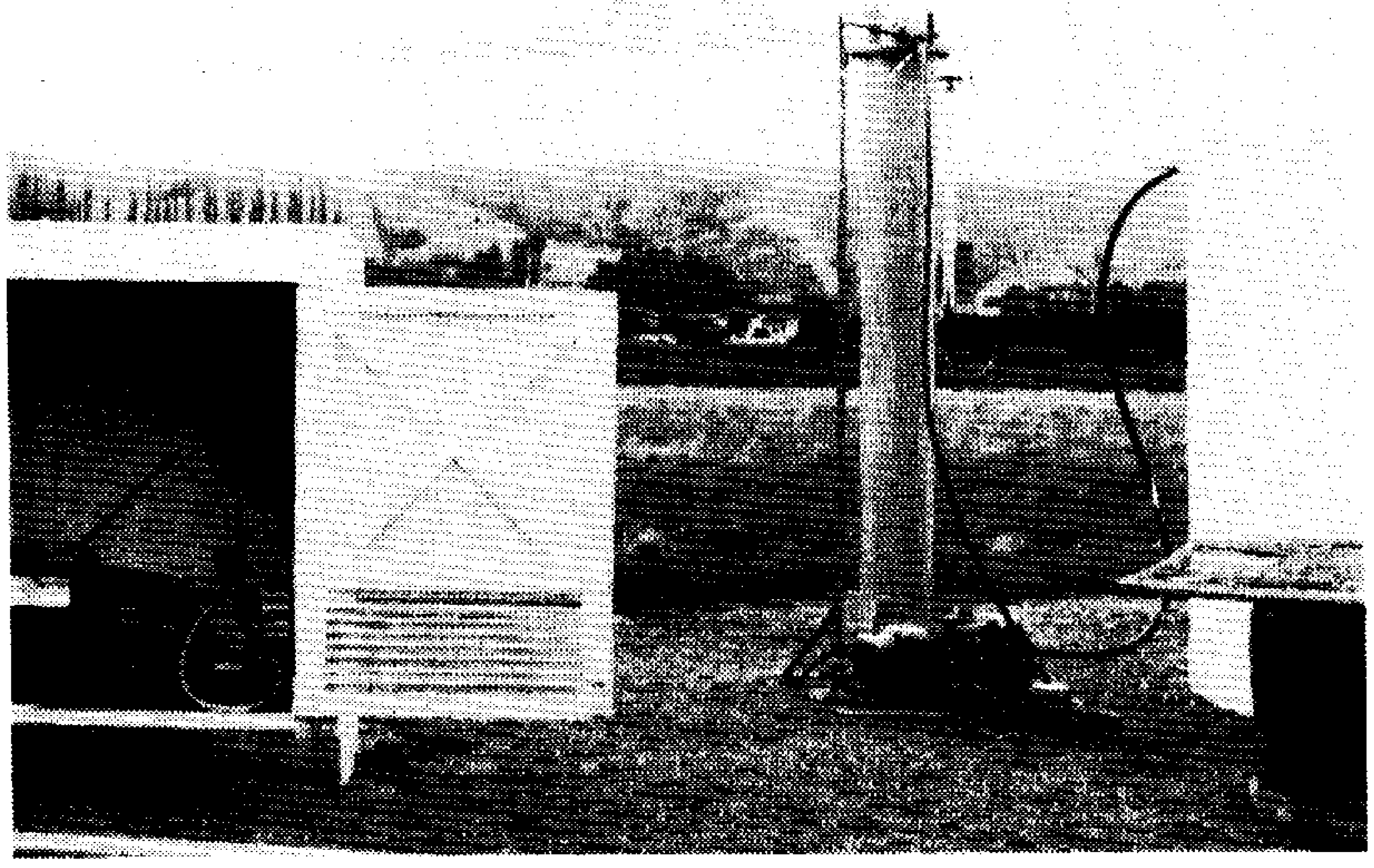
Farm Production & Practice

Ministry of Agriculture and Fisheries



Energy Biogas Scrubbing

Providing Methane for Vehicle Fuel

A scrubber that can remove most of the carbon dioxide is an essential part of any biogas plant intended to produce fuel for vehicles.

In the system established at the Invermay Energy Farm and illustrated above the scrubber tower and water pump (centre) operate in conjunction with a 4-stage compressor (left) and a water tank (right).

Raw biogas contains 50 to 70% methane and 50 to 30% carbon dioxide (CO_2) with trace impurities of sulphide gases. Although the raw gas can be used in boilers, space heaters, cooking stoves, and the stationary engines that drive pumps, blowers, or electricity generators, removal of the sulphides is advisable (to avoid the possibility of the burner elements and controls of the engine-exhaust system corroding).

Biogas that contains a large proportion of CO_2 is not suitable for fuelling vehicles. The CO_2 has no fuel value therefore space it occupies in the vehicle storage tank is wasted, and the distance the vehicle can travel is reduced. Moreover, if the biogas is to be interchanged with petrol in a standard petrol-engine vehicle, it will not produce an acceptable power output unless its CO_2 content is reduced to less than 5% by volume. Finally, CO_2 in compressed biogas can cause problems with freezing at valves or at other points where expansion occurs.

Keywords: **Energy; biogas; scrubbing; vehicle fuel; methane; carbon dioxide; sulphide.**

Carbon-dioxide removal

There are many ways of removing CO_2 from biogas, most of which have been designed to perform the same function with natural gas. However, the only method that is suitable for small-scale operations is washing with water under pressure.

Pressurised water washing: This method takes advantage of the fact that CO_2 dissolves easily in water under pressure (as in the manufacture of carbonated drinks), whilst methane is only slightly soluble. The process is very simple, and the pressurising of the biogas for scrubbing can be part of its overall compression for storage in the vehicle.

In Fig. 2 the process is shown schematically, with one four-stage compressor being used both to scrub and to com-

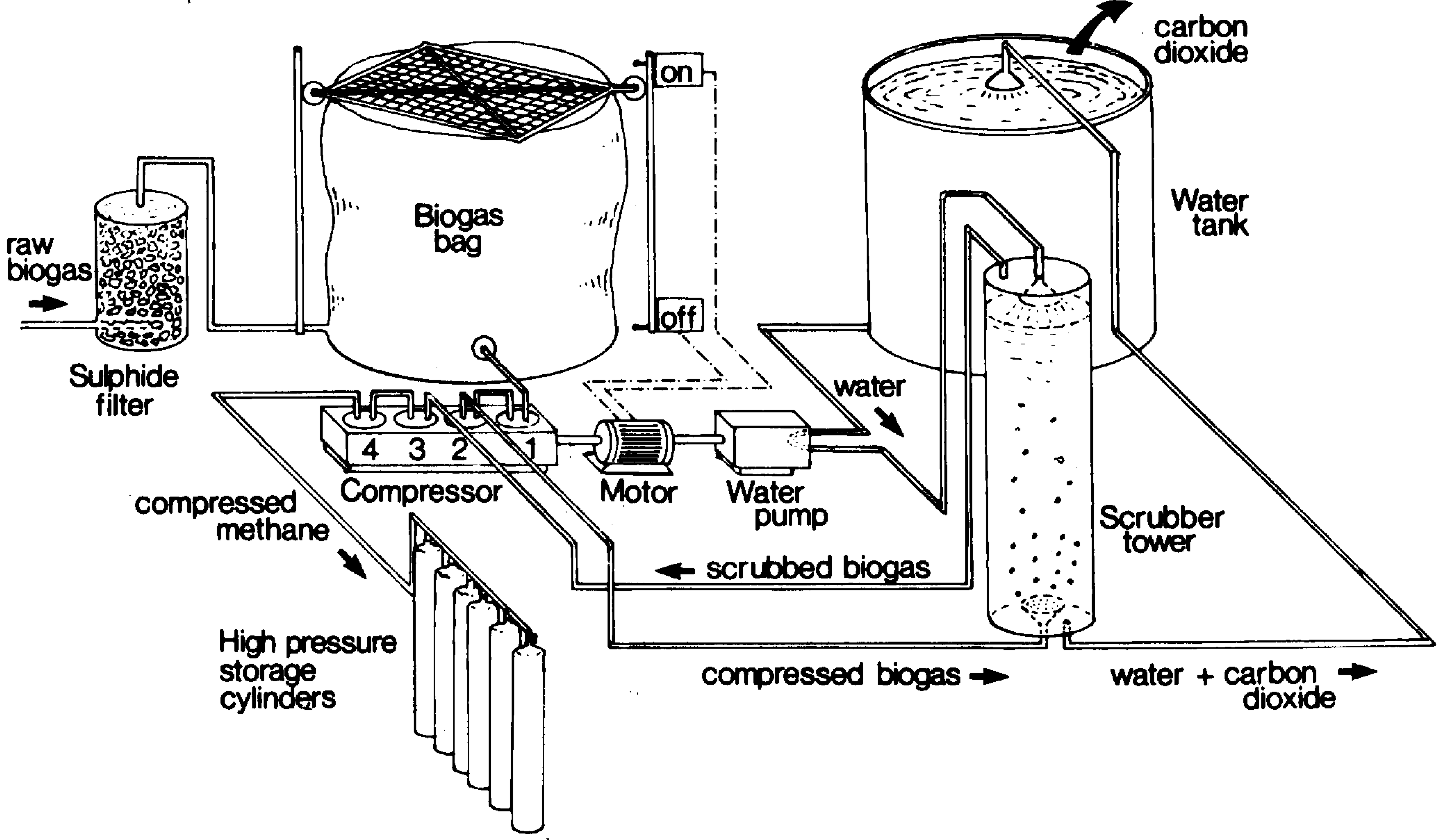


Fig. 1: Schematic illustration of the scrubbing of biogas to produce compressed methane for fuelling vehicles.

press the biogas. A separate compressor for the scrubbing may be used in some situations.

Operation: The operation of scrubbing and compressing the biogas is controlled automatically by the switches on the gas bag. As the bag inflates with biogas, it lifts a stabilising frame above it until, when the bag is full, the frame trips a switch that activates the motor(s) to drive the water pump and compressor. The compressor draws the raw biogas from the bag and pumps it into the bottom of the scrubber tower under pressure, for the removal of the CO_2 by the water.

The water is pumped to the top of the scrubber tower at the same pressure by the water pump. It then flows down through the tower, dissolving the CO_2 and carrying it out through the exit at the bottom. The rate at which the water leaves the tower is governed by a level control device which maintains the desired water level in the scrubber.

The scrubbed biogas is now largely methane. It emerges from the top of the scrubber tower, and passes to the final compression stages of the compressor and thence to the high-pressure storage cylinders. An adjustable pressure-relief valve on the scrubber gas exit maintains the inside pressure by allowing the methane to escape only when it reaches the preset discharge pressure. The water that has been used in the scrubbing is discharged into the water reservoir tank, where it returns to atmospheric pressure. The dissolved CO_2 is released into the atmosphere, as happens when the cap is removed from a bottle of soft drink. The water can then be reused to scrub more biogas. The compression and scrubbing operation is automatically shut down when the gas bag deflates and the stabilising frame activates a lower-limit switch.

Efficiency: The water scrubbing method is capable of removing virtually all the CO_2 content of the biogas, if the scrubbing pressure, water flow rate and purity, and the scrubbing towers dimensions (especially its height) have all been correctly calculated for the given gas-flow rate. Increasing any of these variables will increase the purity of the scrubbed gas. In practice, 100% removal of the CO_2 is unnecessary – most vehicles perform satisfactorily on scrubbed biogas whose methane content is 95 or more percent.

Design calculations

There is no simple formula for choosing the appropriate combination of scrubbing pressure and water and gas-flow rates to produce scrubbed gas of an acceptable purity. However the deciding factor is the degree of solubility of CO_2 in the water under the proposed conditions.

Carbon-dioxide solubility: The solubility of CO_2 in clean water at the normal temperatures (about 15°C) is known to be (0.87 x the partial pressure of the CO_2) litres per litre of water. The partial pressure of CO_2 in biogas is given by the total pressure of the biogas x the fraction of CO_2 in it, so that for biogas containing 65% methane (35% CO_2) at atmospheric pressure the partial pressure of the CO_2 would be 1 x 35/100 = 0.35 atmospheres. Under these conditions 0.87 x 0.35 = 0.30 litres of CO_2 should dissolve in each litre of water. At 10 atmospheres partial pressure (147 psi), 3.0 litres of CO_2 should dissolve in each litre of the water used for scrubbing the biogas.

Unfortunately, the full amount of CO_2 that should dissolve in the water does not do so in practice. This is largely because all the CO_2 does not have time to dissolve on its passage through the scrubbing tower. An even lower solubility must be expected if the scrubbing water is re-used as it will already contain some CO_2 that has not had time to escape back into the atmosphere.

Performance graph: The uncertainties just mentioned make it more practical to base the design of a scrubbing system on the performance of the actual scrubbers – the graph in Fig. 3 has been drawn from such data.

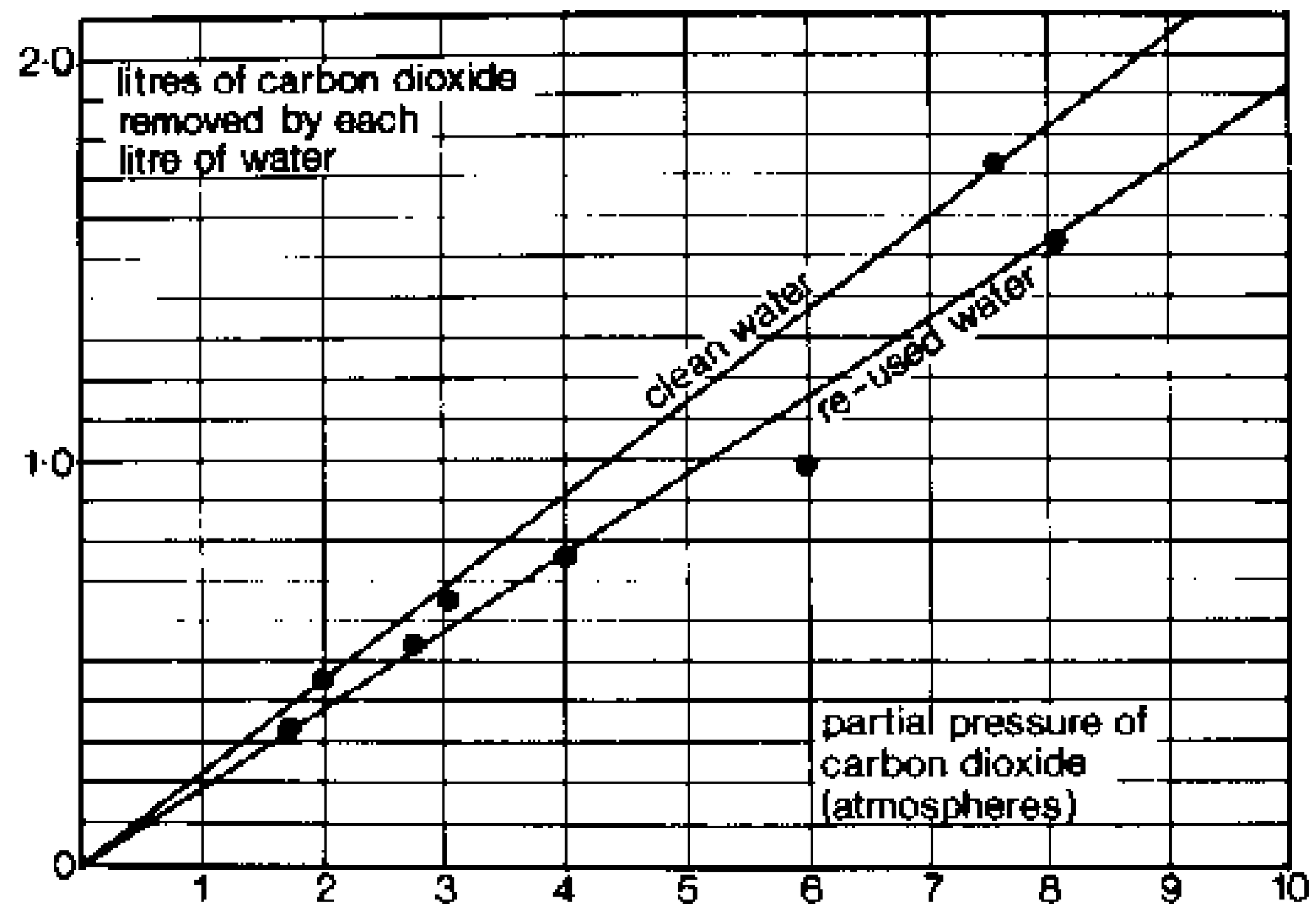


Fig. 2: Correlation graph, showing how much carbon dioxide can be washed from biogas by each litre of water at different scrubbing pressures and carbon-dioxide contents – the points are taken from working scrubber systems. (Note: 1 atmosphere = 14.69 psi).

To use the graph it is necessary to be able to measure the composition of the raw biogas – in general, it can be expected that biogas from manures will contain about 65% methane, while crops and other vegetable matter produce a biogas that contains about 55% methane. The graph can be used to read off the volume of CO_2 that should be removed from the biogas by each litre of water that is pumped through the scrubber tower for whatever partial pressure of CO_2 is produced by the compressor.

This figure and the volume of CO_2 pumped through the scrubber per minute by the compressor enable calculation of the flow rate that the water pump must deliver at the predetermined scrubbing pressure. A working example follows.

Working example: The biogas produced from poultry manure is known to contain 65% of methane and 35% of carbon dioxide. The specifications for the compressor to be used to scrub it state that it will compress 133 litres of biogas per minute (8 m^3/hour) to 14.3 atmospheres (210 psi). What specifications must the water pump have if recycled water is to be used for scrubbing?

- The partial pressure of CO_2 supplied to the scrubber will be 14.3 x 35/100 = 5.0 atmospheres.
- From Fig. 3 it is seen that at 5.0 atmospheres, 0.9 litres of CO_2 can be dissolved in each litre of water.
- The compressor will pump 133 litres/min of biogas which corresponds to 133 x 35/100 = 46.6 litres/min of CO_2.
- Therefore, to remove 46.6 litres of carbon dioxide from the biogas each minute it will be necessary to pump 46.6/0.9 = 51.7 litres of water. A suitable water pump should therefore provide a flow rate of about 52 litres/min at 14.3 atmospheres (210 psi).

Choosing the compressor

If the scrubbed biogas is to be used to fuel vehicles, it must be compressed to about 272 atmospheres (4 000 psi) for storage in the refuelling cylinders. A suitable

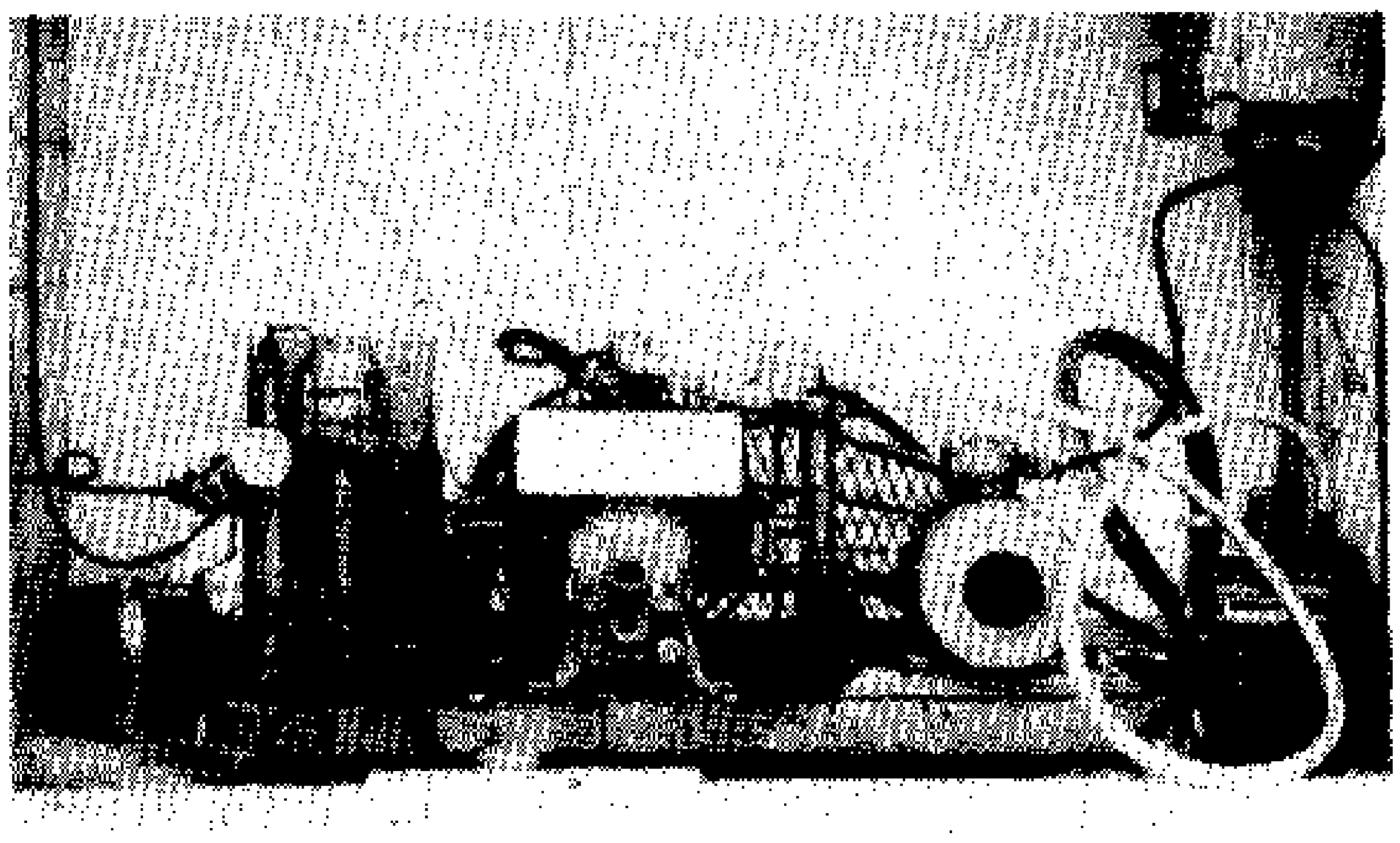


Fig. 3: A four-stage compressor (Luchard HBE 8, marketed in New Zealand by Compair Ltd) being used both for scrubbing and for compressing biogas.