ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN—POLONIA
VOL. XIII, 25 SECTIO AA 1968

Z Katedry Fizyki Ogólnej Wydziału Mat. Fiz. Chem. UMCS
Kierownik: doc. dr Danuta Stachórska

Juliusz SIELANKO, Marek SOWA

Phase Detector of Sound Waves as an Analyser of Gas Concentration in Thermodiffusion Process

Detektor fazy fali dźwiękowej jako analizator składu gazu w procesie termodyfuzji

Фазовый детектор звуковой волны как анализатор состава газовой смеси в процессе термодиффузии

Experimental studies of the thermodiffusion process require an exact determination of the concentration difference of two diffusing gases in the cold and hot parts of the apparatus. This difference is usually small and does not exceed 10% [1]. Thus the accuracy of instruments used for measuring gas concentration ought not to be lower than 0.1%.

There are several methods of determining the concentration of a gas mixture in the thermodiffusion process which are based on the variations of heat conductivity, viscosity, optical refractivity or sound velocity. Contrary to the first methods frequently reported in thermodiffusion, measurements of gas concentration based on the variations of sound velocity in the mixture are rarely described in the literature.

Studies of thermodiffusion separation with ultrasonics were described by Itterbeek and Nihoul [2, 3, 4]. For thermodiffusion measurements they used an apparatus with two bulbs with an acoustic interferometer to measure the difference of concentrations. A simplified scheme of this apparatus is presented in Fig. 1. Piezoelectric properties of quartz were utilized to produce ultrasonic waves in the mixture examined and to detect them. Each time when the distance between the quartz and the reflector equals the total of half-waves, the intensity of the standing sound wave reaches its maximum (resonance) and the

quartz, as an emitter, releases its maximum energy. The positions of the reflector corresponding to the resonance can be registered in various ways [5], e.g. by the power input with a generator feeding the quartz, by measuring the voltage on the electrodes of the quartz or a high frequency current flowing through the quartz. In this way the length of a sound wave and the sound velocity in the gas, or in the mixture of gases, can be determined, provided the quartz vibration is known. Sound velocity for the mixture of two gases is determined by the equation [1]:

$$V^2 = \frac{RT}{c\,M + (1-c)\,M'} \cdot \frac{cCp + (1-c)\,Cp'}{cCv + (1-c)\,Cv'} \tag{1}$$

where: M, M', — molecular masses of both components, C_p, C_v and C'_p, C'_v — specific heat at constant pressure and volume of both kinds of gases, c — concentration of one component. As results from the above formula, gas concentration can be determined if sound velocity in the

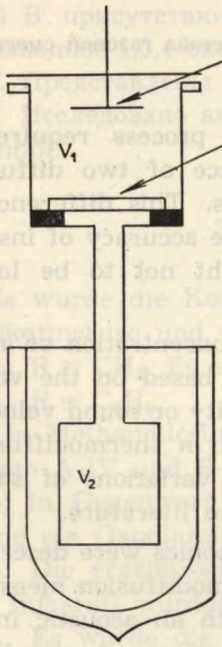

Fig. 1. Simplified scheme of the apparatus designed by A. van Itterbeek and J. Nihoul

mixture is known. In Fig. 2 the relation between v and c (based on formula 1) is given for mixture H_2—CO_2 with c from 40% to 60% of CO_2.

We modified the sound velocity method of analysis of small differences in gas mixture. The blocking scheme of the apparatus is shown in Fig. 3. The sample gas was introduced into a tube container inside of

which a piezo-crystal (Seignette salt), which served as an emitter of sound waves, was placed at one end, and at the other end a piezoelectric microphone. The tube was about 30 cm in length, its diameter was 7 mm. Impulses with phase shift of $t = \frac{l}{v}$ — where l is the tube length and v is the sound velocity — were received by the microphone and then trans-

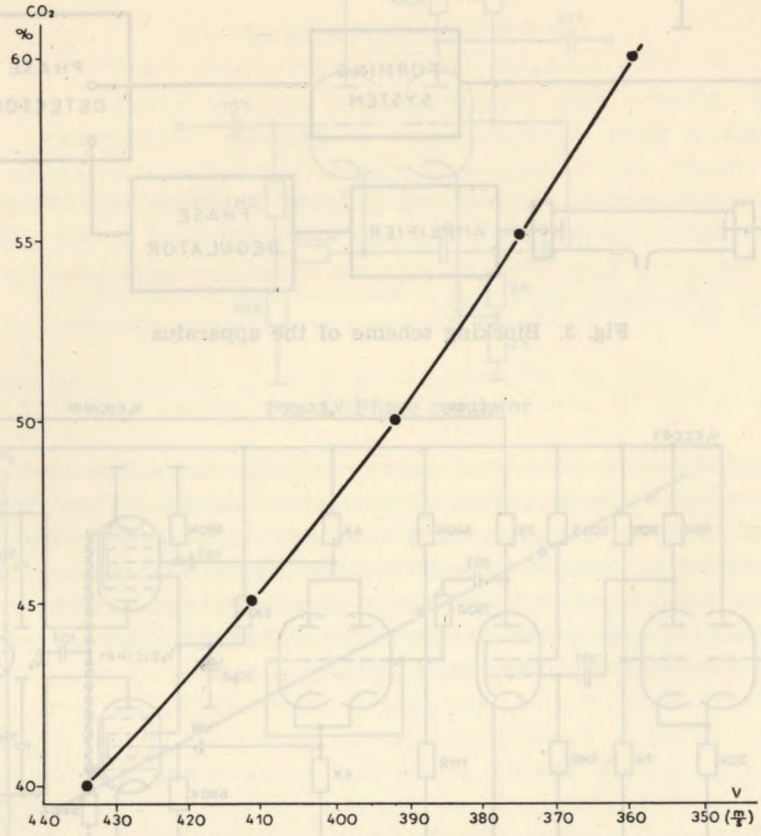

Fig. 2. Sound velocity as a function of gas concentration. Theoretical curve calculated according to formula 1 for the H_2 — CO_2 mixture

ferred into the phase detector. The scheme of the phase detector together with the forming system is presented in Fig. 4. A sinusoidal signal from the generator is transformed into rectangular impulses in the tube system V_1 and V_2. Tube V_2 does the work of a phase invertor. Impulses, shifted by 180° in the phase, pass on to the input of the phase detector with tubes V_4 and V_5, where they are mixed with an emplified signal

a voltmeter of high inner resistance which shows the phase shift of the impulses after they passed through the gas. This phase shift can be changed by a phase regulator shown in Fig. 5. Phase regulation is

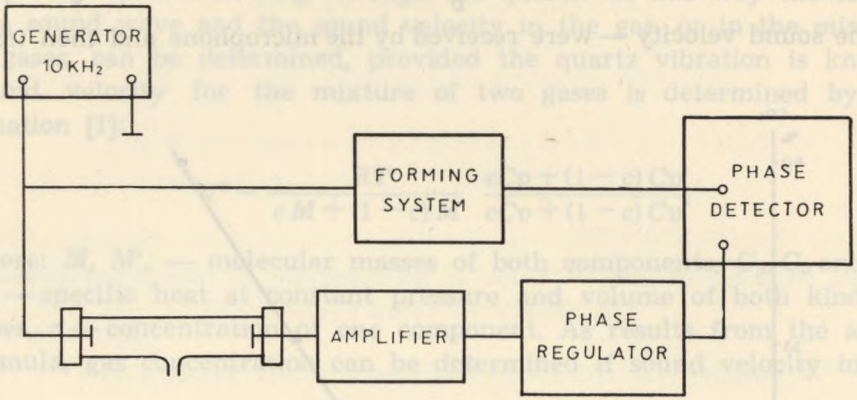

Fig. 3. Blocking scheme of the apparatus

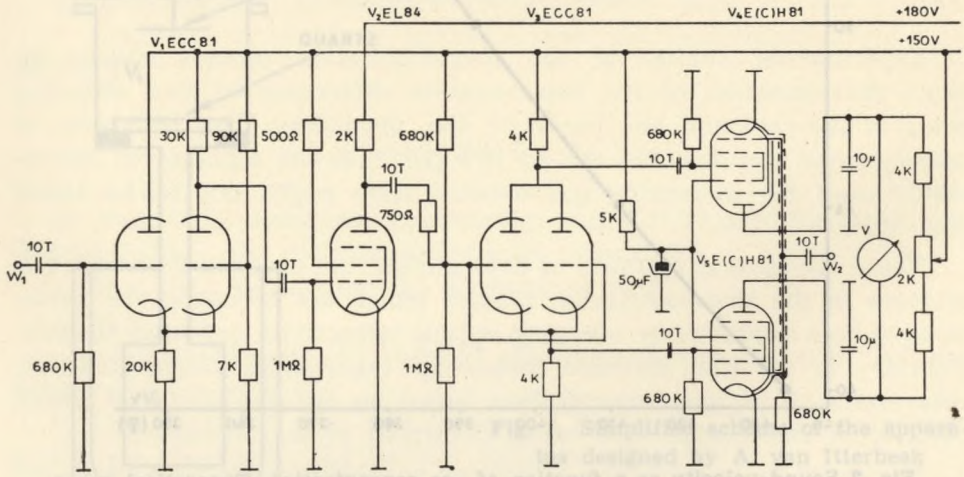

Fig. 4. Forming system and phase detector

necessary for nulling the apparatus for a chosen gas concentration. Our apparatus was nulled for mixture H_2 — CO_2 at a concentration of 50%/50%. The deflection of the voltmeter caused by the change of gas concentration will show the phase shift in comparison with the signal in the mixture for which the apparatus was nulled. The calibration curve of the detector for H_2 — CO_2 is given in Fig. 6.

The work of the above apparatus is adapted especially for thermodiffusion if initial gas concentration is known and only small separation effects are measured, e.g. in the examination of the relationship between the thermodiffusion coefficient and pressure [6, 7].

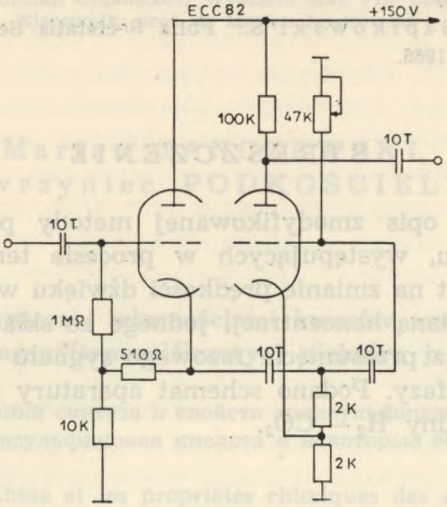

Fig. 5. Phase regulator

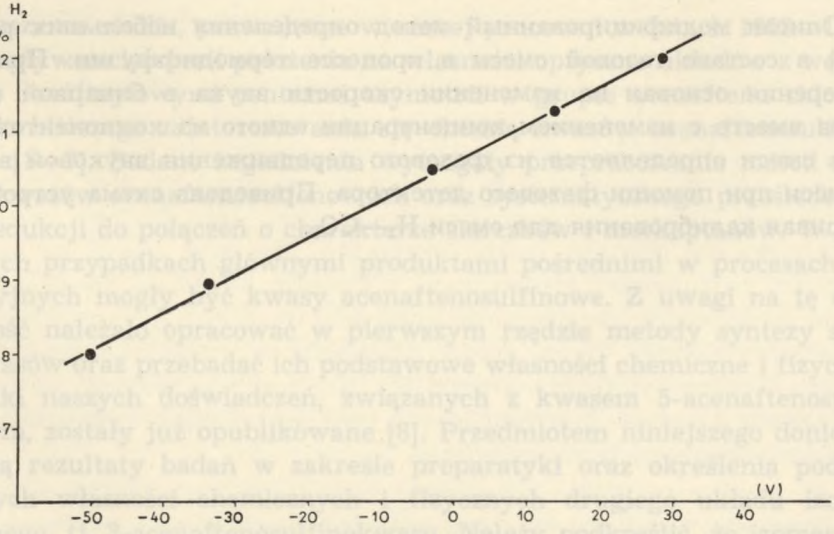

Fig. 6. Calibration curve of the phase detector for the H_2 — CO_2 mixture

REFERENCES

1. Grew K. E., Ibbs T. L.: Thermal Diffusion in Gases. Cambridge at the University Press, 1952.
2. Van Itterbeek A., Nihoul J.: Acustica, 5, 142 (1955).

3. Van Itterbeek A., Forrez G., Mariens P.: Physica, **19**, 525 (1953).
4. Van Itterbeek A., Nihoul J.: Acustica, **7**, 180 1957).
5. Bergmann L.: Der Ultraschall und seine Anwendung in Wissenschaft und Technik. Zürich 1954.
6. Szpikowski S.: Ann. Univ. Mariae Curie-Skłodowska, Lublin, sectio AA, vol. **XIV**, 2, (1959).
7. Sielanko J., Szpikowski S.: Folia Societatis Scientiarum Lublinensis, sectio C, vol. 5/6, 1965.

STRESZCZENIE

Praca zawiera opis zmodyfikowanej metody pomiaru niewielkich różnic składu gazu, występujących w procesie termodyfuzji. Zasada pomiaru oparta jest na zmianie prędkości dźwięku w mieszaninie dwóch gazów wraz ze zmianą koncentracji jednego ze składników. Skład mieszaniny określano z przesunięcia fazowego sygnału w mieszaninie przy pomocy detektora fazy. Podano schemat aparatury oraz krzywą cechowania dla mieszaniny $H_2 - CO_2$.

РЕЗЮМЕ

Описан модифицированный метод определения небольших разностей в составе газовой смеси в процессе термодиффузии. Принцип измерения основан на изменении скорости звука в бинарной смеси газов вместе с изменением концентрации одного из компонентов. Состав смеси определяется из фазового передвижения звуковой волны в смеси при помощи фазового детектора. Приведена схема устройства и кривая калибрования для смеси H_2—CO_2.

Papier druk. sat. III kl. 80 g Format 70 × 100 Druku str. 6
Annales UMCS Lublin 1968 LZGraf. im. PKWN, Lublin, Unicka 4 Zam. 4044. 14.XII.68
600 + 100 egz. F-3 Manuskrypt otrzymano 14.XII.68 Data ukończenia 15.VI.69