METHANE GAS PRODUCTION FROM ANIMAL WASTES

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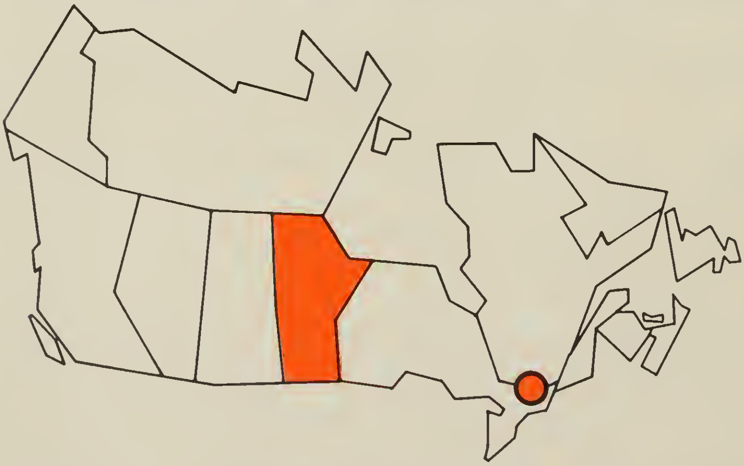

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METHANE GAS PRODUCTION FROM ANIMAL WASTES
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FOREWORD

The conservation of energy is creating interest in new forms of energy for agriculture in Canada. After World War II, a limited number of digesters were built in Europe, Asia and Africa to use manure and crop waste for the production of methane gas as a source of energy for farms. Recently, these experiences have prompted interest in the possible use of digesters to process manure in Canada. At present, there are no known commercial or farm-size units available in this country.

The Canada Animal Waste Management Guide advises that although there are advantages to be gained from manure digesters, such as the production of a stable by-product and a valuable gaseous fuel, several limitations require careful consideration. These include a high capital cost for proper structures, equipment and gas control devices, continual care to avoid explosions, and at least daily feeding of diluted manure to the digester. Continual supervision is necessary and various remedial measures must be taken when the process becomes 'upset' since it is extremely sensitive to changes in environmental conditions, such as pH and operating temperatures. Also, even with the use of a digester, considerable material will still need to be stored for eventual application to cropland.

Because of these limitations and the fact that manure digesters have not been developed or evaluated for our cold climate or assessed for economic feasibility, methane production from animal manure has yet to be proven as a reliable energy source. To consider their potential suitability and use in Canada, some research and development was initiated at the University of Manitoba a few years ago. This publication outlines the process, problems and progress made to date.

METHANE GAS PRODUCTION FROM ANIMAL WASTES

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Animal wastes contain large amounts of organic matter which, if broken down by bacteria in the absence of oxygen, will produce significant quantities of methane gas. The bacterial action results in a form of biodegradation known as anaerobic decomposition. These bacteria are common in nature especially where large amounts of decaying matter, such as animal manure, exist. Under proper environmental conditions the bacteria can be brought to a high degree of activity within a few weeks.

Many farmers are now using liquid manure storage pits and lagoons to store large volumes of animal waste. Since these pits are usually open to the air, unheated, and the manure is not well mixed, they are not efficient for large-scale methane production. Anaerobic digestion, on the other hand, carried on in sealed tanks or digesters, without loss of heat, is a proven performer in methane production. However, the feasibility of producing methane gas from animal wastes under Canadian climatic conditions has yet to be demonstrated. In fact, few anaerobic digesters of animal wastes have been installed on an economic scale in North America, although they have been used successfully in warm climates.

Dairy, poultry and hog manure all have potential for methane production depending on the volume available and the development of a suitable farm-size system of anaerobic digestion for use in Canada (see example of potential gas production from hog manure, page 5).

Unlike propane, methane gas does not liquefy for storage at low pressures and atmospheric temperatures. Therefore, its success as a cooking and heating gas or as a source of power for tractors, trucks and cars will depend on the engineers' ability to devise safe, economical methods of storage.

OPERATION

Several environmental conditions are important for successful operation of an effective methane-producing anaerobic digester.

Temperature The rate of biological activity in anaerobic digesters increases throughout the 32° – 140°F (0° – 60°C) range. However, production of methane gas is severely reduced at the upper and lower ends of this temperature range. Maximum production of methane gas occurs in the 90° – 95°F (32° – 35°C) range. Consequently, external heat, or use of a portion of the energy recovered through methane production, may be required to keep the system operating. The amount of heat or percentage of gas required for heating the digester has not yet been determined for Canadian climatic conditions. Once a satisfactory operating temperature is achieved it is important to maintain close control of that temperature. Fluctuations of greater than ±2°F (1°C) can upset the methane-producing bacteria.

Loading rate Since animal wastes vary widely in solids content, the type that is to be used must be considered carefully before installing an anaerobic digester. The loading rate must also be determined in relation to the operating temperature of the digester. Loading rates are expressed in pounds of volatile solids per cubic foot of digester capacity per day. Volatile solids are an indirect measure of the biodegradable organic content of a waste. Swine wastes in Manitoba have been successfully digested at loading rates of 0.1 to 0.2 lb of volatile solids/cu ft/day at 95°F (1.6 to 3.2 g/litre/day at 35°C).

Mixing A higher rate of biodegradation can be accomplished by continuously mixing the contents of the digester. Mixing prevents formation of an undesirable scum on the surface of the digester contents and brings bacteria into more immediate contact with the organic matter. It also keeps the temperature more uniform.

Retention time Proper selection of digester capacity and loading rate are necessary to ensure that the bacteria have sufficient time to accomplish the necessary reactions. From 10 to 30 days may be required, depending on environmental conditions in the digester.

Seeding Although methane-producing bacteria are found in nature, it may take several weeks for them to multiply into a large, efficient methane-producing population. By seeding an anaerobic digester with sludge from an active digester this time can be reduced significantly. Some municipal sewage treatment plants use anaerobic digesters from which sludge can be obtained for this purpose. Depending on the size of animal waste digester, a few gallons to a few hundred gallons may be useful.

Alkalinity Due to the sequence of biological reactions in anaerobic digestion, organic acids may accumulate. If the alkalinity is too low, these acids may cause the methane-producing bacteria to cease their activity. Control of the alkalinity and the pH of a digester can be accomplished by adding lime if necessary.

Nutrients Nutrients are highly concentrated in animal wastes. Usually the concentration is great enough for good biological activity. Occasionally, the ammonia concentration may become so high that it is toxic to the anaerobic bacteria. Poultry manure, especially, causes this problem.

Gas collection and storage A healthy anaerobic digester will produce gas consisting of about 70% methane and 30% carbon dioxide. Efficient utilization of the methane depends on ability to scrub the CO_2 from the mixture and to store the methane for future use. Much work remains to be done in developing safe, effective collection and storage methods amenable to modern Canadian farm systems.

POTENTIAL GAS PRODUCTION

The following example of potential gas production, through anaerobic digestion of the manure from 1000 hogs, is based on work done at the University of Manitoba.

Assumption: Average weight per hog = 100 lb (45 kg)

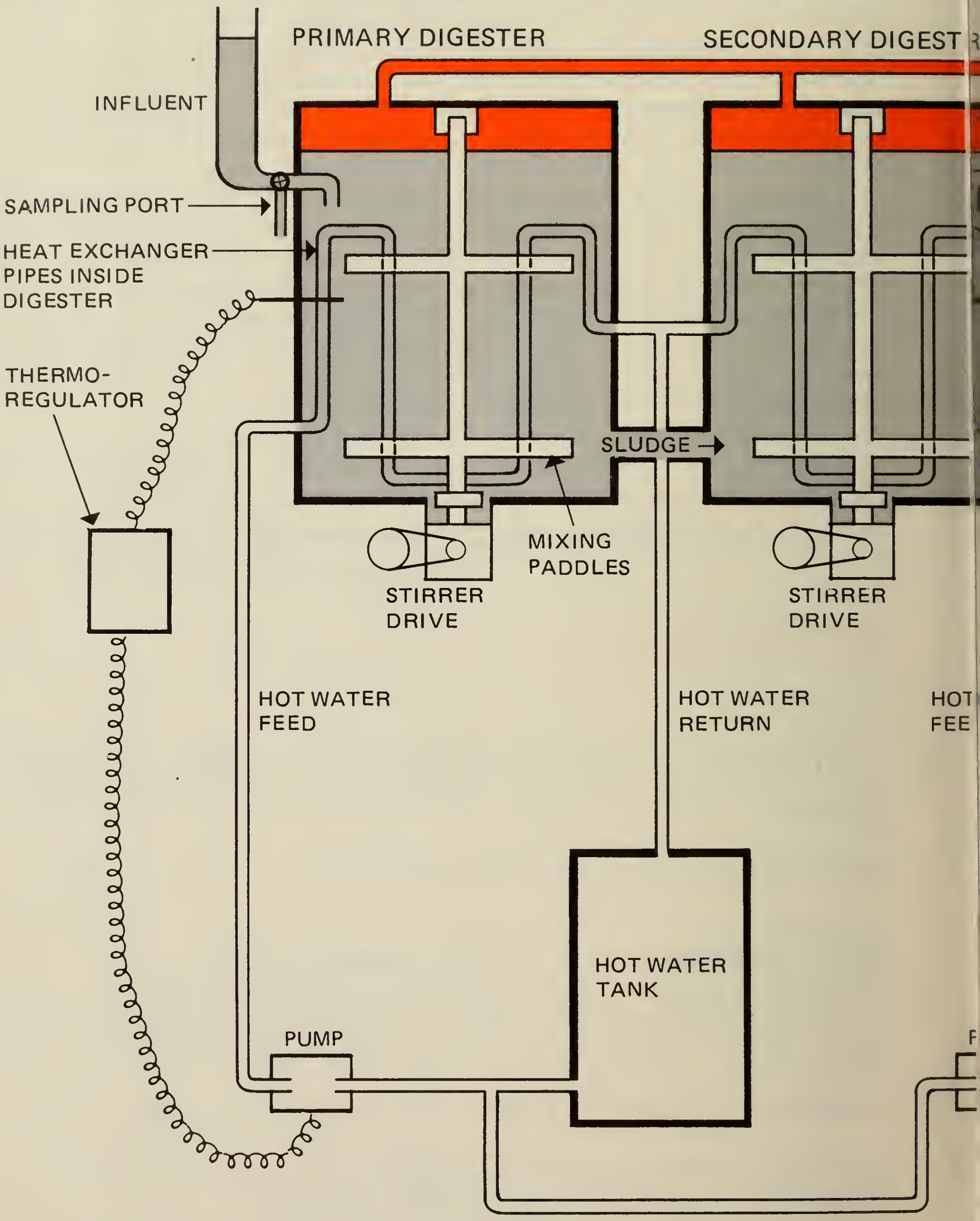
Digester capacity:

Manure production	7.0	lb/day/hog (3.2 kg/day/hog)
Volatile solids (14% wet basis)	0.98	lb/day/hog (445 g/day/hog)
Total volatile solids production	980.0	lb/day/1000 hogs (445 kg/day/1000 hogs)
Loading rate	0.15	lb/cu ft/day (2.4 g/litre/day)

Therefore, digester capacity is 980/0.15 = 6533 cu ft (185 416 litres)

Gas production: Range may be 4 to 10 cu ft/hog (115 to 280 litres/hog)
[use 7 cu ft/hog/day (200 litres/hog/day)]
Assume 65% methane; therefore, methane production rate is
0.65 X 7 X 1000 = 4550 cu ft/day (65% X 200 X 1000 =
130 000 litres/day)

SCHEMATIC DIAGRAM OF EXPERIMENTAL LIVESTOCK WASTE DIG



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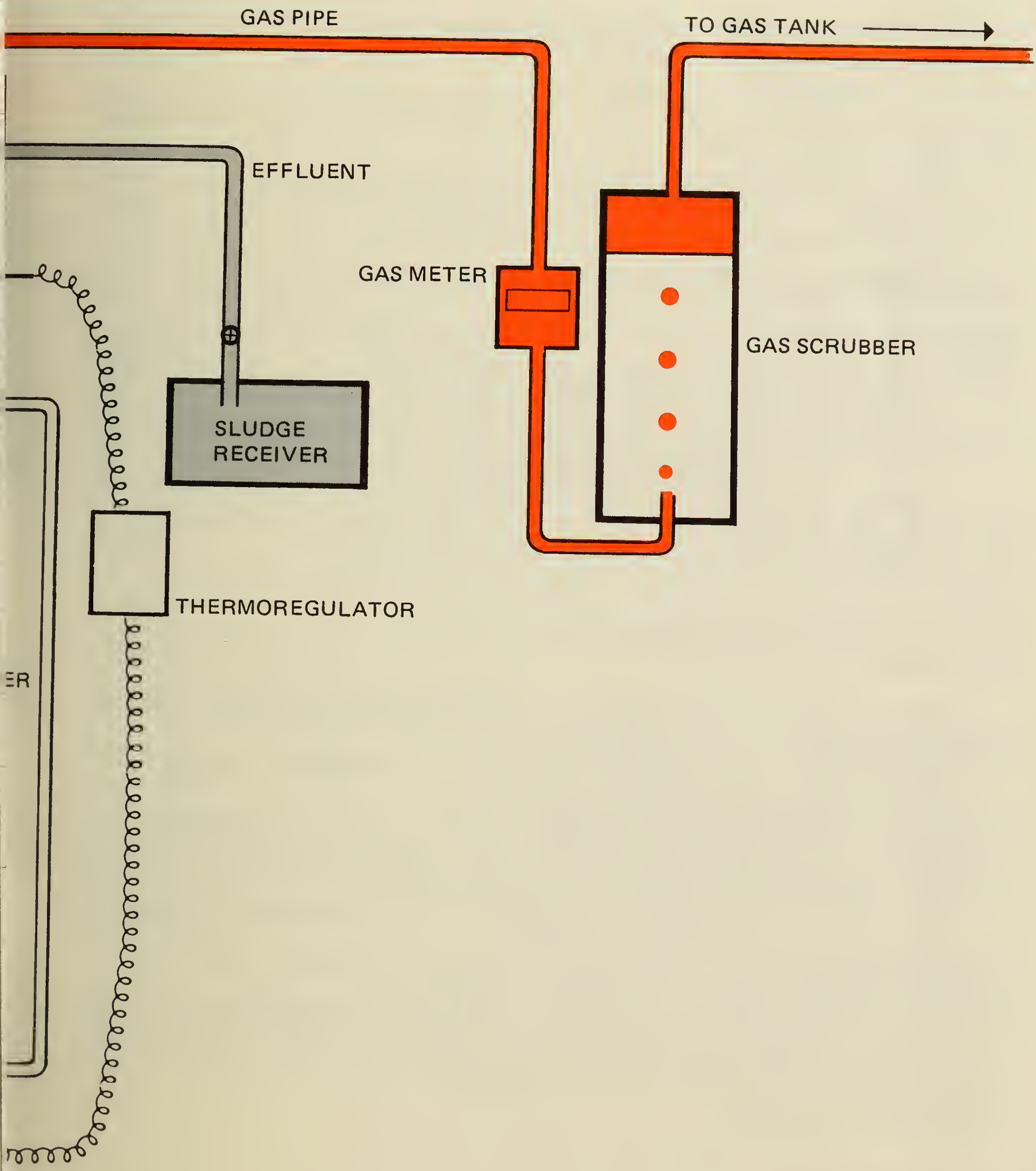
GAS PIPE
TO GAS TANK
EFFLUENT
GAS METER
GAS SCRUBBER
SLUDGE RECEIVER
THERMOREGULATOR
ER

Heat value: Heat value of 1 cu ft of pure methane at atmospheric pressure = 1000 Btu (1055 kJ)

Therefore, heat value of methane from a 1000-head hog operation could be 4550 X 1000 = 4,550,000 Btu/day (4 800 250 kJ/day).

Compare this to heating oil which has a heat value of 19,134 Btu/lb (44 500 kJ/kg) and weighs 9.041 lb/gal (900 g/litre).

Therefore, the daily heat production from this 1000-head hog operation would be equivalent to:

$$\frac{4{,}550{,}000}{19{,}134 \times 9.041} = 26.32 \text{ Imp gal of heating oil } \left[\frac{4\,800\,250}{44\,500 \times .9} = 120 \text{ litres}\right]$$

However, in practice this may be equivalent to 7-10 gal (32-45 litres).

NOTE: It cannot be assumed that all of this energy would be available for external use since a portion is used to maintain a temperature conducive to good bacterial activity in the digester. In a pilot-scale digester at the University of Manitoba, the objective has been to maintain a temperature of 90°F (35°C) for the methane-forming bacteria. Although the amount of heat required for this purpose is not known under Canadian climatic conditions, it may be greater than 50% of the total. Energy for the operation of pumps and stirrers also reduces the energy potential.

PROBLEMS UNDER STUDY

Further problems associated with methane production from anaerobic digestion being studied at the University of Manitoba are:

1. Finding a satisfactory method of removing carbon dioxide from the gas to improve its heating value per unit volume.
2. Storage of methane gas. Unlike propane, methane gas does not liquefy at low pressures and environmental temperatures. The critical pressure to produce a liquid is 659 psi (4545 kPa) at a temperature of −115°F (−81°C). It appears that practical storage must be in the gaseous form at relatively low pressures.
3. Methane gas is asphyxiating, combustible and when mixed with air, explosive. Therefore, special safety precautions are necessary.
4. Installation costs. Studies have not reached the point where system designs and cost estimates can be offered for on-farm installations. Most installation cost estimates currently available have originated from warmer climates and are not applicable to Canada.

PILOT PROJECT

A pilot-scale digestion system was installed in 1973 at the Glenlea Research Station, located 13 miles (20 km) south of Winnipeg, Manitoba (see illustration).

Although this experimental system contains a primary and a secondary digester, single-stage digestion systems may prove feasible.

The primary and secondary digesters consist of fiberglass septic tanks, 8 feet in diameter and 10 feet high (2.44 X 3.05 m), equipped with mechanical stirrers and internal hot water coils. The total digester sludge volume is maintained at 200 cubic feet (5.66 m^3 or 5663 litres).

Hot water from a thermostatically controlled reservoir is pumped through the heating coils of the tanks. The flow of the water is controlled by means of an adjustable thermoregulator on the power supply to the pump, to maintain a digester temperature of 95°F (35°C).

Gas generated in both units is measured by a wet-test meter before being bubbled through a tower of limewater to remove the carbon dioxide in the gas. The methane is stored in an inverted gas-holding tank over water.

The digesters were seeded with partly digested sludge from the Winnipeg North Main Sewage Treatment Plant. The seed sludge was maintained at a temperature of 95°F (35°C) and was continuously agitated by the mechanical stirrers. Daily feeding of the digesters with raw swine manure began 4 days after the digesters were seeded. Initially, the digesters were loaded at a rate of 0.015 lb volatile solids/cu ft/day (0.24 g/litre/day) at a 40-day retention time. This was slowly increased to a loading of 0.10 lb volatile solids/cu ft/day (1.6 g/litre/day) at a 20-day retention time over a period of 30 days. At this loading rate, the digester showed no signs of failure and obviously had not reached maximum loading rate.

The digesters were fed daily with a mixture of tap water and manure in proportions to yield the desired loading rate and retention times. An equal volume of digested manure was removed from the secondary digester before each feeding.

Measurement of pH, volatile acids and gas composition was taken every 2 days. Analysis of gas showed a methane content of 60 to 69%. Gas production rates were lower than expected and failed to reach the 7 cu ft/day/hog (200 litres/day/hog) achieved in earlier laboratory studies.

The digested manure was a black, free-flowing liquid with no offensive odor. When two open beakers, one containing raw manure, the other digested manure, were placed on a table, no flies approached the beaker with the digested manure but flies covered the beaker containing raw manure. This indicated that the organic matter in the raw manure was stabilized by the digestion process. The ammonia content of the manure was increased by about 50% through digestion, making its nitrogen content more immediately available for plant growth if it were to be used as a fertilizer.

Pilot plant operational studies are continuing at the University of Manitoba to evaluate the technical and economic feasibility of producing methane from animal wastes by anaerobic digestion under Canadian climatic conditions.

METRIC EQUIVALENTS

LENGTH

inch = 2.54 cm
foot = 0.3048 m
yard = 0.914 m
mile = 1.609 km

millimetre = 0.039 in.
centimetre = 0.394 in.
decimetre = 3.937 in.
metre = 3.28 ft
kilometre = 0.621 mile

AREA

square inch = 6.452 cm^2
square foot = 0.093 m^2
square yard = 0.836 m^2
square mile = 2.59 km^2
acre = 0.405 ha

cm^2 = 0.155 sq in.
m^2 = 1.196 sq yd
km^2 = 0.386 sq mile
ha = 2.471 ac

VOLUME (DRY)

cubic inch = 16.387 cm^3
cubic foot = 0.028 m^3
cubic yard = 0.765 m^3
bushel = 36.368 litres
board foot = 0.0024 m^3

cm^3 = 0.061 cu in.
m^3 = 31.338 cu ft
hectolitre = 2.8 bu
m^3 = 1.308 cu yd

VOLUME (LIQUID)

fluid ounce (Imp) = 28.412 ml
pint = 0.568 litre
gallon = 4.546 litres

litre = 35.2 fluid oz
hectolitre = 22 gal

WEIGHT

ounce = 28.349 g
pound = 453.592 g
hundredweight (Imp) = 45.359 kg
ton = 0.907 tonne

gram = 0.035 oz avdp
kilogram = 2.205 lb avdp
tonne = 1.102 short ton

PROPORTION

1 gal/acre = 11.232 litres/ha
1 lb/acre = 1.120 kg/ha
1 lb/sq in. = 0.0702 kg/cm^2
1 bu/acre = 0.898 hl/ha

1 litre/ha = 14.24 fluid oz/acre
1 kg/ha = 14.5 oz avdp/acre
1 kg/cm^2 = 14.227 lb/sq in.
1 hl/ha = 1.112 bu/acre

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