

A STUDY OF THE MOISTURE ADSORPTION QUALITIES
OF SOME OF THE IMPORTANT
FIBERS,

by

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CHAPTER I.

INTRODUCTION .

The subject of moisture adsorption of fibers is a very important one because of its practical and theoretical value.

In connection with a recent smoke survey, it was learned that it would be very difficult to determine the most suitable fiber for filtering dust out of the air because of the wide variation of moisture in fibers.

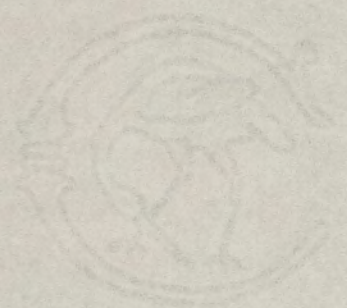
The object of this investigation is therefore to determine the quantity of moisture that various fibers will actually adsorb, and to determine the time required to remove this moisture to a constant weight by passing dry air over the fiber at a definite temperature and rate of flow.

Another practical value of moisture adsorption in fibers is found in its relation to the textile industry. In various processes of dyeing, large quantities of moisture are given off and often must be removed to prevent any harm from being done to the fiber in the various stages of the process. In the spinning and weaving industries, a certain amount of humidity is essential to prevent the thread from becoming brittle, and also to prevent any accumulation of heavy charges

of static electricity. The purchaser should know just how much moisture is present in the particular fiber that he is buying, in order to safeguard himself from paying large sums of money for wet fiber.

Very little written material could be found on the moisture adsorption of fibers, and no quantitative data whatsoever could be found on this particular phase of the subject of air filtration.

GRAVES



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CHAPTER II.

GENERAL THEORY

Bancroft defines adsorption as "a condensation on the surface", and it depends upon the temperature and pressure, and upon the nature of the substance adsorbed and that of the adsorbing agent. All solids tend to adsorb the gases or vapors which come into contact with them, the amount of adsorption depending upon the physical state of the substances. When the same solid and liquid are taken into consideration, the amount of adsorption increases with an increase in pressure and decreases with a rise in temperature.^{1.}

"If a liquid is adsorbed at a solid surface, it forms a liquid film and we say that it wets the solid. If a liquid is not adsorbed by a solid, it does not wet the latter. There has been a good deal of question whether the liquid meets the wall at a definite angle, the contact angle, or whether the contact angle is zero. Lord Raleigh states definitely that in his opinion the contact angle is zero, and this must be true if we consider that the liquid is adsorbed by the solid. The formation of a liquid film over the surface of a wetted solid accounts for the generally accepted fact that the rise of a liquid in a capillary tube is independent of

Note: 1. W.D. Bancroft, Ap. Col. Chem. P 3, 1921.

the nature of the walls of the tube. This has always been a very improbable state of things and one that could only be justified by the fact that it was so".².

The fibers used in this bit of research were cotton, wool, glass wool, Rayon, and asbestos, the object being to determine the rate of adsorption in these fibers and also to determine the rate of desaturation when dry air and dry hydrogen were passed over the adsorbed materials. In order to avoid calculations, the weights of the fibers used in the different measurements were made equal, and the rate of flow of the moist air, dry air, and hydrogen was kept constant.

Note 2: W.D. Bancroft, Ap. Col. Chem. P 61, 1921.

CHAPTER III.

A DESCRIPTION OF THE METHOD AND APPARATUS USED.

The present method was used because it seemed to be the simplest and most accurate solution to the problem in question.

The apparatus used in this determination is shown in figure I, page 6. A 110 volt A.C. motor (1), was used to operate an air pump (2), which was used for the purpose of forcing air through the train apparatus. After air flows from the pump it enters the bottle (3) in which calcium chloride is placed to dry the air, then into a bottle (4) containing sulfuric acid to dry the air which is left undried by the calcium chloride and also to prevent any impurities such as dust from passing on, then into a bottle (5) containing glass wool which condenses any of the acid which happens to come over, then into the three bottles (6,7, and 8) which saturates the air, and then into a bottle (9) which contains cotton and glass wool for the purpose of preventing a spray of water from entering the tube of weighed fiber.

When it was desired to pass dry air over the fiber, a valve was placed between (4) and (5) which makes the dry air flow directly from (4) into the weighing tube.

When it was desired to pass dry hydrogen over the fiber, the hydrogen tank was attached to a bottle containing calcium chloride, and then into the weighing tube.

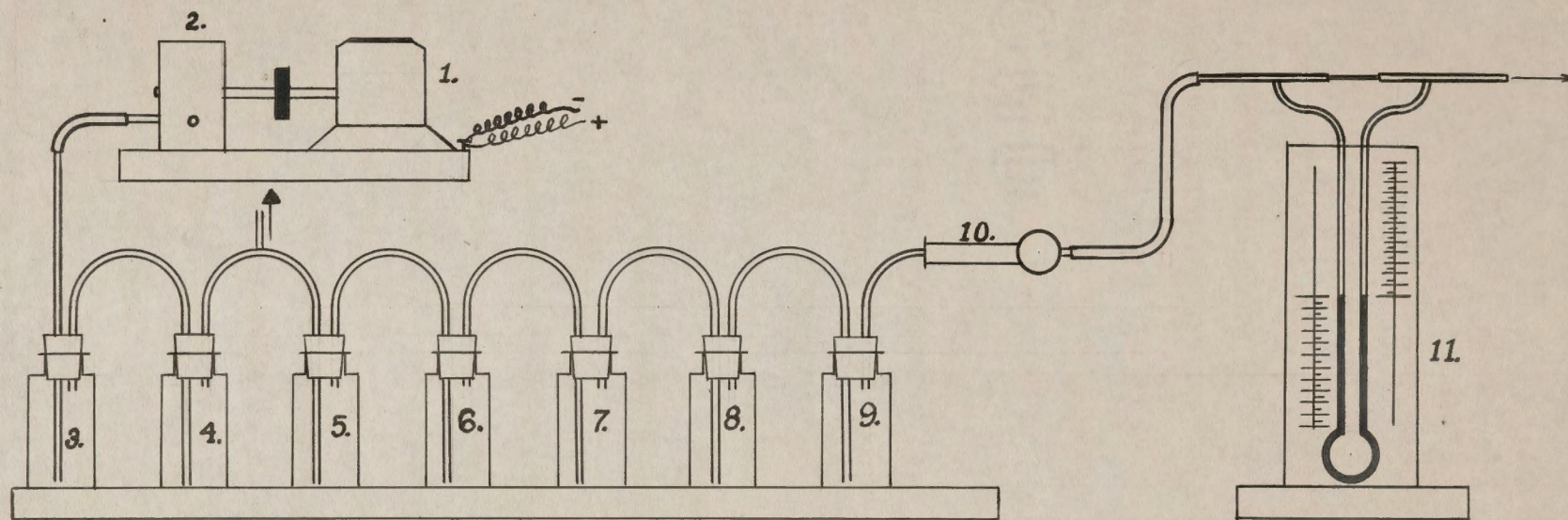


Figure
A Diagram Of The Apparatus Used In Determining
Saturation And Desaturation.

A flow meter constructed for measuring the rate of flow of moist air, dry air, and hydrogen in cubic centimeters per second, was connected to the outlet of the weighing tube(10) thus enabling the observer to maintain a constant flow through the apparatus.

Before any accurate work can be done in determining adsorption and desaturation, the materials must be dried as much as possible and dried uniformly. Warm dry air was passed over the fibers which were then placed in a desiccator and let stand over night.

The dried material was placed in a weighing tube which had previously been weighed (in each case a weight of material was made to be equal to .215 grams). The apparatus was set up exactly as shown in figure I, and moist air was passed over the material at the rate of 4.4 cc per second (kept constant) and the weighing tube was weighed at intervals of 5 minutes and in some cases every minute where adsorption was found to be very slow, until the material reached its maximum weight. For each fiber under consideration, enough tests were made so as to assure a reasonable amount of accuracy.

After the material had been saturated, the valve between (4) and (5), figure I, was opened and dry air was passed over the fibers weighing the tube at equal intervals as above, until the weight of the material had reached a minimum weight.

Hydrogen (dried) was likewise passed over the adsorbed material and the minimum weight of material was determined.

After the values for adsorption and desaturation were found, graphs were drawn in which the time element was plotted against the amount of adsorption and desaturation for the purpose of representing graphically the rate of adsorption and desaturation.

Adsorption and desaturation tests on fibers are very difficult to make correctly due to the fact that it is hard to completely dry the material, and also because the fibers are likely to gain or lose weight during the process of weighing. Much care was taken to assure a completely dried fiber, and the weighings were made under glass to prevent as much as possible the outside air from coming in contact with the material while it was being weighed.

It is interesting to note that Rayon, a material which is made artificially from wood, has the highest adsorption value of all. One would hardly think that man could make a fiber which would surpass the natural fiber in this respect.

CHAPTER IV.

CALIBRATION OF FLOWMETER .

In conducting research on any material where the rate of flow of air or gas is an important factor, it is very necessary that the rate of flow of the air or gas is known so that a check may be made of the numerous tests carried out. The rate of flow of air and hydrogen must be known in this investigation in order to determine the time required for adsorption and desaturation.

For the purpose of measuring the flow of a gas or air, a very simple device was constructed known as a flow meter, and meaning a measure of flow. It consisted of the apparatus as shown in figure II, page 10, and was made as follows: A long tube (about 2 feet in length) was heated in the center over a wing top flame, until the glass was sufficiently soft to bend easily. The center of the tube was then bent into a circle and the sides of the tube were brought close together as shown in the figure. A very small capillary tube was connected with this bent tube so as to be between the left and right side arm of the bent tube, and after the tube had been partly filled with methyl orange solution the meter was ready for calibration.

The principle upon which the flow meter is based is very simple. When a gas enters the left arm of the meter,

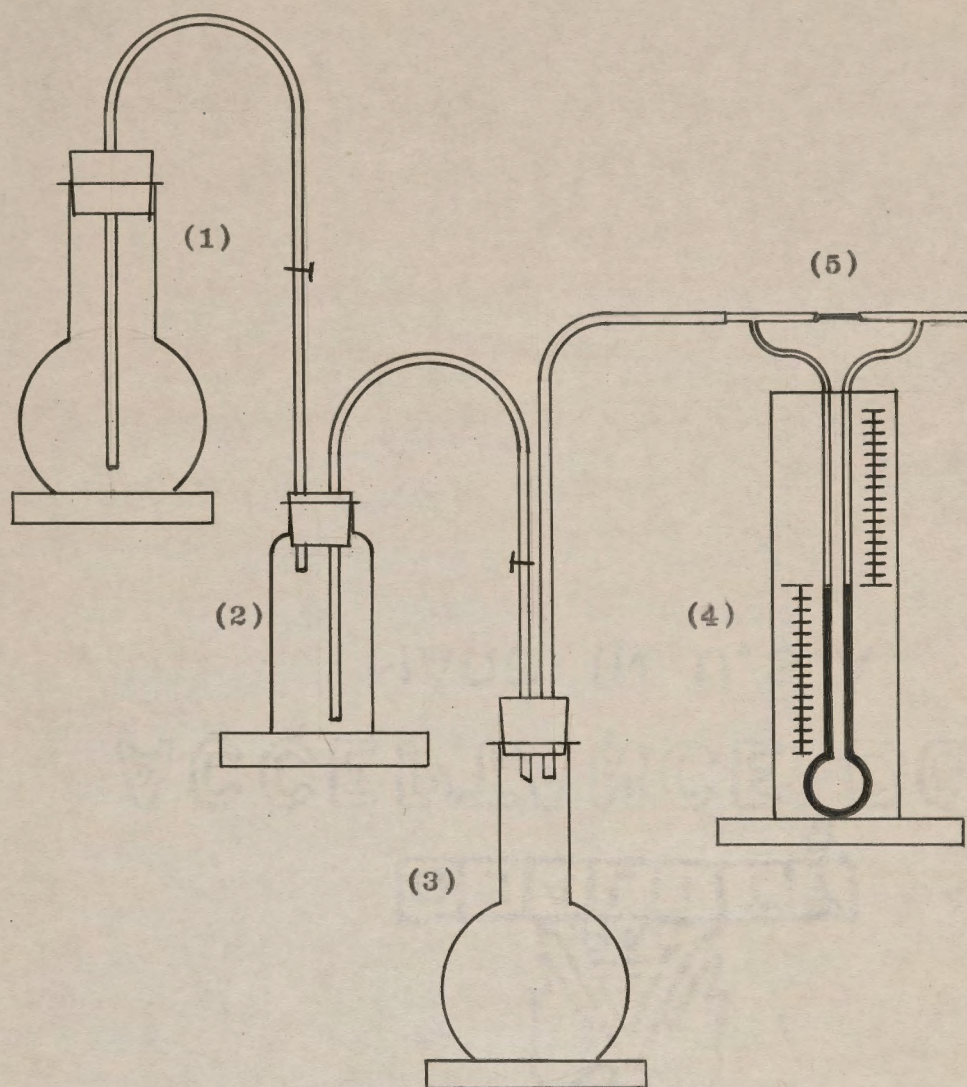


Figure II. A Diagram Of The Hookup Used In
Calibrating Flowmeter.

due to the fact that there is a pressure produced by the gas trying to force its way through the capillary tube in the left side of the apparatus, the methyl orange solution drops on the left side and rises on the right side. The difference in the level of the methyl orange in the left and right side is a measure of the rate of flow of the gas which passes through the apparatus, because the rate of flow of the gas passed through the apparatus is proportional to the difference in the two levels.

The principle upon which the flowmeter was calibrated was as follows: A definite amount of air or gas was displaced which passed through the flowmeter in a definite time, and marks were made on the scale corresponding to the difference in levels. After this was known, the rate of flow was easily calculated by dividing the cc of air passed through by the time of flow in seconds. This rate of flow corresponded to the length of the difference in the two levels and was divided up into units representing 1 cc per second and each of these units were divided up into tenths.

It was necessary to calibrate the meter for air and hydrogen both due to the lightness of hydrogen.

Method used in calibration.

Three bottles, two, 2 liter; and 1 long bottle, were connected as shown in figure II, and the upper bottle (1) was filled with water and the cocks were closed. The flow meter (4) was attached as shown. The

cocks were opened, and the water was allowed to siphon over from (1) into (2), and into (3), the time of the start of flow being recorded at the same time. The water flowing into (3) forced an amount of air (or hydrogen) equal to the amount of the water displaced which caused the deflection in the flowmeter. The time at the end of the flow of the water was recorded. The length of the difference in levels was stepped off on a sheet of paper. By knowing the time of flow of water and the volume of water, the rate of the corresponding flow was calculated by the equation

$$\frac{\text{cubic centimeters}}{\text{time}} = \text{cc per second.}$$

This length of the difference in levels was a measure of the rate of flow which was divided up into units representing 1 cc per second.

Calibration of flowmeter using air.

	I	II	III	IV
Time :Start	9:31	10:05	10:20	10:35
Time :End	10:36 $\frac{1}{2}$	10:10 $\frac{1}{2}$	10:25 $\frac{1}{2}$	10:40 $\frac{1}{2}$
Minutes required for flow	5 $\frac{1}{2}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$

Mean time = 5 1/2 minutes = 330 seconds.

Volume of water displaced from (1) = 1940 cc

Volume of Air displaced in (3) = 1940 cc

$$\frac{\text{cc}}{\text{time}} = \text{cc per second} = \frac{1940}{330} = 5.88 \text{ cc per second}$$

Length of difference in levels = 10.2 cm

$$\frac{10.2 \text{ cm}}{5.88 \text{ cc per sec}} = 1.74 \text{ cc. for each cc per second}$$

Calibration of flowmeter using Hydrogen.

	I	II	III
Time :Start	10:20	10:27	10:42
Time :End	10:23	10:30	10:45
Minutes required for flow	3	3	3

Mean time of flow of hydrogen = 3 minutes = 180sec.

cc of water displaced = 1180 cc

cc of hydrogen displaced = 1180 cc

Rate of flow of hydrogen = $\frac{1180}{180} = 6.55$ cc per sec

Length of difference in levels = 6.6 cm

Therefore 1 cc per second = $\frac{6.60}{6.55} = 1.00$ cm

CHAPTER V.

TABLES AND GRAPHS.

THE ADSORPTION OF MOISTURE BY COTTON.

Weight gained in	Time of adsorption in minutes						
	5	10	15	20	25	30	35&40
I.	.0106	.0024	.0010	.0008	.0006	.0004	.0000
II.	.0106	.0032	.0018	.0006	.0006	.0004	.0000
III.	.0124	.0034	.0012	.0008	.0006	.0004	.0000
IV.	.0120	.0026	.0014	.0008	.0006	.0004	.0000
V.	.0112	.0032	.0012	.0008	.0006	.0004	.0000
VI.	.0114	.0028	.0012	.0008	.0006	.0004	.0000
Average	.0113	.0029	.0012	.0008	.0006	.0004	.0000
Rate of flow of moist air = 4.2 4.6 4.4							

Average rate of flow = 4.4 cc per second

Weight of cotton = .215 grams

Room temperature = 28 degrees C.

THE DESATURATION OF COTTON.

Weight lost in	Time of desaturation in minutes						
	5	10	15	20	25	30	35&40
I.	.0102	.0036	.0010	.0008	.0006	.0004	.0000
II.	.0100	.0030	.0012	.0008	.0006	.0004	.0000
III.	.0114	.0032	.0012	.0008	.0006	.0004	.0000
IV.	.0120	.0032	.0012	.0008	.0006	.0004	.0000
V.	.0140	.0036	.0010	.0008	.0006	.0004	.0000
VI.	.0136	.0032	.0012	.0008	.0006	.0004	.0000
Average	.0118	.0033	.0011	.0008	.0006	.0004	.0000

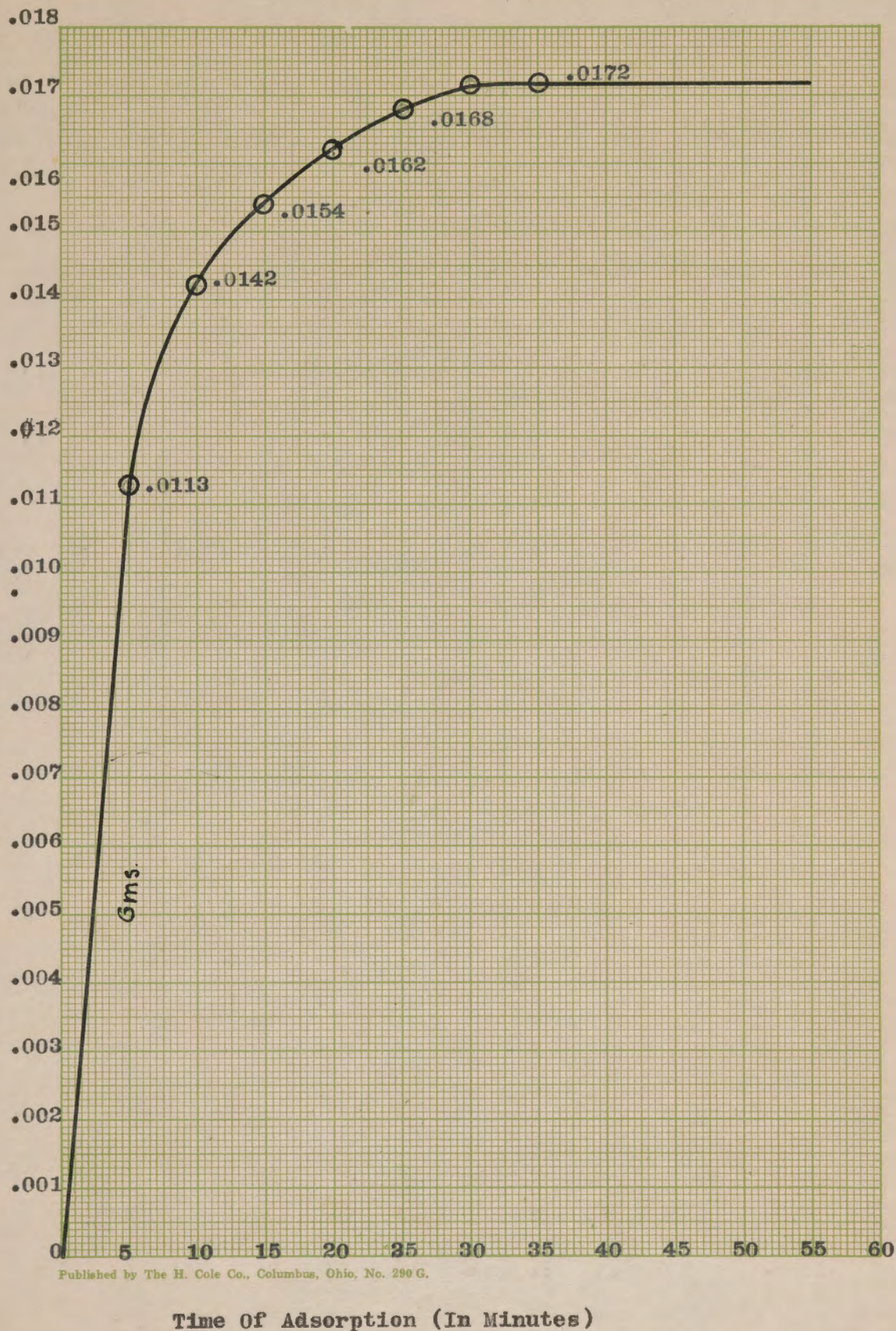
Weight of cotton = .215 grams

Rate of flow of dry air = 4.4 4.2 4.6

Average rate of flow of dry air = 4.4 cc per second

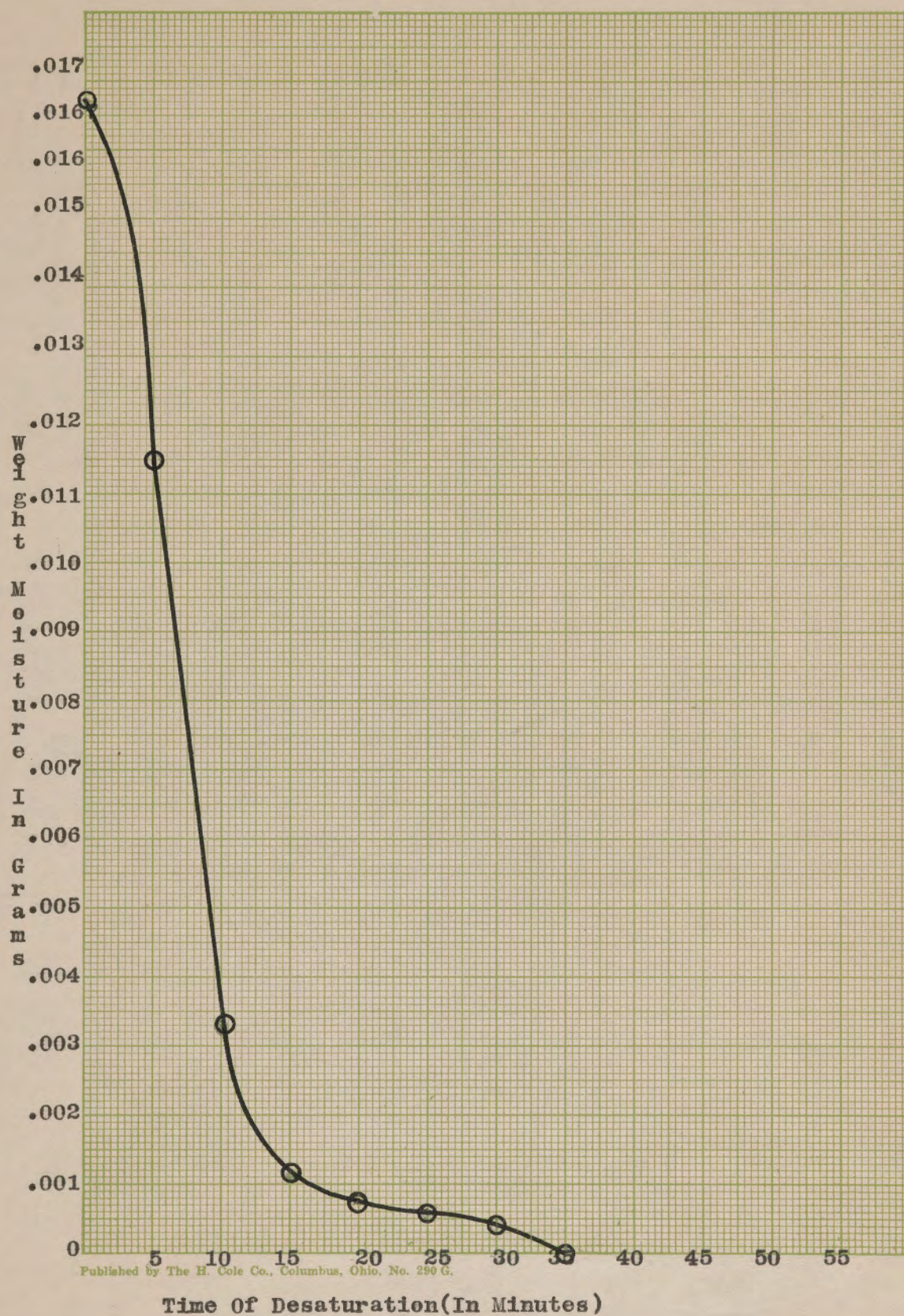
Room temperature = 28 degrees centigrade.

SATURATION CURVE OF COTTON SHOWING RATE OF SATURATION.



Time Of Adsorption (In Minutes)

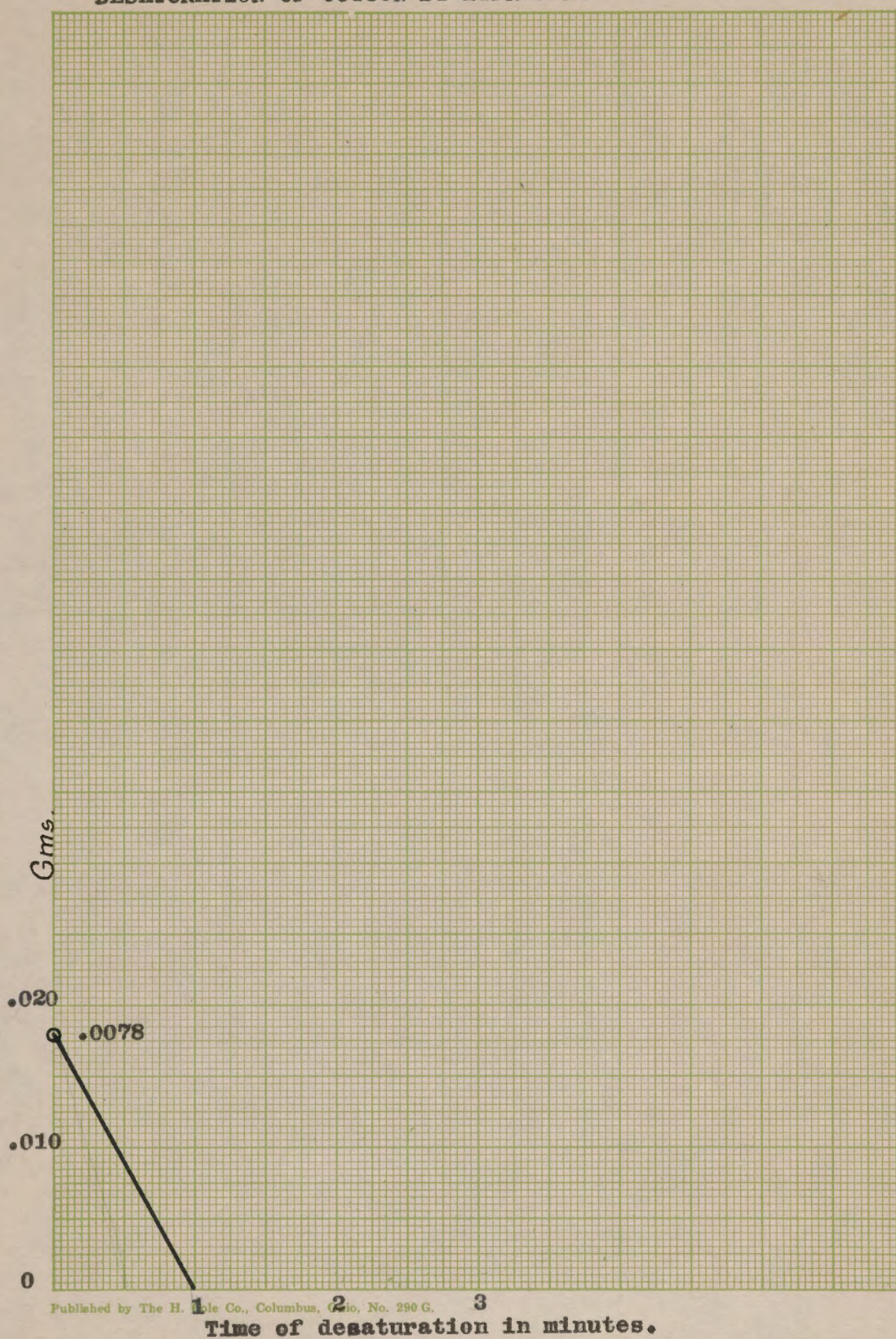
Desaturation Curve Of Cotton Showing Rate Of Desaturation.



RATE OF DESATURATION OF COTTON BY HYDROGEN.

Time in minutes	Weight lost in grams in	
	I	II
1	.0178	.0178
2	.0000	.0000
3	.0000	.0000

DESATURATION OF COTTON BY HYDROGEN.



ADSORPTION OF MOISTURE BY RAYON.

Time in minutes	Weight gained in grams in	
	I	II
5	.0186	.0186
10	.0088	.0088
15	.0058	.0058
20	.0042	.0042
25	.0026	.0026
30	.0018	.0018
35	.0016	.0016
40	.0016	.0016
45	.0008	.0008
50	.0008	.0008
55	.0008	.0008
60	.0002	.0002
65	.0000	.0000
70	.0000	.0000
75	.0000	.0000

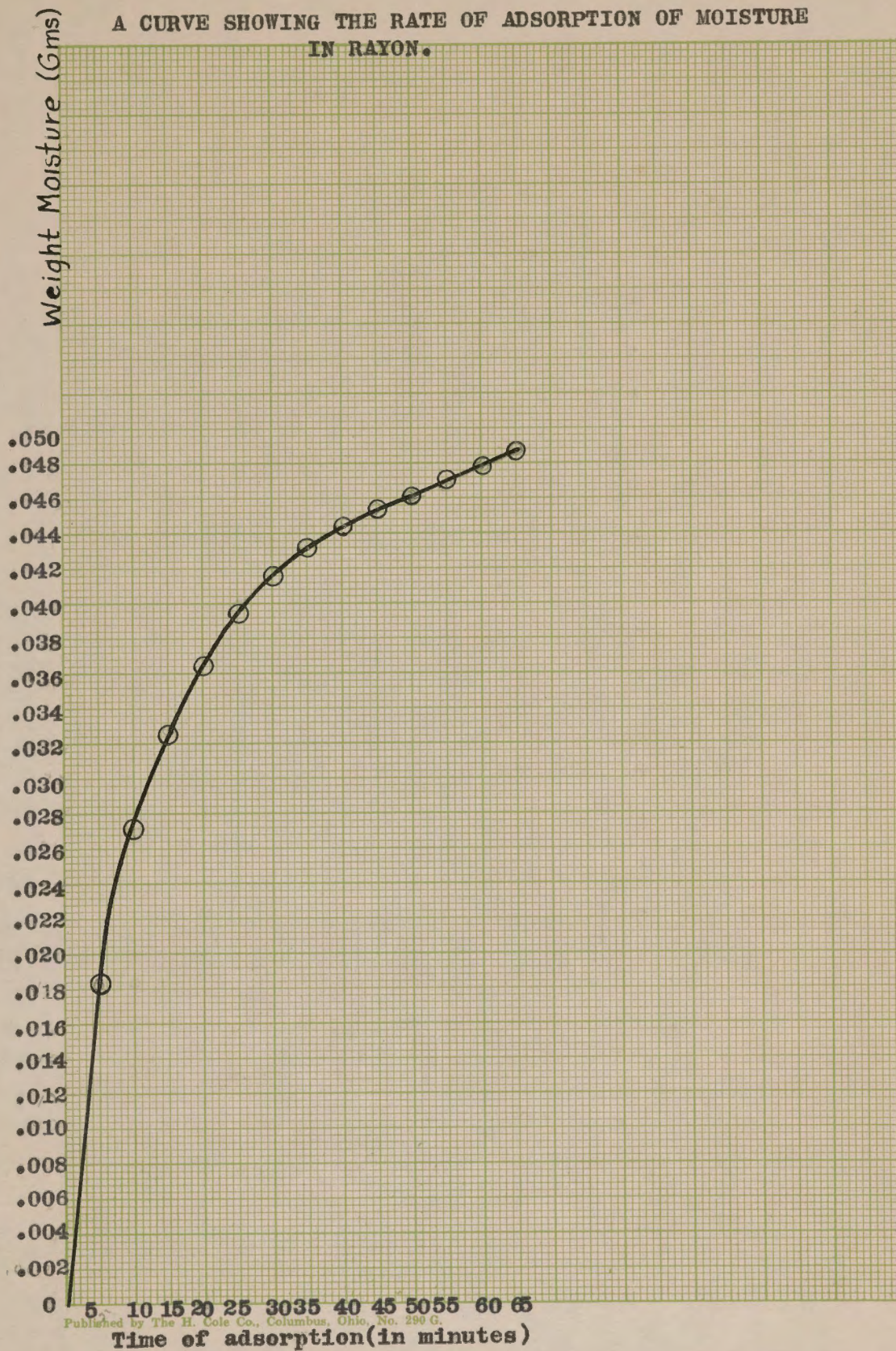
Rate of flow of moist air = 4.4 4.6 4.2

Average rate of flow = 4.4 cc per second.

Weight of Rayon = .215 grams.

Room Temperature = 28 degrees C.

A CURVE SHOWING THE RATE OF ADSORPTION OF MOISTURE
IN RAYON.



THE DESATURATION OF RAYON BY AIR.

Time in minutes	Weight lost in grams in	
	I	II
5	.0194	.0194
10	.0184	.0184
15	.0098	.0098
20	.0018	.0018
25	.0000	.0000
30	.0000	.0000
35	.0000	.0000
40	.0000	.0000

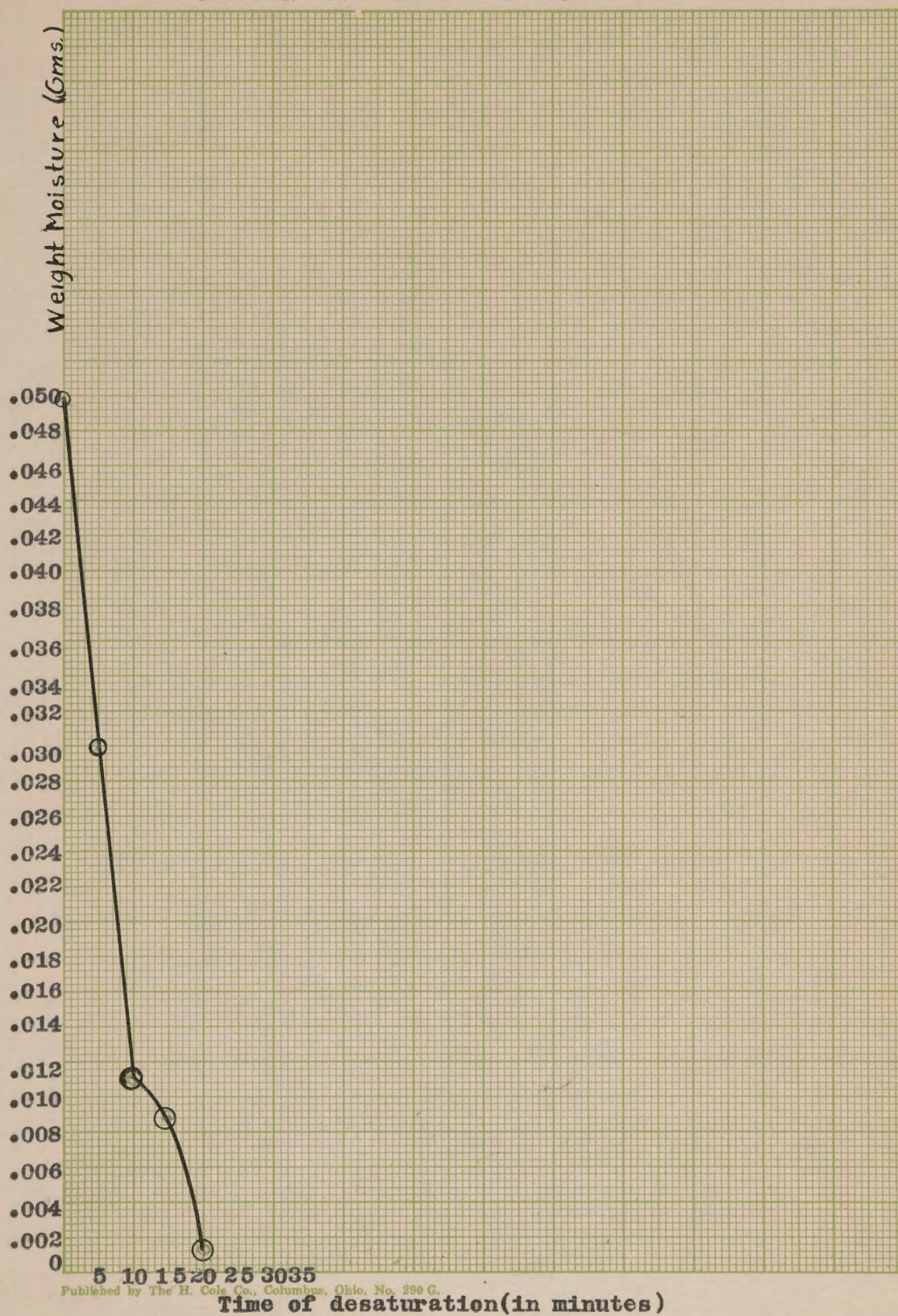
Weight of sample of Rayon = .215 grams.

Rate of flow of dry air = 4.4 4.2 4.6

Average rate of flow = 4.4 cc per second.

Room temperature = 28 degrees centigrade.

DESATURATION CURVE OF RAYON.



THE RATE OF DESATURATION OF RAYON BY HYDROGEN.

Time in minutes	Weight lost in grams in		
	I	II	III
1	.0138	.0138	.0138
2	.0092	.0092	.0092
3	.0078	.0078	.0078
4	.0000	.0000	.0000
5	.0000	.0000	.0000

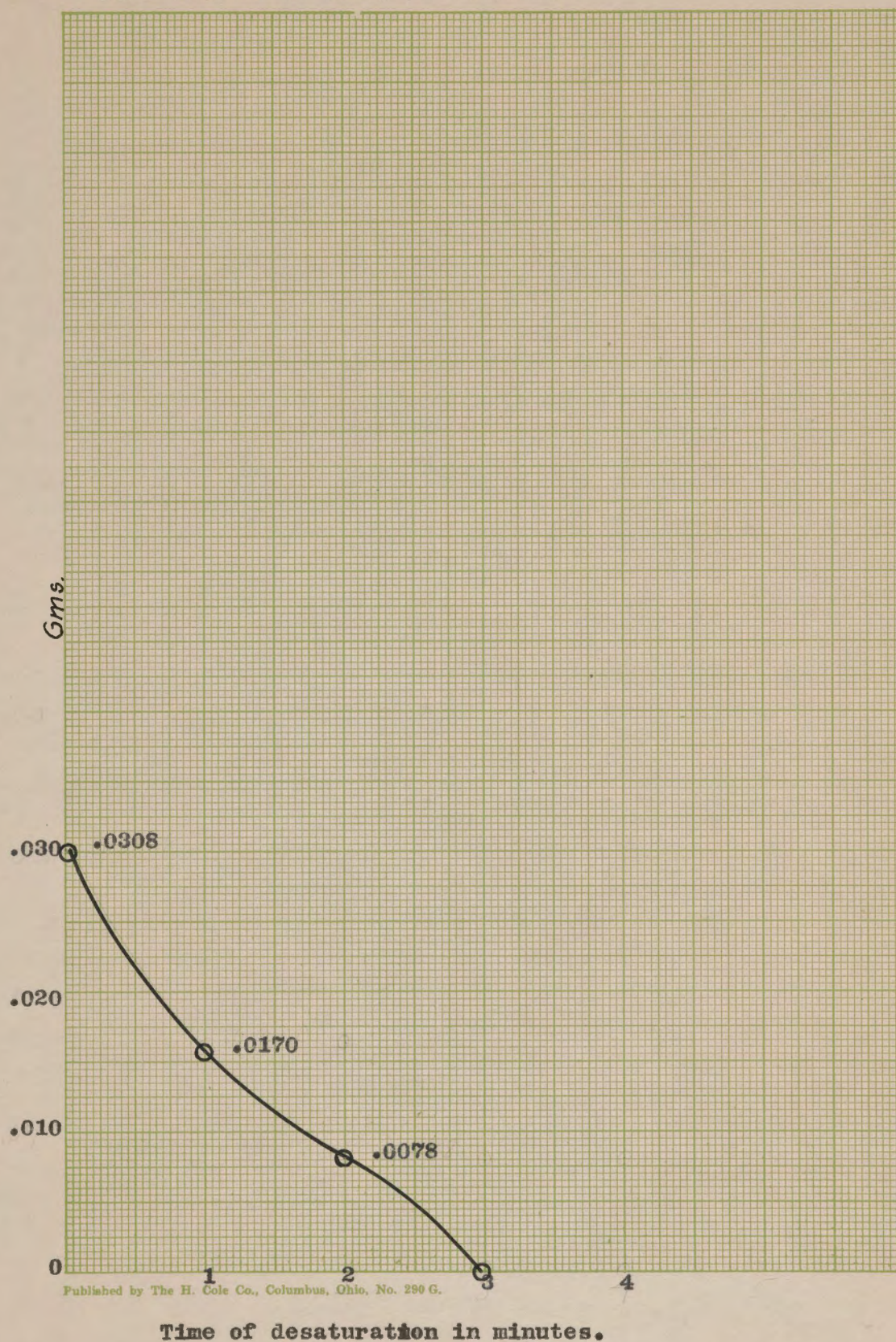
Rate of flow of hydrogen = 4.2 4.4 4.6

Average rate of flow = 4.4 cc per second.

Weight of rayon = .215 grams.

Room temperature = 28 degrees C.

DESATURATION OF RAYON BY HYDROGEN.



Time of desaturation in minutes.

EXPERIMENTAL VALUES OBTAINED IN THE ADSORPTION OF
MOISTURE BY GLASS WOOL (readings taken each min).

Weight gained in	Time of adsorption				
	1	2	3	4	5
I.	.0012	.0010	.0000	.0000	.0000
II.	.0012	.0010	.0000	.0000	.0000
Average	.0012	.0010	.0000	.0000	.0000

Weight of glass wool = .215 grams

Rate of flow of moist air = 42 4.6 4.4

Average rate of flow = 4.4 cc per second

Room Temperature 26 degrees centigrade.

EXPERIMENTAL VALUES OBTAINED IN DESATURATING GLASS
WOOL BY DRY AIR (readings taken every minute)

Weight lost in	Time of desaturation				
	1	2	3	4	5
I.	.0022	.0000	.0000	.0000	.0000
II.	.0022	.0000	.0000	.0000	.0000
Average	.0022	.0000	.0000	.0000	.0000

Weight of glass wool = .215 grams

Rate of flow of dry air = 4.2 4.4 4.6

Average rate of flow = 4.4 cc per second

Room temperature 26 degrees centigrade.

EXPERIMENTAL VALUES IN THE ADSORPTION OF MOISTURE BY
GLASS WOOL.

Weight gained in	Time of adsorption in minutes			
	5	10	15	20
I.	.0022	.0000	.0000	.0000
II.	.0022	.0000	.0000	.0000
III.	.0022	.0000	.0000	.0000
IV.	.0022	.0000	.0000	.0000
V.	.0022	.0000	.0000	.0000
Average	.0022	.0000	.0000	.0000

Weight of glass wool = .215 grams

Rate of flow of moist air = 4.2 4.4 4.6

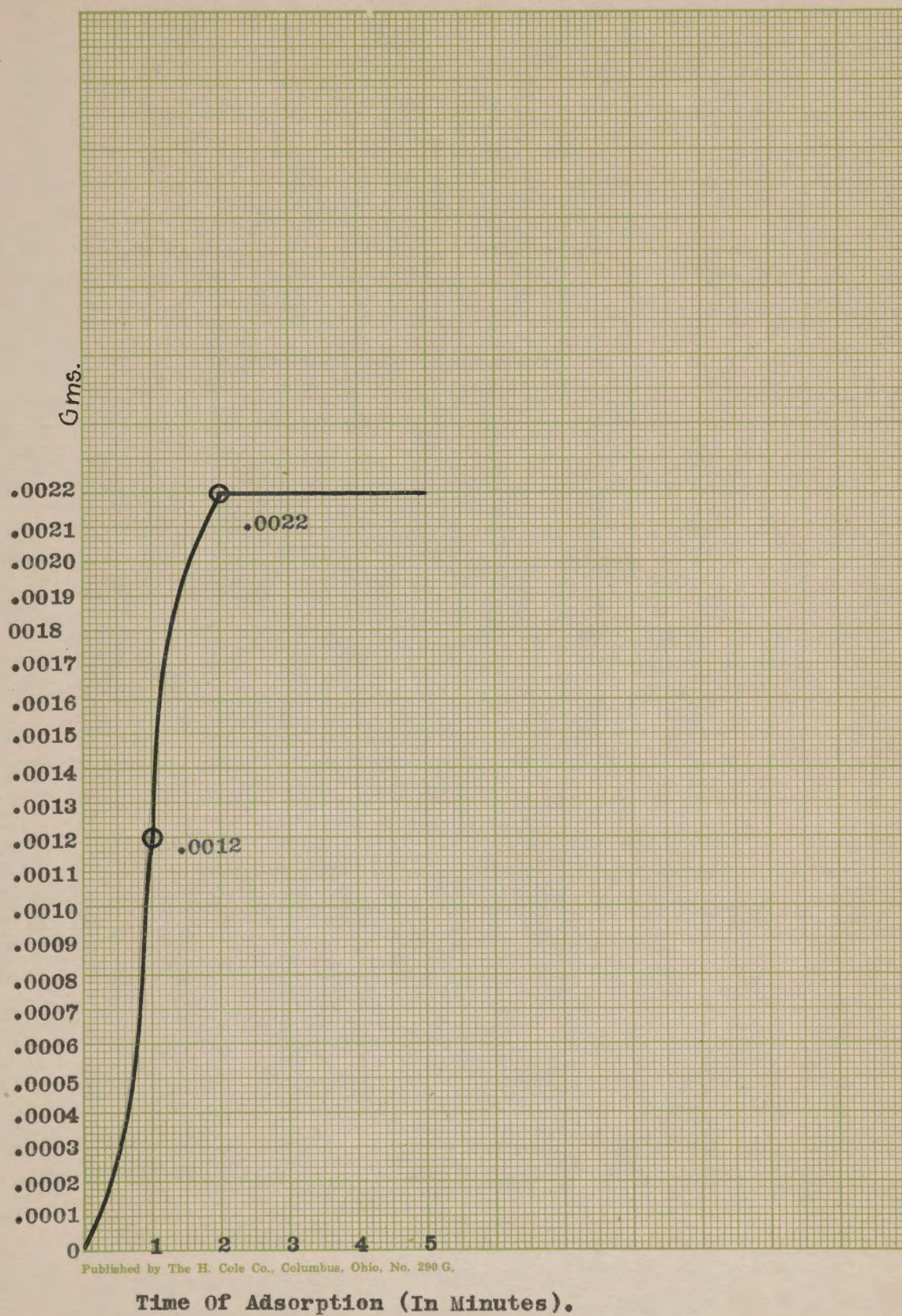
Average rate of flow = 4.4 cc per second.

Room temperature = 26 degrees C.

DESATURATION OF GLASS WOOL BY DRY AIR.

Weight lost in	Time of desaturation in minutes			
	5	10	15	20
I.	.0022	.0000	.0000	.0000
II.	.0022	.0000	.0000	.0000
III.	.0022	.0000	.0000	.0000
IV.	.0022	.0000	.0000	.0000
V.	.0022	.0000	.0000	.0000
Average	.0022	.0000	.0000	.0000

Other data same as above.





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Time Of Desaturation(In Minutes)

RATE OF DESATURATION OF GLASS WOOL BY HYDROGEN.

Time of flow in minutes	Weight lost in grams	
	I	II
1	.0022	.0022
2	.0000	.0000
3	.0000	.0000

Weight of Glass wool = .215 grams

Rate of flow of hydrogen = 4.4 4.6 4.2

Average rate of flow = 4.4 cc per second.

Room Temperature = 26 degrees C

DESATURATION OF GLASS WOOL BY HYDROGEN.



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3

Time of desaturation in minutes.

THE RATE OF ADSORPTION IN ASBESTOS.

Weight gained in	Time of Adsorption in minutes						
	1	2	3	4	5	6	7
I.	.0004	.0004	.0002	.0002	.0002	.0000	.0000
II.	.0004	.0004	.0002	.0002	.0002	.0000	.0000
III.	.0004	.0004	.0002	.0002	.0002	.0000	.0000
IV.	.0004	.0004	.0002	.0002	.0002	.0000	.0000
Average	.0004	.0004	.0002	.0002	.0002	.0000	.0000

Weight of asbestos = .215 grams.

Rate of flow of moist air = 4.2 4.6 4.4

Average rate of flow = 4.4 cc per second.

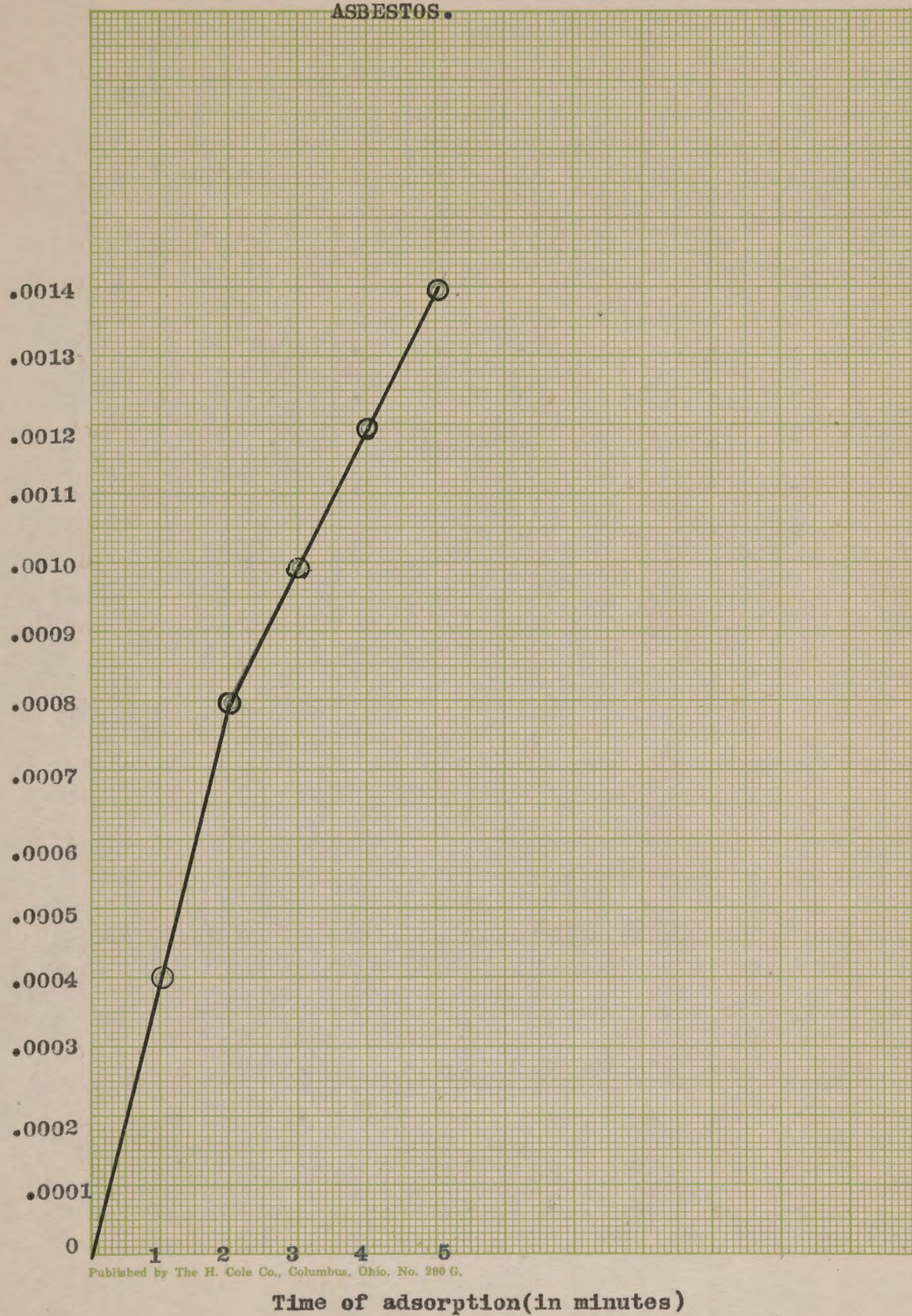
Room temperature = 28 degrees C.

THE RATE OF DESATURATION IN ASBESTOS.

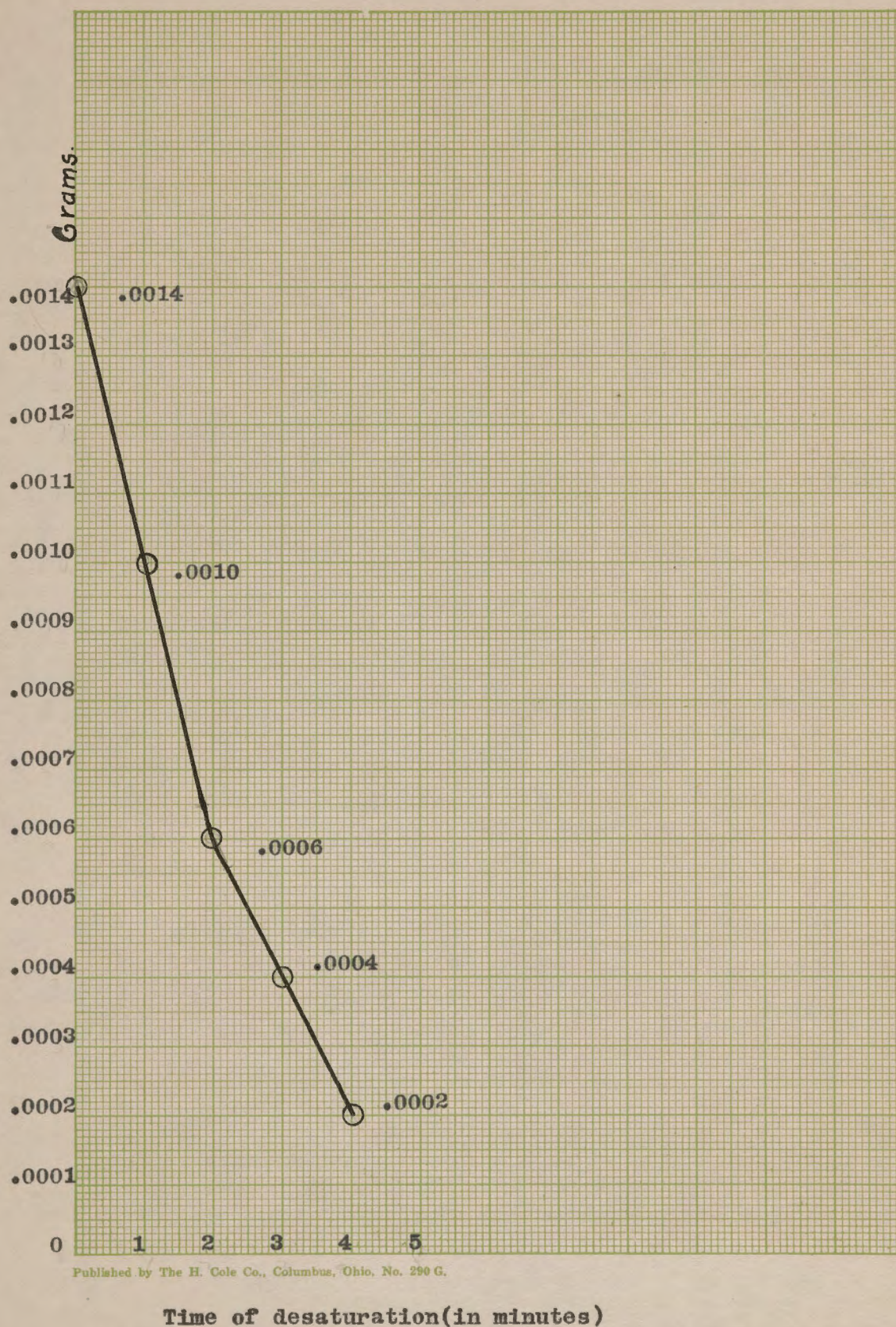
Weight lost in	Time of desaturation in minutes.						
	1	2	3	4	5	6	7
I.	.0004	.0004	.0002	.0002	.0002	.0000	.0000
II.	.0004	.0004	.0002	.0002	.0002	.0000	.0000
III.	.0004	.0004	.0002	.0002	.0002	.0000	.0000
IV.	.0004	.0004	.0002	.0002	.0002	.0000	.0000
Average	.0004	.0004	.0002	.0002	.0002	.0000	.0000

Other data the same as above.

CURVE SHOWING THE RATE OF ADSORPTION OF MOISTURE IN
ASBESTOS.



Time of adsorption(in minutes)



Time of desaturation(in minutes)

RATE OF DESATURATION OF ASBESTOS BY HYDROGEN.

Time of flow in minutes	Weight lost in grams in	
	I	II
1	.0014	.0014
2	.0000	.0000
3	.0000	.0000

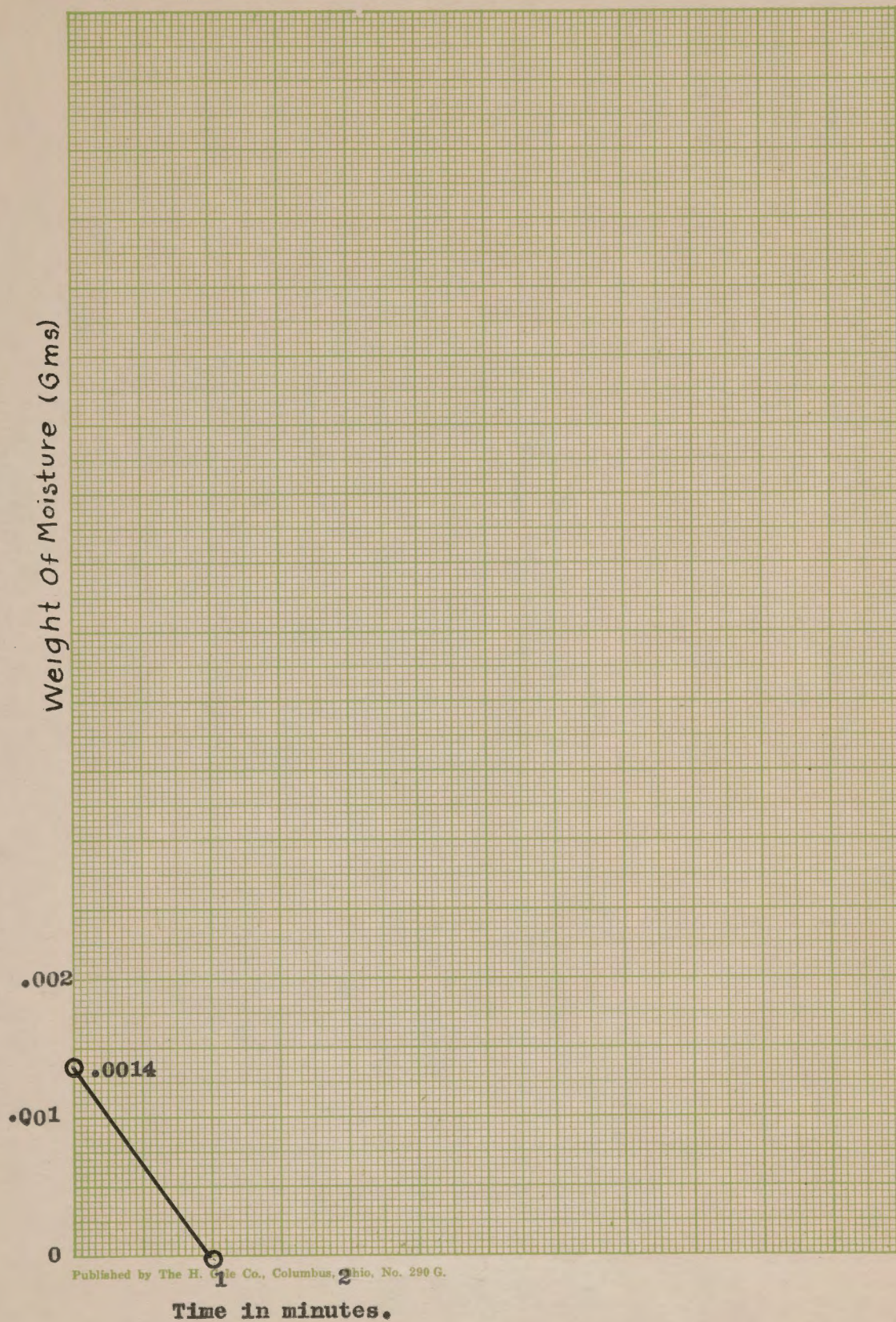
Weight of asbestos = .215 grams

Rate of flow = 4.4 4.6 4.2

Average rate of flow = 4.4 cc per second

Room temperature = 28 degrees C.

DESATURATION OF ASBESTOS BY HYDROGEN.



ADSORPTION OF MOISTURE BY WOOL.

Time in minutes	Weight gained in grams in	
	I	II
5	.0160	.0160
10	.0072	.0072
15	.0038	.0038
20	.0024	.0024
25	.0024	.0024
30	.0014	.0014
35	.0012	.0012
40	.0012	.0012
45	.0006	.0006
50	.0002	.0002
55	.0000	.0000
60	.0000	.0000

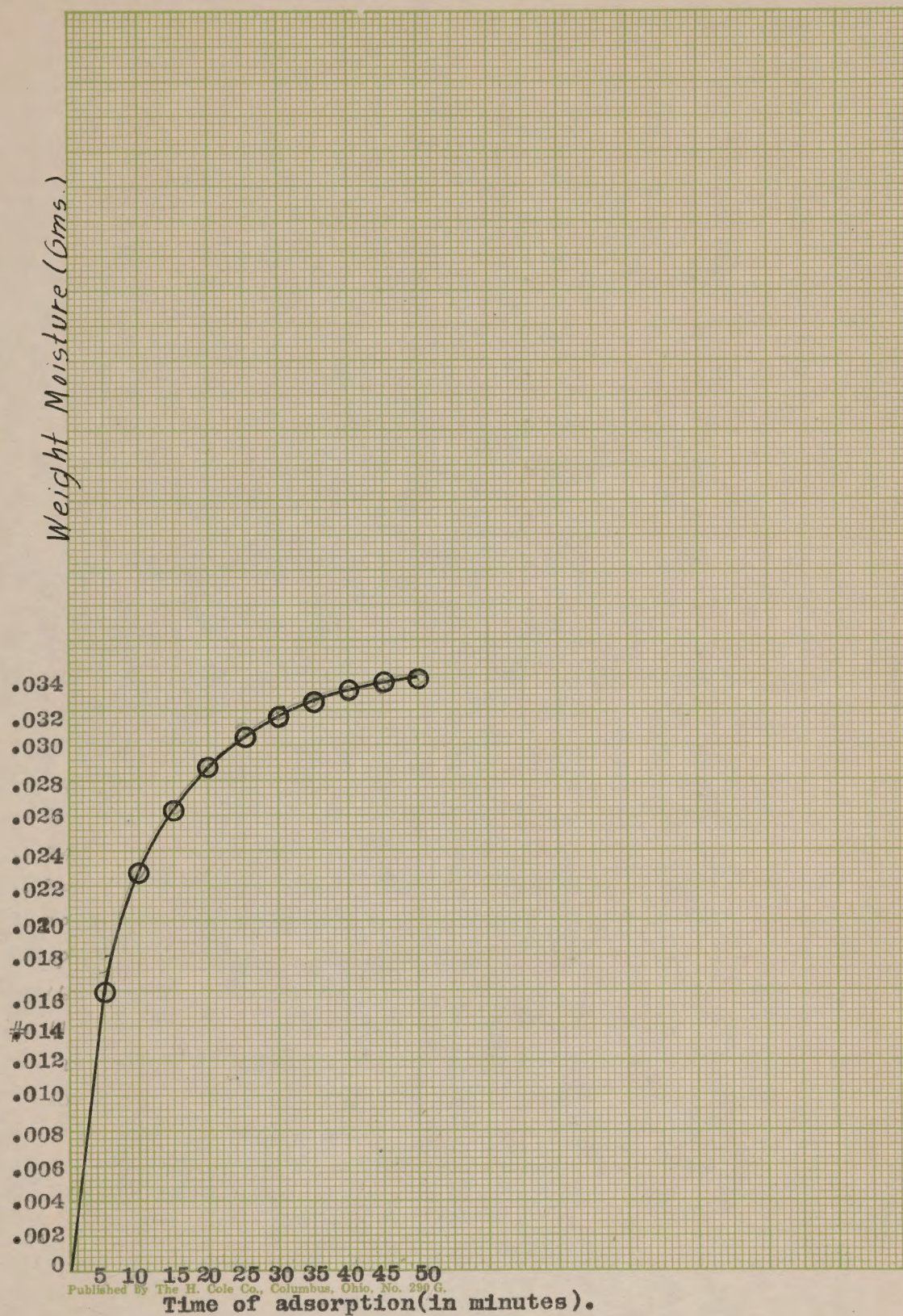
Rate of flow of moist air = 4.4 4.2) 4.6

Average rate of flow = 4.4 cc per second

Weight of wool = .215 grams

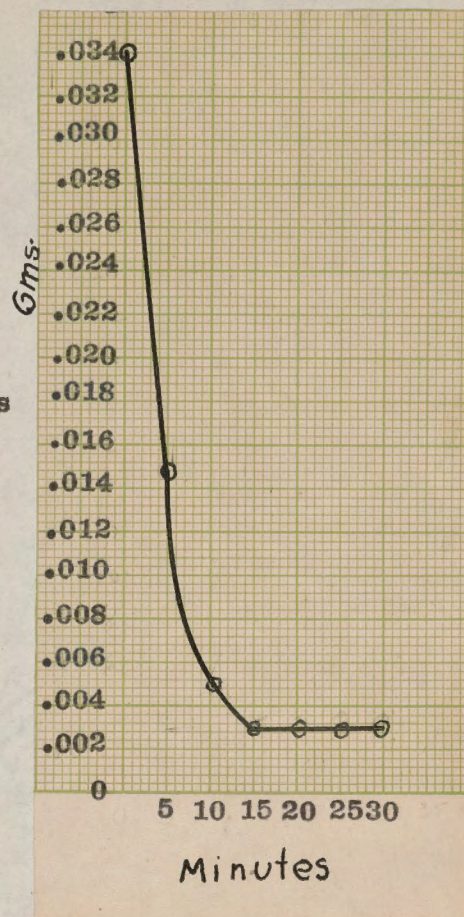
Room temperature = 28 degrees C.

ADSORPTION CURVE OF WOOL.



Desaturation of Wool.

Time	Lost Weight in grams	
	I	II
5	.0198	.0198
10	.0100	.0100
15	.0052	.0052
20	.0014	.0014
25	.0000	.0000
30	.0000	.0000



Rate of flow = 4.4 cc per second.

Weight of wool = .215 grams

RATE OF DESATURATION OF WOOL BY HYDROGEN.

Time in minutes	Weight lost in grams.		
	I	II	III
1	.0154	.0154	.0154
2	.0096	.0096	.0096
3	.0070	.0070	.0070
4	.0000	.0000	.0000
5	.0000	.0000	.0000

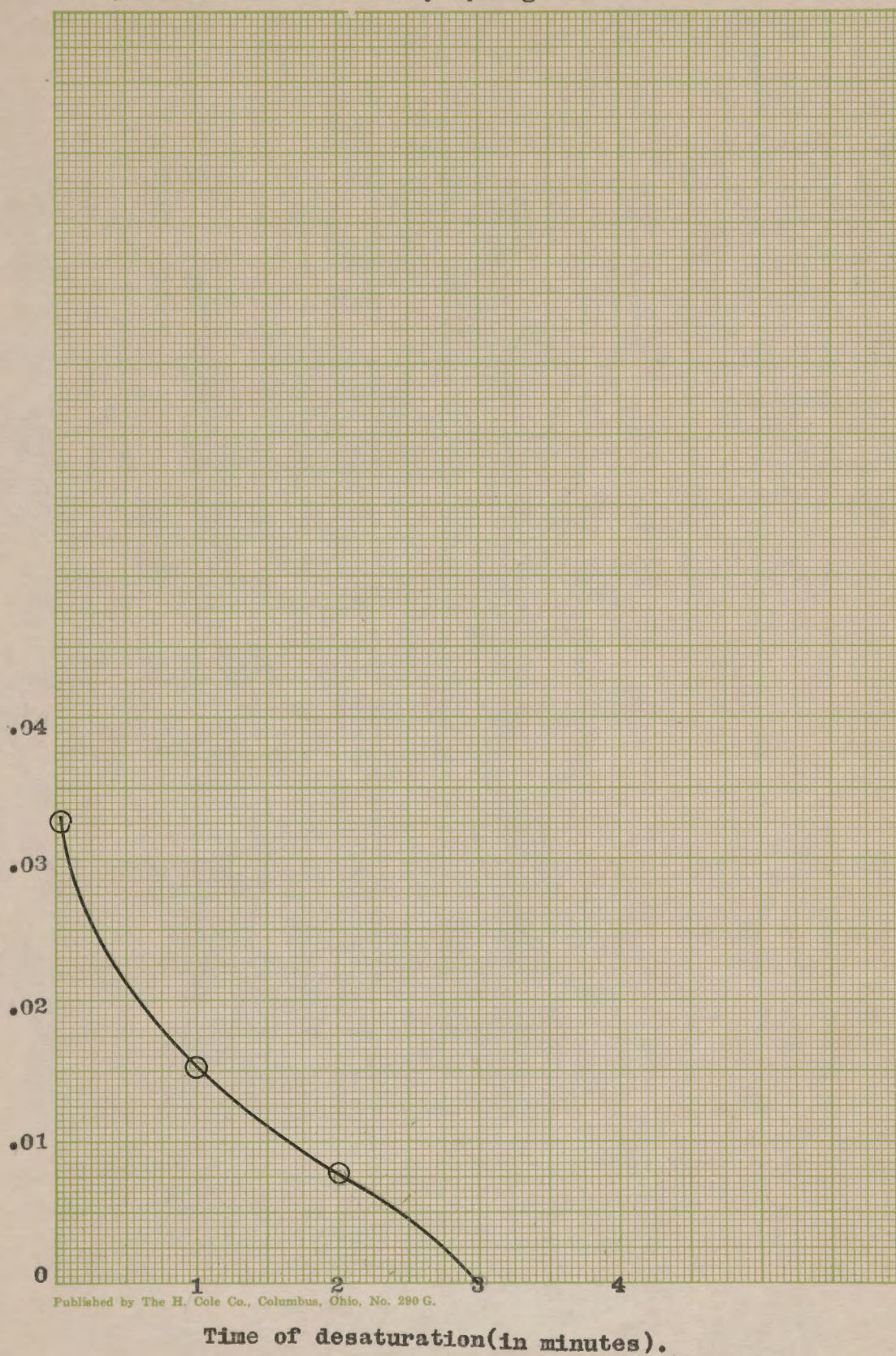
Weight of wool = .215 grams

Rate of flow of Hydrogen = 4.2 4.6 4.4

Average rate of flow = 4.4 cc per second

Room temperature = 28 degrees C.

Desaturation of Wool By Hydrogen.



Time of desaturation(in minutes).

CHAPTER VI.

CONCLUSSIONS AND REMARKS .

From the data on the preceding pages it is seen that the amount of moisture that a fiber will adsorb varies enormously. For instance, Rayon, an artificial fiber produced from wood, was found to adsorb more moisture than any other fiber tested, its value being equal to 22.93% of the original weight of material; wool came next with a percentage of 16.93% ; cotton came next with 8% ; glass wool, another artificial fiber, came next with 1.02% ; and asbestos came last with a very low percentage of .65% . The wide variation in the amount of moisture that a given fiber will adsorb is due largely to the fact that some fibers are more porous, or in other words have more surface area. Adsorption is defined as a condensation on the surface and if this is true some fibers have a greater amount of surface area than others.

Each of the fibers tested were seen to adsorb the largest amount of moisture during the first unit of time, and then gradually fell off as the time increased. During the process of desaturation by both dry air and hydrogen, the largest amount of desaturation took place during the first unit of time and then gradually fell off as the time went on.

Contrary to what one would ordinarily think would be true with regard to the rate of adsorption and desaturation it was found that in case of wool, asbestos, and Rayon that the rate of desaturation was greater than that of saturation. It would be a difficult matter to offer a satisfactory explanation for this.

Due to the fact that hydrogen was found to desaturate fibers more rapidly than ordinary dry air, there must be something about the nature of the molecule of hydrogen that accounts for such rapid evaporation.

Since asbestos is desaturated more rapidly than any of the other fibers tested, it would be the most suitable fiber for air filtration purposes. Glass wool comes next in line for filtering purposes, wool and Rayon comes next, and cotton comes last.

BIBLIOGRAPHY .

**W.D. Bancroft, Applied Colloid Chemistry, pages 3 and 61,
1921.**

APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it is submitted. It is understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves this thesis only for the purpose for which it is submitted.

NAME Judson H. Robertson
TITLE Professor of Chemistry