130
ml gas/g VS destroyed		606	399
CH_4 content (%)			63.5
Comments:		ph of influence affected by PH variations of tapwater used as diluent	

		Cross and Duran (326)								
Feed Source		Solid Excreta from floor of pens, passed through 1/8" screen								
Loading rate (g VS/l/day)		← 0.8 →			← 1.6 →			← 3.2 →		
Detention time (days)		All 15 →								
Temperature (°C)		10	21	32	10	2	32	10	21	32
Loading Schedule		All Daily →								
Mixing method and schedule		? All Daily	?	?	?	?	?	?	?	?
Duration of experiment		13	15	15	13	15	15	13	15	15
Average TS (%)	Inf:									
	Eff:									
Volatile solids (as % TS)	Inf:									
	Eff:									
pH	Inf:									
	Eff:									
Volatile acids conc. (mg/l as CH_3COOH)										
Alkalinity	Inf:									
(mg/l as $CaCO_3$)	Eff:									
Organic nitrogen	Inf:									
	Eff:									
Ammonia nitrogen	Inf:									
	Eff:									
Average BOD_5 (mg/l)	Inf:	All 90,000 ppm								
Reduction in BOD_5	(%)									
Average COD	Inf:									
	Eff:									
Reduction in COD	(%)									
VS conc. (mg/l)	Inf:	2.5 →1%	4% →2%	1% steady	1.5% steady	.5% →1%	1% steady	1% →2.5%	.75% →2%	1 1/3% steady
Reduction in VS	(%)									
ml gas/g VS added										
ml gas/g VS destroyed										
CH_4 content (%)										

Comments:

"The PH determinations were all between 6 & 7.8 and decreased during the test periods."
They extrapolated from the kinetics of VS Conc. in the digesters of this short experiment (13-15 days) the following: active systems --

active system	approaching equilibrium	success or failure uncertain	approaching failure	difficult to establish success or failure

Fong (362)

Feed Source				Manure collected monthly from pit				As at left				
Loading rate (g VS/l/day)				← 2.4 →						← 2.4 →		
Detention time (days)				← 10 →						← 15 →		
Temperature (^{o}C)			32 →	37 →	42 →	47 →	52	32 →	37 →	42 →	47 →	52
Loading Schedule					Daily					Daily		
Mixing method and schedule				Mechanical; Thrice daily on weekdays, once on Sundays — This is true for the remainder of his work, the next 2 pages								
Duration of experiment												
Average TS (%)	Inf:											
	Eff:											
Volatile solids	Inf:			← 84.72 →						← 84.72 →		
(as % TS)	Eff:											
pH	Inf:		7	7	7	7	7	7	7	7	7	7
	Eff:		6.8	6.82	6.98	7.03	7.09	6.8	6.9	7.04	7.1	7.1
Volatile acids conc. (mg/l as CH_3COOH)			580	780	910	960	1150	200	300	410	470	500
Alkalinity	Inf:		1580 →					2370 →				
(mg/l as $CaCO_3$)	Eff:		2000	2050	2400	2800	4100	2450	2700	3000	3400	4700
Organic nitrogen	Inf:	mg/l	992 →					1488 →				
	Eff:	as	760	740	700	680	600	1320	1220	1230	1170	1010
Ammonia nitrogen	Inf:	N	268 →					402 →				
	Eff:		320	330	380	420	570	480	510	520	550	630
Average BOD_5	Inf:											
(mg/l)	Eff:											
Reduction in BOD_5	(%)											
Average COD	Inf:	mg/l		← 31,600 →						← 47,400 →		
	Eff:											
Reduction in COD	(%)		23	31	35	37	43	30	40	44	45	60
VS conc. (mg/l)	Inf:			← 24,000 →						← 36,000 →		
Reduction in VS	(%)		33	44	52	55	60	49	60	62	54	73
ml gas/g VS added			160	240	320	340	400	230	310	330	360	460
ml gas/g VS destroyed			480	550	610	620	670	470	520	540	560	630
CH_4 content (%)			62	63	64	63	65	61.5	62	62	62	64
Comments:												

Feed Source			Fong (362) cont'd. See previous page									
Loading rate (g VS/l/day)					← 3.2 →					← 3.2 →		
Detention time (days)					← 10 →					← 15 →		
Temperature (^oC)			32 →	37 →	42 →	47 →	52	32 →	37 →	42 →	47 →	52
Loading Schedule												
Mixing method and schedule												
Duration of experiment												
Average TS (%)	Inf:											
	Eff:											
Volatile solids (as % TS)	Inf:		84.72 →					84.72 →				
	Eff:											
pH	Inf:		7 →					7.05 →				
	Eff:		6.9	7.0	7.04	7.1	7.2	7.0	7.0	7.1	7.14	7.2
Volatile acids conc. (mg/l as CH_3COOH)			620	820	950	1040	1320	220	350	460	510	560
Alkalinity	Inf:		2106.6 →					3160.0 →				
(mg/l as $CaCO_3$)	Eff:		2300	2500	3250	3900	5000	3200	3400	3700	4200	5400
Organic nitrogen	Inf:	mg/l	1322.6 →					1984.0 →				
	Eff:	as	1050	1030	980	970	920	1750	1700	1650	1580	1400
Ammonia nitrogen	Inf:	N	357.3 →					536.0 →				
	Eff:		410	470	500	570	760	560	560	600	630	930
Average BOD_5 (mg/l)	Inf:											
Reduction in BOD_5	(%)											
Average COD	Inf:	mg/l	42133 →					63200 →				
	Eff:											
Reduction in COD	(%)		21	30	33	36	42	25	38	42	43	55
VS conc. (mg/l)	Inf:		32000 →					48000 →				
Reduction in VS	(%)		30	42	47	50	56	41	56	60	61	69
ml gas/g VS added			180	280	320	350	430	210	300	330	350	450
ml gas/g VS destroyed			600	660	680	700	760	500	530	550	580	650
CH_4 content (%)			60	61	62	61	64	59.5	59.5	60	60	63
Comments:												

Fong (362) cont'd.

Feed Source			See Swine IV									
Loading rate (g VS/1/day)				← 4.0 →						← 4.0 →		
Detention time (days)				← 10 →						← 15 →		
Temperature (^oC)			32 →	37 →	42 →	47 →	52	32 →	37 →	42 →	47 →	52
Loading Schedule												
Mixing method and schedule												
Duration of experiment												
Average TS (%)	Inf:											
	Eff:											
Volatile solids	Inf:		84.72 →					84.72 →				
(as % TS)	Eff:											
pH	Inf:		7.1 →					7.1 →				
	Eff:		7.0	7.05	7.1	7.2	7.3	7.0	7.05	7.15	7.3	7.4
Volatile acids conc. (mg/l as CH_3COOH)			670	860	980	1170	1460	230	390	480	550	580
Alkalinity	Inf:		2633.3 →					3950.0 →				
(mg/l as $CaCO_3$)	Eff:		3300	3700	4100	5000	6950	4000	4300	5200	6800	8700
Organic nitrogen	Inf:	mg/l	1653.3 →					2480.0 →				
	Eff:	as	1600	1560	1510	1480	1050	2560	2330	2140	2000	1710
Ammonia nitrogen	Inf:	N	446.0 →					670.0 →				
	Eff:		560	580	670	700	1160	720	730	780	970	1420
Average BOD_5 (mg/l)	Inf:											
Reduction in BOD_5	(%)											
Average COD	Inf:	mg/l	52,666 →					79,000 →				
	Eff:											
Reduction in COD	(%)		19	29	32	33	40	23	33	39	40	52
VS conc. (mg/l)	Inf:		40,000 →					60,000 →				
Reduction in VS	(%)		27	40	44	46	52	35	48	55	58	67
ml gas/g VS added			230	370	440	460	540	180	260	310	360	440
ml gas/g VS destroyed			850	930	990	1000	1040	520	540	570	620	660
CH_4 content (%)			57.5	58.5	60	59	62	57	58	59	58	60
Comments:												

Feed Source		Gramms et al (368) One-day collection of feces scraped from floor				Hobson and Shaw (372) Dilute Hog Wastes		Kroeker et al (383) Swine Manure	
Loading rate (g VS/l/day)		1.9	1.9	3.8	3.8	0.21	2.2	1.3	2.7
Detention time (days)		10	15	10	15	37.5	14	30	15
Temperature (^oC)		32.5 →				35	35	35°C (nominal)	
Loading Schedule		All Daily →				Daily		Daily	
Mixing method and schedule		Swirled by hand? Twice Daily on Weekdays, once/day weekends				80 RPM Paddle Stirrers;?		Rotating paddles, continuous	
Duration of experiment		13 weeks						ongoing	
Average TS (%)	Inf:					2 →			
	Eff:								
Volatile solids	Inf:	83.4 →							
(as % TS)	Eff:								
pH	Inf:	7.0	6.9	7.0	6.9				
	Eff:	6.76	7.14	7.17	7.27			8.0	8.0
Volatile acids conc. (mg/l as CH_3COOH)		1,090	200	1,080	290	< 2000 ppm		1750	2090
Alkalinity	Inf:	1,670	2,500	3,340	5,000				
(mg/l as $CaCO_3$)	Eff:	2,960	4,440	6,330	7,130			15500	16050
Organic nitrogen	Inf:	700	1,050	1,400	2,100				
	Eff:	440	674	1,000	1,244				
Ammonia nitrogen	Inf:	190	285	380	570			3410	3440
	Eff:	450	594	730	1,010				
Average BOD_5	Inf:					5,400	9,500		
(mg/l)						4,300	4,200		
Reduction in BOD_5	(%)					76	56		
Average COD	Inf:	23,300	35,000	46,600	70,000	24,300	42,500		
	Eff:	33.7	54.6	35.5	41.8	14,900	29,400		
Reduction in COD	(%)	19,200	28,800	38,400	57,600	39	31		
VS conc. (mg/l)	Inf:	51.6	60.9	49.2	59.2			44	36
Reduction in VS	(%)								
ml gas/g VS added		250	422	405	350			770	650
ml gas/g VS destroyed		490	693	824	762			1730	1900
CH_4 content (%)		61	60	58	59			67	67.5
Comments:					TS: IN	20,800	36,400	figures in each column are averages of two similar digesters.	
					OUT	12,900	26,800		
					Reduction	38%	26%		

		Jeffrey et al (305)			Ngoddy et al (393)			Schmid and Lipper (342)			
Feed Source		Primarily fecal waste from feeding floor - some urine			Flushing wastewater passed through #60 screen			Waste scraped from floor, stored in pit 24-48 hours			
Loading rate (g VS/l/day)		2.4 →	2.82 →	3.2	1.84	2.6	5.4	3.3	6.7	3.2	6.4
Detention time (days)		20 →			?	?	?		10 or 20 days - unclear		
Temperature (^oC)		35 →			35	35	35	35	35	20	20
Loading Schedule					All daily				Daily		
Mixing method and schedule					Baffled - impeller mixing Assembly; schedule unknown				Paddle ?		
Duration of experiment *		28	19	12 (days)	10	15	10	?			
Average TS (%)	Inf:	5.7	6.3	7							
	Eff:	3.5	3	3.2							
Volatile solids	Inf:	86	88.5	89	0.13	0.2	0.34 as %TS	←	80% →		
(as % TS)	Eff:	67	71.2	74.6	%TS In?	Out?					
pH	Inf:	6.0	6.0	6.0							
	Eff:	7.4	7.47	7.4	- 7 -	8 →		6.65	6.75	6.80	6.90
Volatile acids conc. (mg/l as CH_3COOH)		123	514+	3300				16500	19000	16800	17500
Alkalinity	Inf:										
(mg/l as $CaCO_3$)	Eff:										
Organic nitrogen	Inf:							10700	11800	15000	15000
	Eff:										
Ammonia nitrogen	Inf:										
	Eff:							1800	1800	2200	2500
Average BOD_5 (mg/l)	Inf:										
Reduction in BOD_5	(%)										
Average COD	Inf:										
	Eff:			ppm	3000	3000	2850				
Reduction in COD	(%)										
VS conc. (mg/l)	Inf:										
Reduction in VS	(%)	51	61.5	61.5	33	20	38				
ml gas/g VS added		530	510	375				62	57	19	
ml gas/g VS destroyed		1030	830	610							
CH_4 content (%)										15	
Comments:	TS reduction	37%	52.5%	54.6%	6.5	15	7	TS reduction %		33	23
		Digestion began to fail ca. 0.176 feeding rate, and at 0.2 lb loading volatile acids were 5000 mg/l and gas production was 4 ft^3/day/lb. vs dest.			Predicted detention time (days) for 50% COD reduction						

* days after 52 day acclimation

Taiganides (317)

Feed Source											
Loading rate (g VS/1/day)		1.3/1.95	1.2/1.73	1.1/1.5	1.3/1.99	1.1/1.5	1.2/1.73	0.82/1.3	*2 0.59/1.94	1.0/3.24	1.0/2.69
Detention time (days)					Detentions 8-80 days				7.9-10	8.7-20.	7.9-10
Temperature (°C)		All 35°C ⟶									
Loading Schedule		Daily ⟶									
Mixing method and schedule		Rotating bottles with flexible paddles, constantly mixed									
Duration of experiment		116	119	56	55	115	121	121	74	74	74
Average TS (%)	Inf:	5.0/6.0	5.4/7.1	3.7/5.0	4.7/4.8	4.0/7.1	4.2/8.5	4.0/6.1	0.84-1.80	2.32-3.32	1.23-2.50
	Eff:										
Volatile solids	Inf:								0.73-1.53	2.01-2.82	1.07-2.12
(as % TS)	Eff:										
pH	Inf:										
	Eff:	7.0/7.4	7.0/7.5	7.0/7.3	7.0/7.5	7.0/7.4	7.0/7.4	7.0/7.5			
Volatile acids conc. (mg/l as CH_3COOH)		1350/4430	1640/3640	810/1280	1950/4740	1310/2400	1280/2800	1130/1830	880/1220	1000/1600	840/1350
Alkalinity	Inf:										
(mg/l as $CaCO_3$)	Eff:										
Organic nitrogen	Inf:										
	Eff:										
Ammonia nitrogen	Inf:										
	Eff:	1467/2100	1523/2010	1040/1220	1326/2110	1240/1590	1199/1870	1285/1620			
Average BOD_5 (mg/l)	Inf:										
Reduction in BOD_5	(%)										
Average COD	Inf:	mg/mg/vs All 1.32 ⟶									
	Eff:										
Reduction in COD	(%)	*1*3 4.1/5.0	4.6/6.0	3.2/4.2	3.9/4.0	3.4/6.0	3.6/7.0	3.4/5.2			
VS conc. (mg/l)	Inf:	1.9	2.2	1.9	2.6	1.8	1.6	2.0			
Reduction in VS	(%)	*1 54/70	57/79	41/46	34/50	47/75	54/70	43.62	59	66	64
ml gas/g VS added		260	280	200	170	230	260	230	290	370	310
ml gas/g VS destroyed		479	489	497	506	488	479	537	484	560	485
CH_4 content (%)		58.6	58.7	-	58.8	59.2	58.5	59.6			
Comments:							Mean loading rate		1.27	1.71	1.60
							Mean detention time		8.8	15.0	9.1
							Mean TS (%) in		1.30	3.07	1.66
							Mean VS (%wet) in		1.12	2.65	1.43

* 2 min/max. *1 mean/max. *3 % wet weight

Feed Source		Taiganides cont'd.		Hobson and Shaw (373) 10-14 day-old swine waste collected beneath slatted floor				
Loading rate (g VS/l/day)		3.75/0.5		0.96 →	1.6 →	2.2 →	2.9 →	3.2
Detention time (days)		7.9-35		19 →	14	14	14	14
Temperature (^{o}C)				All 35^{o}C				
Loading Schedule				All daily				
Mixing method and schedule				40 RPM 3-vaned propeller type stirrer				
Duration of experiment		74 days	*31 wks.	20(7)	4.5	(4) 5	(4) 4	5 - 80 wks.
Average TS (%)	Inf:	1.26-3.60	ppm	20800	26000	36400	46600	51800
	Eff:		ppm	18200		29000	35000	44500
Volatile solids	Inf:	1.10-3.06						
(as % TS)	Eff:							
pH	Inf:							
	Eff:							
Volatile acids conc. (mg/l as CH_3COOH)		1000/2370		163	216	1530	222	685
Alkalinity	Inf:							
(mg/l as $CaCO_3$)	Eff:			5880	3320	4300	5480	6800
Organic nitrogen	Inf:							
	Eff:							
Ammonia nitrogen	Inf:							
	Eff:		mg/l	581	731	1148	1008	1288
Average BOD_5	Inf:		pmm	5400	6700	9500	12100	13400
(mg/l)			pmm	1400	2000	2900	9130	6240
Reduction in BOD_5	(%)			74	71	79	24.6	53.4
Average COD	Inf:		pmm	24300	30400	42500	54400	60500
	Eff:		pmm	17000	23400	19800	49445	49630
Reduction in COD	(%)			30	23	54	9.1	18.0
VS conc. (mg/l)	Inf:		pmm	16700	21000	29200	37400	41600
Reduction in VS	(%)	68		27	27	35	24.6	17.9
ml gas/g VS added		400		240	280	290	230	250
ml gas/g VS destroyed		584		880	1000	830	930	1400 ← w/15 digester
CH_4 content (%)					←	60%	→	
Comments:		1.23 16.0 2.26 1.95		feed 2.5% TS				feed 4-4.5% TS

Cu concentration in feed 850 ppm (dry st. basis)

* Intermediate step times in parenthesis

Robertson et al (401)

Feed Source		Piggery waste						
Loading rate (g VS/1/day)								
Detention time (days)		7	10	10	20	15	20	30
Temperature (^{o}C)		35^{o}	30^{o}	35^{o}	35^{o}	35^{o}	35^{o}	35^{o}
Loading Schedule								
Mixing method and schedule		Mixed						
Duration of experiment		Months						
Average TS (%)	Inf:	3.66	3.35	3.3	3.2	4.9	5.3	4.3
	Eff:	2.6	2.19	2.1	1.2	2.7	3.3	3.1
Volatile solids	Inf:							
(as % TS)	Eff:							
pH	Inf:							
	Eff:							
Volatile acids conc. (mg/l as CH_3COOH)		924	715	274	394	1240	406	1354
Alkalinity	Inf:							
(mg/l as $CaCO_3$)	Eff:							
Organic nitrogen	Inf:							
	Eff:							
Ammonia nitrogen	Inf:	2156	1734	1237	890	2216	2217	2329
	Eff:	2118	1952	1044	1024	2173	2263	2402
Average BOD_5	Inf:	18917	9550	14672	10750	22500	28500	17500
(mg/l)		2787	2200	2567	1520	3666	1700	1800
Reduction in BOD_5	(%)	85.0	77	82.5	86.0	83.7	94.0	89.7
Average COD	Inf:	79980	41305	46920	30250	67526	62933	77000
	Eff: mg	41910	20971	21956	1676	31680	43867	36792
Reduction in COD	(%)	47.6	49	53.2	94.0	53.1	30.3	52.2
VS conc. (mg/l)	Inf:							
Reduction in VS	(%)							
ml gas/g VS added								
ml gas/g VS destroyed								
CH_4 content (%)		65%				65%		
Comments:	Gas production, digester volumes/day:		.922	.98		.836	.748	.558

------------100 liter laboratory digester------- --------13620 liter field unit-------