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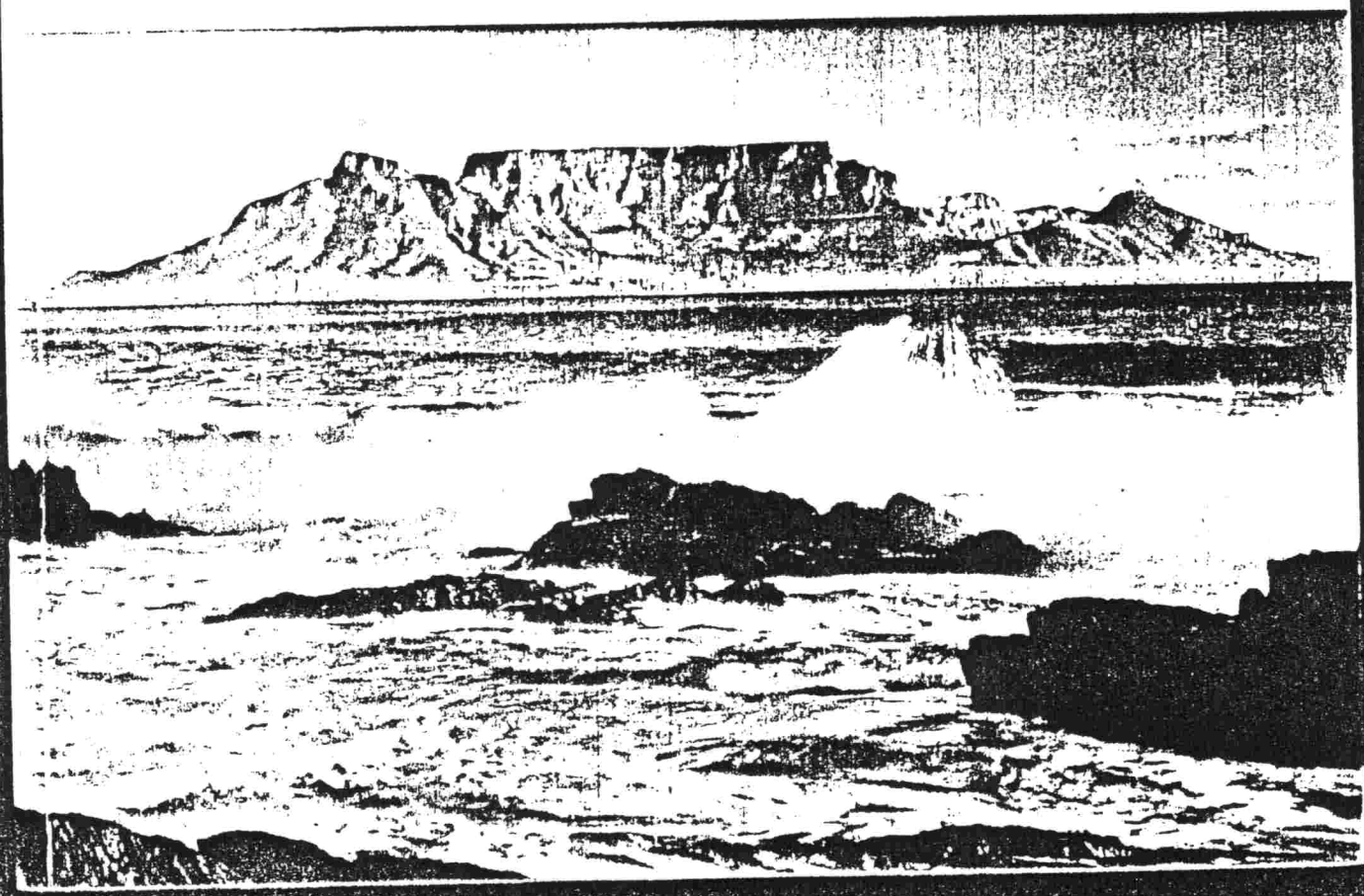

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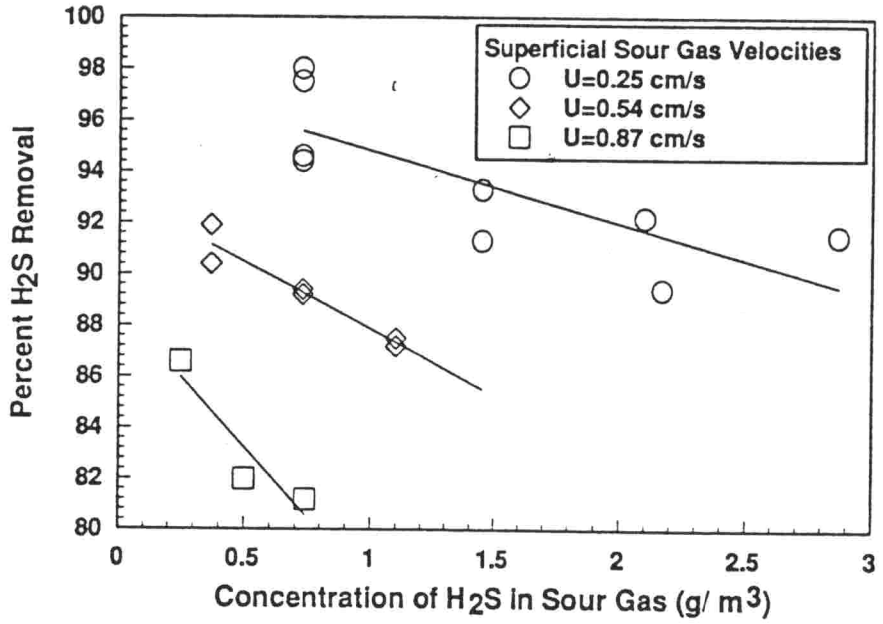

Figure 1. Removal of hydrogen sulfide (H_2S) from a sour gas in a pilot-scale bubble column. MLSS = 0.5-1.7 g/L, culture volume = 0.44 m^3, liquid height = 1.83 m and aeration rate = 0.13 m^3/min-m^3.

NEW LIQUID MEMBRANE SYSTEM FOR BIOGAS SEPARATION

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INTRODUCTION

An area of biotechnology which is connected with aerobic or anaerobic processes of continuing interest is the improvement of selectivity and flexibility of the gas-supply systems. These gas-controlling systems must be maintained at optimal balance to ensure a gas composition without any contaminants (Aragno and Schlegel, 1992).

For many years investigations have been made to develop a convenient and reliable methods to purify methane fermentation gas so as to increase its efficiency of burning (Bhatnagar et al., 1991). The main problem is the removal of CO_2 from biogas. The problems of CO_2 utilization and waste effluent treatment are obvious.

The other reason for the separation and utilization of CO_2 is its application in biotechnology as a source of carbon for algae or cyanobacterial growth (Drews and Imhoff, 1991). Phototrophic eukariotes and prokariotes use CO_2 as the only carbon source in the reductive pentose phosphate cycle of carbon dioxide fixation and its conversion to carbohydrates (Kondratieva et al., 1992). There are also the acetate-forming bacteria (homoacetogenes) which use the H_2/CO_2 mixture to produce acetate (Wood and Ljungdahl, 1991).

In this case the application of gas-separation and mixture regulation membrane systems can become very important in biotechnology. The main reasons for the application of non-porous polymeric membrane systems are the flexibility, selectivity, good productivity and the sterile properties of these systems. Another important reason is that they are non-toxic to bacteria.

Integrated membrane systems which possess simultaneously gas- separation and sterile properties can be useful for the improvement of bioprocesses and for the utilization of gases.

Recently, flowing liquid membranes (Sirkar,1988, Teramoto,1989) in which a liquid membrane solution flows along a microporous or nonporous membrane (Shelekhin and Beckman, 1990, Bessarabov and Beckman, 1993) have been proposed.

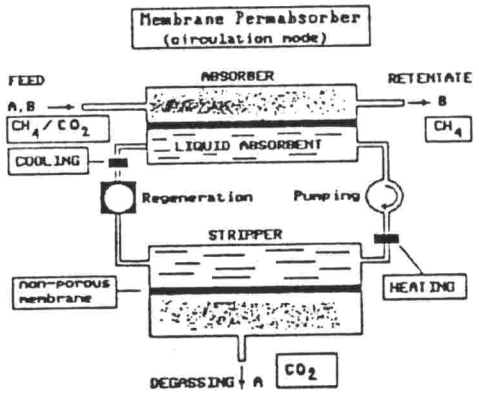
A new integrated membrane system involving a liquid flowing along non-porous gas-separation membranes (membrane permabsorber) is considered in this paper. Mobile membranes can be used to separate gas mixtures which are otherwise difficult to separate by conventional methods, and selectively separate of components of gas mixtures. The proposed technique for separation of gases was tested on biogas (CO_2/CH_4) with a permabsorber containing asymmetric non-porous membranes made from poly(vinyltrimethylsilane) (PVTMS), and flowing liquid absorbents containing monoethanolamine and K_2CO_3 water solutions as carrier for CO_2. The initial CO_2/CH_4 gas mixture consisted of 37,5% CO_2, 62,5% CH_4 or 46% CO_2 and 54% CH_4. Separation effectiveness for each of the gases was more than 95% at the outlets of the membrane permabsorber. The results of CO_2/CH_4 separation by pilot equipment connected to a lab-scale bioreactor are shown. The phenomenological theory of the mass transfer in a membrane permabsorber is considered. Computer simulation of the separation process in a membrane permabsorber was carried out.

MEMBRANE PERMABSORBER

The membrane permabsorber can consist of at least one membrane absorption module (absorber) and one membrane desorption module (stripper). The absorber and stripper contain non-porous polymeric membranes. The liquid absorbents move between absorber and stripper at different flow rates and temperatures.

The use of flowing liquid absorbents in combination with non-porous membranes permits performing in one system two gas-separation methods, that is, membrane and absorption.

The membrane permabsorber has one inlet for the feed and two outlets for the products (retentate and stripper gas). The first component of the feed (retentate, CH_4) is insoluble in a liquid; the other one (CO_2) is soluble in a liquid, and diffuses through the non-porous polymeric membrane where it is absorbed and pumped to be degassed in a stripper.



In the absorption module the feed gas mixture is passed over the membrane consisting of a thin polymer film and a thin layer of flowing liquid. The gas components which permeate through the polymeric membrane and which are soluble in the liquid layer pass into the desorption module to be degassed through the other polymeric membrane. These membranes can be similar or different in composition, etc.

As a rule the permabsorber consists of the absorption and desorption membrane modules operating in circulation mode.

In this study absorption and desorption modules consisting of 24 membrane-liquid cells with an active surface 0.6 m^2 were used.

The liquid absorbent could be nonspecific in relation to the components of the gas separation mixture; also, the solubilities of the gas components in a liquid could differ considerably ; finally, a liquid could react with one or several of the gas components. The productivity and selectivity of the membrane permabsorber depends on the gas-transport properties of the polymeric membranes, on the temperature of the liquid absorbents in absorber and in stripper, on the flow rate of a liquid absorbents, on the concentration of a selective "carrier" in a liquid, on the salting-out factor and on the physical parameters of the process.

MATHEMATICAL MODEL

The gas permeability of a two-layered medium consisting of a polymeric membrane (M) and a thin layer of a liquid (L) flowing at a volume flow rate is considered here in relation to phenomenological theory.

The basic system of the differential equations for mass transfer for steady-state diffusion in a membrane permabsorber is proposed. The proposed models of mass transfer are discussed in terms of the following assumptions:

the permeability of any species is independent of pressure and composition; pressure drops are negligible in the feed and permeate streams; piston flow is maintained in the feed and stripper streams in the gas and liquid phases of permabsorber.

The analytical solutions of the above mentioned system are discussed. The experimental results and computer simulation are compared.

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