

NATIONAL INSTITUTE FOR SAFETY AND HYGIENE AT WORK

Quality Study of Self-Contained Closed Circuit Breathing Apparatus on the Spanish Market

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Introduction

The great importance that these equipments have for personal protection in situations that involve high risk, inspired the National Institute for Safety and Hygiene of Spain to carry out a study to determine the quality of this equipment in the labor field, principally in mines and fires protection.

RELACION ENTRE PRODUCCION DE CO₂ Y VOLUMEN MINUTO DEPENDIENDO DE DIFERENTES TASAS DE TRABAJO, PARA UNA PERDIDA DE CARGA DE 64MM. c.d.a.

Clases de trabajo	Volumen (l/minuto)	Consumo de O ₂		Producción de CO ₂ (ml/minuto)	% de CO ₂ respecto volumen minuto	
		ml/min	% de V _{min}		%	p.p.m.
Sedentario	9'1	304	3'34	259	2'84	28.400
208 kgm/minuto	19'8	812	4'10	709	3'58	35.800
415 kgm/minuto	27'0	1.159	4'29	1.039	3'55	38.500
525 kgm/minuto	32'0	1.396	4'36	1.274	3'95	39.800
622 kgm/minuto	36'6	1.606	4'39	1.482	4'05	40.500
830 kgm/minuto	48'9	2.052	4'19	1.976	4'04	40.400
1.107 kgm/minuto	64'4	2.591	4'02	2.621	4'07	40.700
1.334 kgm/minuto	81'3	3.033	3'73	3.231	3'97	39.700
1.660 kgm/minuto	90'3	3.245	3'59	3.450	3'82	33.200

Table 1

Silverman, Plotkin, Sawyers and Yancey: Air Flow Measurements on Human Subjects with and without Respiratory Resistance at Several Work Rates", Arch. Ind. Hyg. Occupationa Med. 3: 461, May 1951.

The tests were conducted on two equipments corresponding to the class without production of oxygen.

The parameters that we observed and determined with more attention were: carbon dioxide content, temperature of the inhaled air, the operation of the lung governed oxygen supply and the work carried out by the equipment of integral form.

To execute the test with simulated ambient air (as similar as possible to the function of the human organism), we were interested at first to know the average of the carbon dioxide contamination produced by the lungs. For that we studied all the articles published by the international specialists among whom we point to Silverman and Raven, and we see that this average can be approximated without much error to four percent (4%) in volume. Another interesting subject to be known is the permitted limit of the carbon dioxide in the respirable air or inhalation air. In this point the specialists do not fully agree, and although we understood that this data cannot be given in a sharply and absolute form, we thought that although with reservation to the specific attitude of the individual this data could be given within a reasonable average.

The limit that we have found in respect to the carbon dioxide is the same given in the TLVs. USA (0.5% by the TWA and 1.5% to the STEL) and those indicated by the CEN in the preN 145 of February 1985, 1.5% in volume when the equipment has incorporated a facepiece. Nevertheless many specialists as Craig, Forester, Shershow and Lum give caution avoiding elevated carbon dioxide (CO₂) because it may produce giddiness, nausea, hyperventilation... which for many persons are the favorable conditions to suffer a labor accident.

Another parameter to be studied in these equipments

of respiratory protection was temperature (as the elimination of carbon dioxide is carried out by an exothermic reaction). The level that the users have to tolerate and to know if this average of temperature were able to produce situation of human insecurity because some stress will be originated that will cause a lack of reflex in the persons that will drive to an accident. Another interesting aspect was to know the limits given by the two organizations that protect and regulate these equipments. Meanwhile the United States was permitted up to fifty-seven degrees centigrade (57°C) during fifteen minutes, the CEN in his preN 145 does not authorize more than forty-five degrees centigrade (45°C).

Test

Once we knew all the limits of the principal parameters such as the concentration of CO₂ and temperature, the breathing machine was used to operate the SCBA without and with production of oxygen as follows:

Closed circuit equipments without production of oxygen.

These equipments are characterized due to the elimination of carbon dioxide produced by the respiration by the alkaline hydroxides or by soda lime the lack of produced oxygen is compensated for by means of a small bottle (2 litre approximately) at a pressure of 200 bars.

The test set up for the development of these tests is shown in Chart 1 and 1A with the following components:

- Alternative breathing machine or artificial lung with sinusoidal breathing corresponding to work of 622 kilogrametre at a minute volume of forty litres (2 l/strokes x 20 strokes/min.)
- Solenoid valves controlled by a breathing machine.
- Humidifier with psicometer in order to get a relative humidity in the equipment during the test.
- Carbon dioxide analyzer.

- Oxygen analyzer.
- Meters of pressure and temperature before and after the equipment tested.
- Bottle of carbon dioxide (CO₂) in order to get the desired contamination in the test.
- Meter of flows and keys for regulation and obtention of the flow of the test.
- Bottle of N₂ in order to get a minor proportion of O₂ in the exhalation air.
- Breathing apparatus.

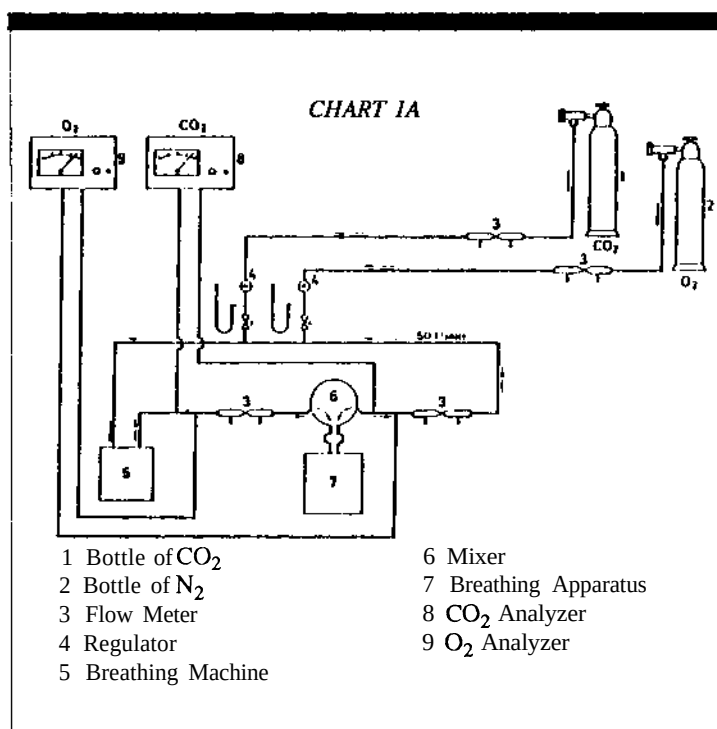
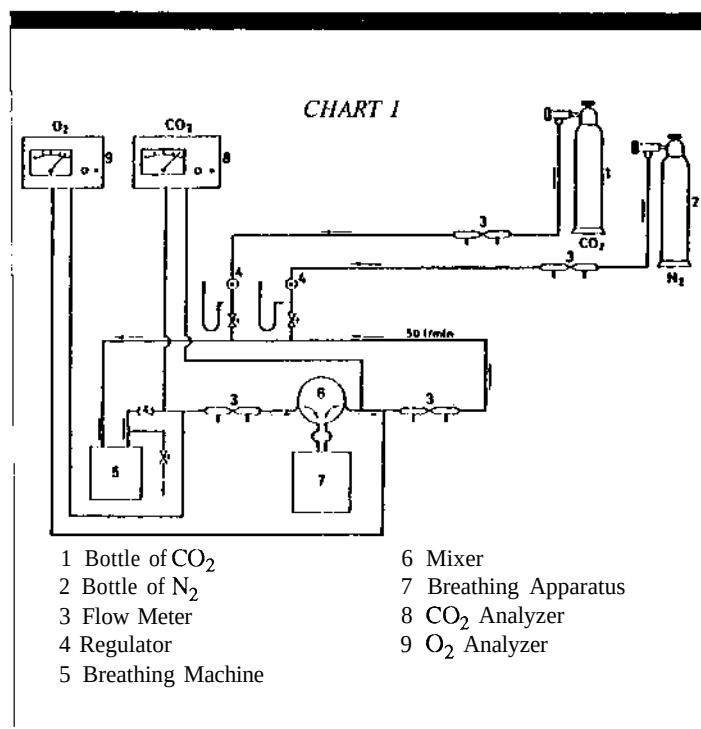
The equipments chosen were among the most utilized in the Spanish labor field that we named by the letters "B" and "C".

The first one was an equipment with a cartridge of soda lime and with an endurance according to the manufacturer of one hour of utilization.

The second equipment was a model of endurance and with a cartridge of alkaline hydroxide.

The conditions of the test were as follows:

- Concentration of CO₂ in the inhalation air = 4%



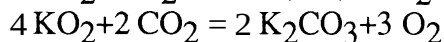
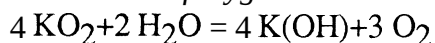
- Relative humidity = 90 to 100%
- Minute volume = 40 l/min. (21 stroke x 20 strokes/min.)

The results of CO₂ concentrations in the inhalation air are represented in the chart 22 and 39 and the others belonging to the temperatures in the same air in the graphics 4 and 5. All these data will be analyzed later on.

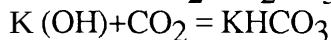
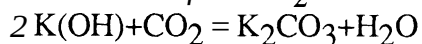
Equipments of closed circuit with production of oxygen.

These equipments eliminate the carbon dioxide and at the same time they produce some quantity of oxygen allowing the contaminated exhalation air to pass through filters generally using metallic peroxides of potassium (KO₂) producing an exothermic reaction rather strong or by sodium chlorate (NaClO₃) filters. A reaction type could be as follows:

Generation of oxygen:

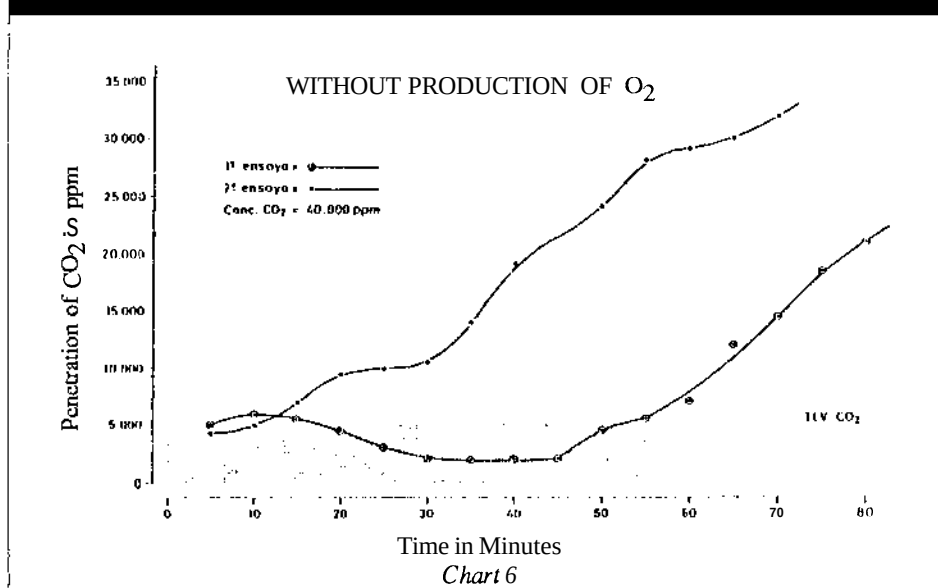
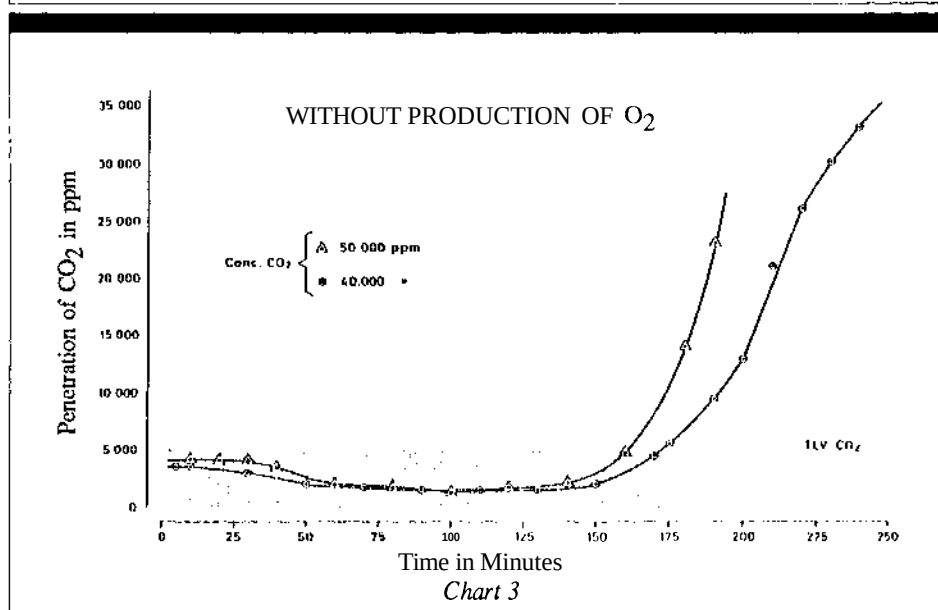
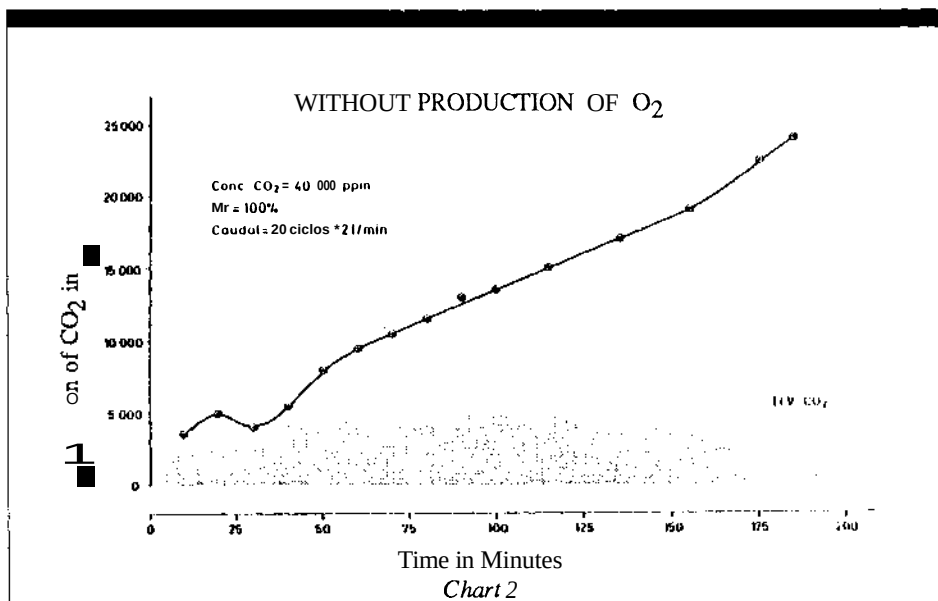


Elimination of the CO₂:



The scheme of mounting for this test is similar to the prior experiment with the only difference is the incorporation of oxygen. Meanwhile a small bottle in the same equipment replaces the reaction of the filter. In order to see the quality of these equipments the tests were made with the models named by the letters "D", "E" and "F".

The equipment D was the potassium peroxide (KO₂) with an endurance of sixty (60) minutes. The E used a filter of chlorate with



an endurance of one hour and the F also used of KO_2 and endurance of sixty (60) minutes, (according to the manufacturers).

The tests were made with alternative machine or artificial lung under the following conditions:

- Concentration of CO_2 in the exhalation air = 4%
- Minute volume = 40 l/min. (2 l/stroke x 20 strokes/min)

The results of concentration of CO_2 in the inhalation air are represented in the inhalation air are represented in the graphics 6, 7 and 8 and the temperatures in 9 and 10.

The data are analyzed as follows:

Analysis of the results

First we are going to analyze the quality of the equipments in regard to their capacity for eliminating the CO_2 and therefore the endurance of the apparatus.

Equipment without production of oxygen.

The "B" exceeds the 0.5% of carbon dioxide to the forty (40)

minutes of the working time and the 1.5% from the start of the 115 minutes of work, because of this data European use would be valid if it is used with a mask, and it is classified equipment of one hour.

If we take into consideration the American TLVs. In Spain we would not officially approve because it does not reach one hour of working time below the 0.5%. Nevertheless as the STEL is of 1.5% and the resting time is 20 minutes, it would be nearly in the limits of utilization.

The equipment "C" was tested at 4 and 5% of carbon dioxide but we are going to analyze only the results obtained with contamination of the 4% of CO_2 .

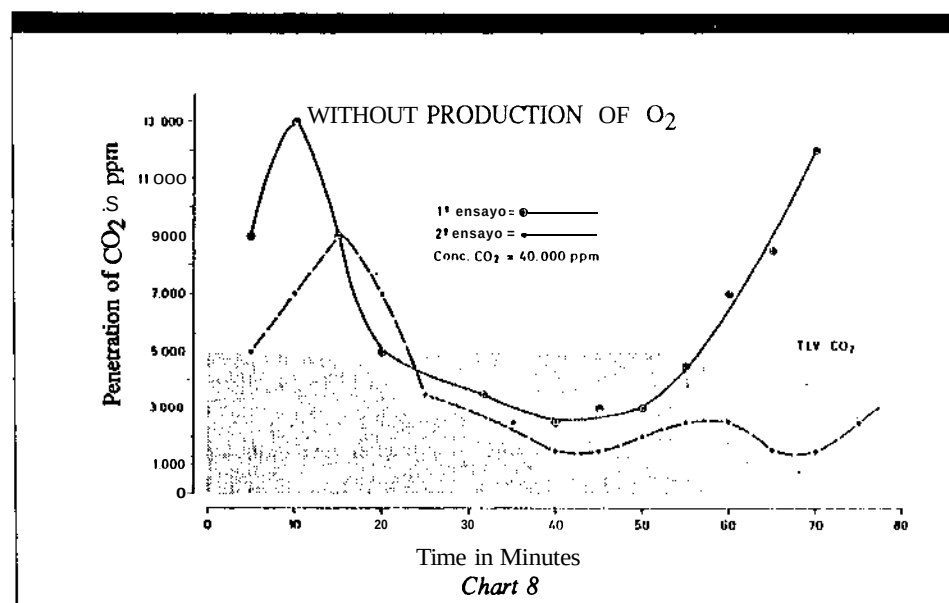
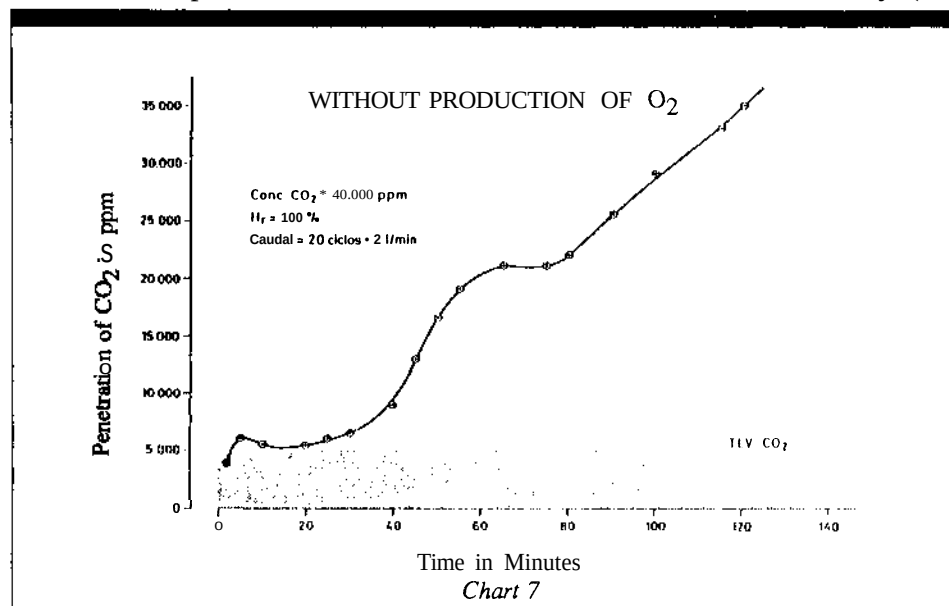
According to the chart 3 we may see that the 0.5% exceeds at 175 minutes and the 1.5% at 205 minutes.

The manufacturer was considering this equipment for 4 hours and applying the American limitations. The Europeans as well would be contradictory because it reaches the permitted limits before the 240 minutes.

Equipment with production of oxygen.

The equipment "D" was made two tests with great disparity in results as we may see in the chart 6. In this one we may see that the 0.5% of CO_2 is reached at 55 and 10 minutes in the first and second test respectively and the 1.5% at 72 and 37 minutes according to the test. In no case may we consider this equipment good with this disparity in the results considering American and European Standard.

The equipment "E" shows its results in the chart 7 and in this



graphic we may see that it reaches the 0.5% of CO_2 at 15 minutes and the 1.5% at 49 minutes. In no case, either by the CEN nor by the TLVs, would it be acceptable for use.

The equipment "F" is considered by the manufacturer as one hour and two tests made. The results are shown in the chart 8, reaching the 0.5% of CO at the 56 minutes in the first and at more than 80 minutes in the second. The 1.5% point was reached at more than 75 minutes in the first test and many more minutes in the second test. Because of this performance this equipment is apt to be used.

As we analyze the graphics of the temperature reached during the test carried out on the equipment, we see that the equipments "B", "C", "D" and "E" do not reach the 45 degrees centigrade indicated as limit

by the CEN during all the period of the test as it is shown in the charts 4, 5, 9, and 10.

The equipment "F" reached the 45 degrees centigrade at the 47 and 45 minutes in the first and second test carried out. Since this test according to the CEN, it would not be used as equipment for one hour. Chart 11.

Conclusions

The equipment utilized in Spain and from which the most significant were chosen, showed many failures in reference to the retention of CO_2 and in one case

(in which it is correct) the temperature raises above the 45 degrees centigrade. Therefore, it is necessary that as soon as possible standards would be drafted and published concerning these equipments so that experiments may be accomplished with the minimum requirements in Europe.

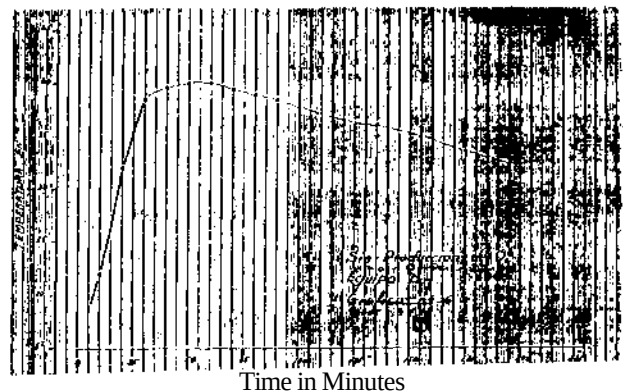


Chart 4

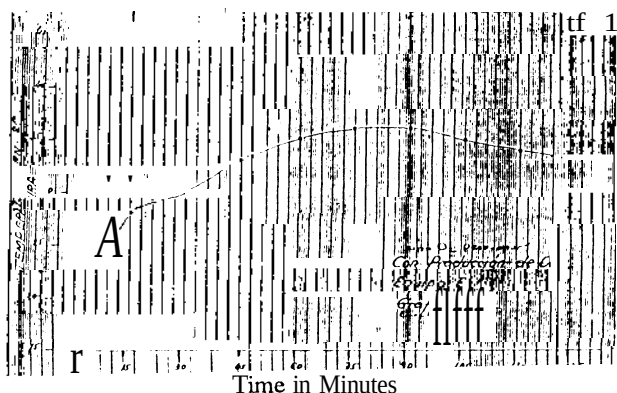
WITHOUT PRODUCTION OF O_2 

Chart 10

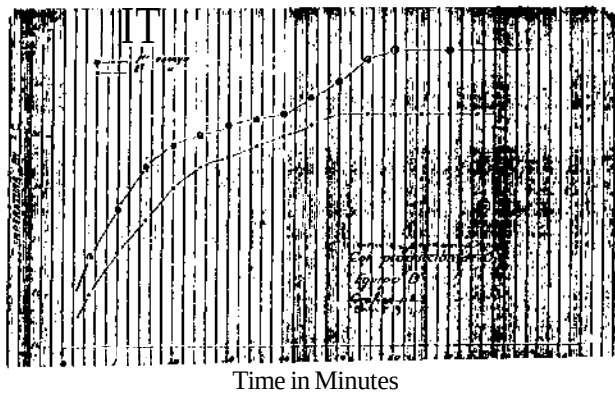
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Chart 9

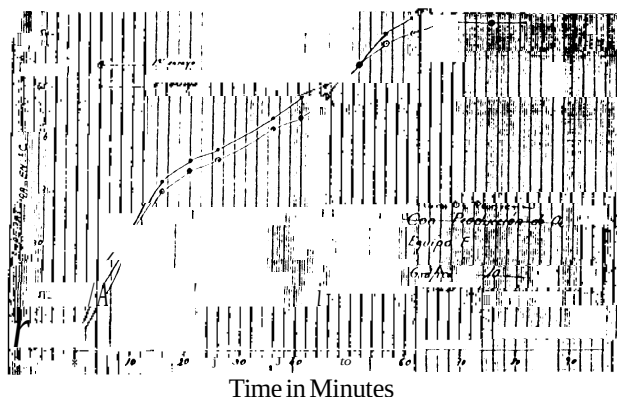
WITHOUT PRODUCTION OF O_2 

Chart 11

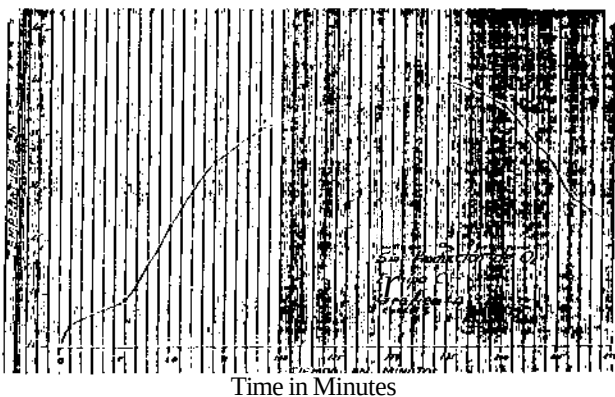
WITHOUT PRODUCTION OF O_2 

Chart 5

WITHOUT PRODUCTION OF O_2