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RINGELMANN SMOKE CHART

(Revision of IC 7718)

By Staff, Bureau of Mines

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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ABSTRACT

The Ringelmann Smoke Chart fulfills an important need in smoke abatement work and in certain problems in the combustion of fuels. A knowledge of its history and method of preparation is, therefore, of interest to many. Since instructions on its use are not shown on the recent edition of the chart, those included in this revision of the previous Bureau of Mines publication now are a necessary complement to the chart. More detail regarding the use of the chart is included than was given in the earlier version.

INTRODUCTION

The Ringelmann Smoke Chart, giving shades of gray by which the density of columns of smoke rising from stacks may be compared, was developed by Professor Maximilian Ringelmann of Paris. Ringelmann, born in 1861, was professor of agricultural engineering at l'Institute National Agronomique and Director de la Station d'Essais de Machines in Paris in 1888, and held those positions for many years thereafter.

The chart apparently was introduced into the United States by William Kent in an article published in Engineering News of November 11, 1897, with a comment that he had learned of it in a private communication from a Bryan Donkin of London. It was said to have come into somewhat extensive use in Europe by that time. Kent proposed in 1899 that it be accepted as the standard measure of smoke density in the standard code for power-plant testing that was being formulated by the American Society of Mechanical Engineers.

The Ringelmann Chart was used by the engineers of the Technologic Branch of the U.S. Geological Survey (which later formed the nucleus of the present Bureau of Mines) in their studies of smokeless combustion beginning at St. Louis in 1904, and by 1910, it had been recognized officially in the smoke ordinance for Boston passed by the Massachusetts Legislature.

The chart is now used as a device for determining whether emissions of smoke are within limits or standards of permissibility (statutes and ordinances) established and expressed with reference to the chart. It is widely used by law-enforcement or compliance officers in jurisdictions that have adopted standards based upon the chart.

[1]Office of the Director of Coal Research, Washington, D.C.

In 1908, copies of the chart were prepared by the Technologic Branch of the Geological Survey for use by its fuel engineers and for public distribution. Upon its organization in 1910, the Bureau of Mines assumed this service together with the other fuel-testing activities of the Technologic Branch.

DESCRIPTION AND METHOD OF PREPARING THE CHART

The Ringelmann system is virtually a scheme whereby graduated shades of gray, varying by five equal steps between white and black, may be accurately reproduced by means of a rectangular grill of black lines of definite width and spacing on a white background. The rule given by Professor Ringelmann by which the charts may be reproduced is as follows:

Card 0—All white.

Card 1—Black lines 1 mm thick, 10 mm apart, leaving white spaces 9 mm square.

Card 2—Lines 2.3 mm thick, spaces 7.7 mm square.

Card 3—Lines 3.7 mm thick, spaces 6.3 mm square.

Card 4—Lines 5.5 mm thick, spaces 4.5 mm square.

Card 5—All black.

The chart, as distributed by the Bureau of Mines, provides the shades of cards 1, 2, 3, and 4 on a single sheet, which are known as Ringelmann No. 1, 2, 3, and 4, respectively. A copy of the chart is included in this report.

USE OF CHART

Many municipal, state, and federal regulations prescribe smoke-density limits based on the Ringelmann Smoke Chart, as published by the Bureau of Mines. Although the chart was not originally designed for regulatory purposes, it is presently used for this purpose in many jurisdictions where the results obtained are accepted as legal evidence.

While the chart still serves a useful purpose, it should be remembered that the data obtained by its use is empirical in nature and has definite limitations. The apparent darkness or opacity of a stack plume depends upon the concentration of the particulate matter in the effluent, the size of the particulate, the depth of the smoke column being viewed, natural lighting conditions such as the direction of the sun relative to the observer, and the color of the particles. Since unburned carbon is a principal coloring material in a smoke column from a furnace using coal or oil, the relative shade is a function of the combustion efficiency.

While the Ringelmann Smoke Chart has many limitations, it gives good practical results in the hands of well-trained operators. However, it is questionable whether results should be expressed in fractional units because of variations in physical conditions and in the judgement of the observers.

To use the chart, it is supported on a level with the eye, at such a distance from the observer that the lines on the chart merge into shades of gray, and as nearly as possible in line with the stack. The observer glances from the smoke, as it issues from the stack, to the chart and notes the number of the chart most nearly corresponding with the shade of the smoke, then records this number with the time of observation. A clear stack is recorded as No. 0, and 100 percent black smoke as No. 5.

To determine average smoke emission over a relatively long period of time, such as an hour, observations are usually repeated at one-fourth or one-half minute intervals. The readings are then reduced to the total equivalent of No. 1 smoke as a standard. No. 1 smoke being considered as 20 percent dense, the percentage "density" of the smoke for the entire period of observation is obtained by the formula:

$$\frac{\text{Equivalent units of No. 1 smoke} \times 0.20 \times 100}{\text{Number of observations}} = \text{percentage smoke density.}$$

A convenient form for recording and computing the percentage of smoke density appears at the end of this report. This procedure is often used on acceptance tests of fuel-burning equipment.

The timing and extent of observations made for the purpose of determining compliance with a local smoke abatement ordinance depends upon the wording and smoke limitations of the ordinance.

RINGELMANN-CHART READING

Location . . . . . .

Hour. . . 9:00 - 10:00 a.m. . . . Date. . . . . .

9

	0	1/4	1/2	3/4		0	1/4	1/2	3/4
0	-	-	-	-	30	1	1	1	1
1	-	-	-	-	31	1	1	1	1
2	-	-	-	-	32	-	-	-	-
3	1	1	1	1	33	-	-	-	-
4	1	1	1	1	34	-	-	-	-
5	2	2	2	2	35	1	1	1	1
6	2	3	3	3	36	1	1	1	1
7	3	3	3	3	37	1	1	1	1
8	2	2	1	1	38	1	1	-	-
9	1	1	-	-	39	-	-	-	-
10	-	-	-	-	40	-	-	-	-
11	-	-	-	-	41	-	-	-	-
12	-	-	-	-	42	-	-	-	-
13	-	-	-	-	43	-	-	-	-
14	-	-	-	-	44	1	1	2	2
15	-	-	-	-	45	2	2	3	3
16	-	-	-	-	46	3	3	3	3
17	-	-	-	-	47	3	3	4	3
18	-	-	-	-	48	2	2	2	2
19	2	2	2	2	49	2	2	2	2
20	2	2	2	2	50	2	1	1	1
21	2	2	2	2	51	1	1	1	1
22	3	3	3	3	52	1	1	1	-
23	3	4	4	4	53	-	-	-	-
24	4	5	5	5	54	-	-	-	-
25	5	5	5	5	55	-	-	-	-
26	4	4	3	3	56	-	-	-	-
27	3	3	3	3	57	-	-	-	-
28	2	2	1	1	58	-	-	-	-
29	1	1	1	1	59	-	-	-	-

Point of observation . . . . . .

Distance to stack . . . . . .

Direction of stack . . . . . .

Direction of wind . . . . . .

Velocity of wind . . . . . .

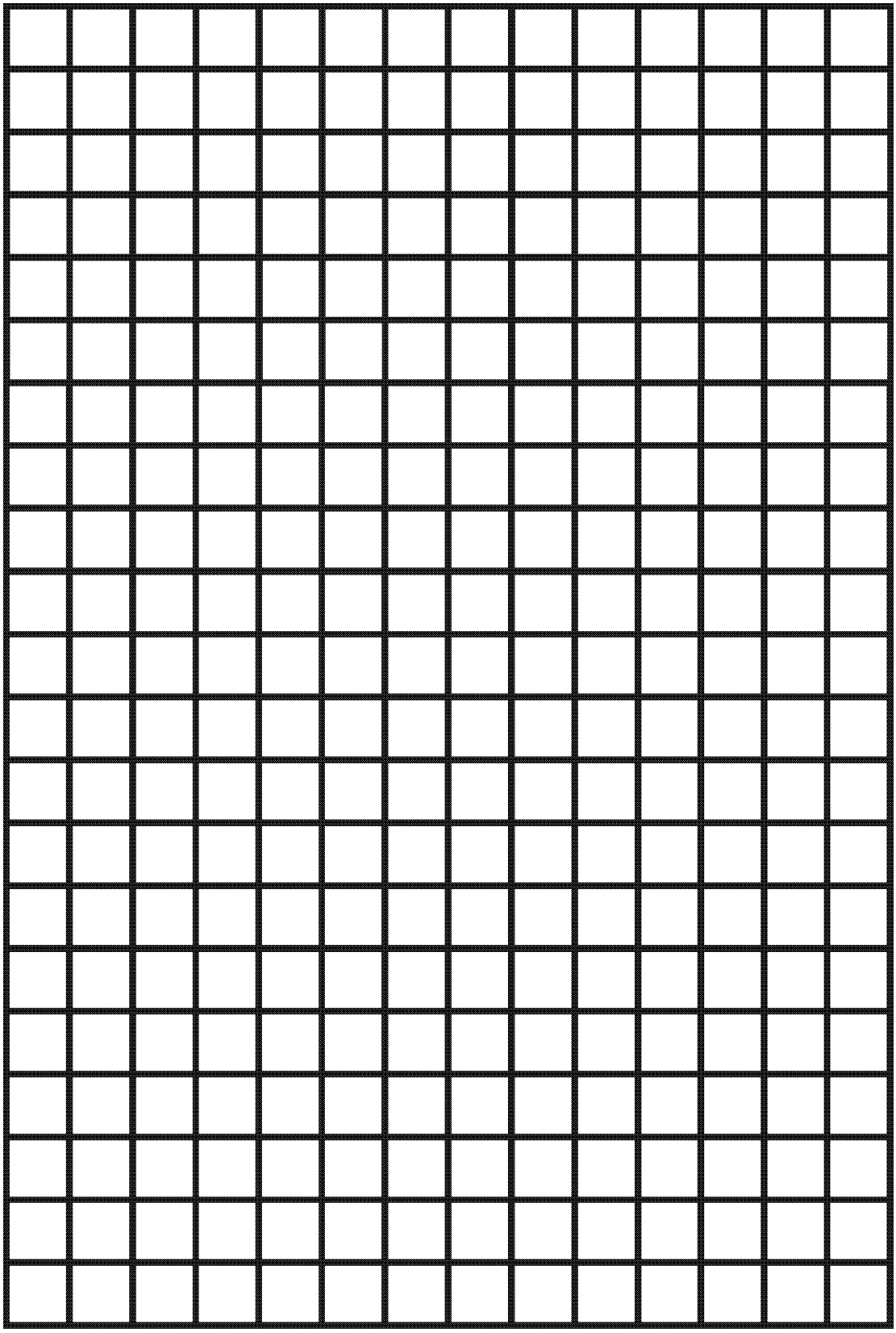
	Equiv. No. 1 Units
7 Units No. 5	35
7 Units No. 4	28
27 Units No. 3	81
34 Units No. 2	68
52 Units No. 1	52
113 Units No. 0	0
240 Units	264

$\frac{264}{240} \times 20$ pct = 22 pct Smoke density

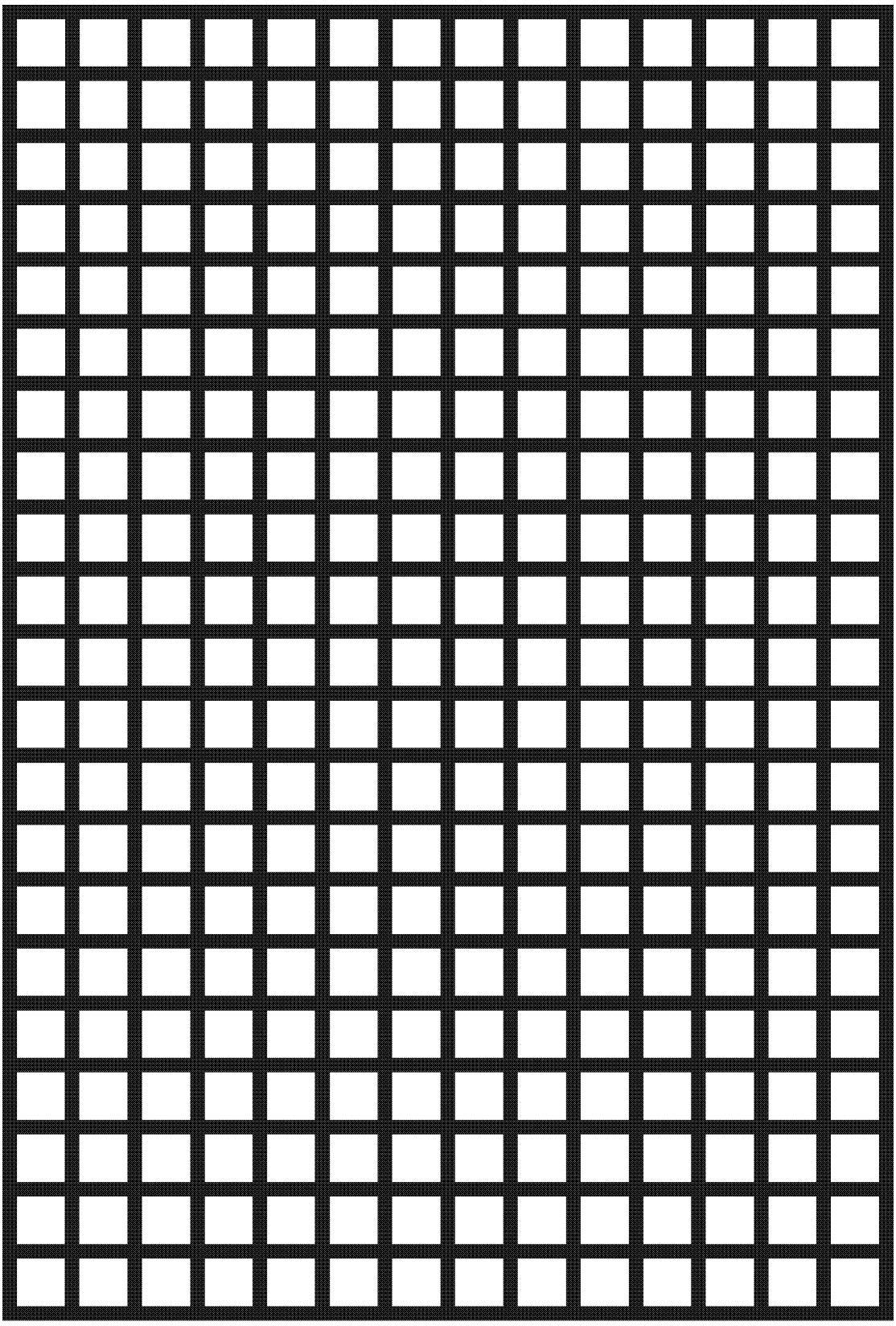
Observer. . . . . .

Checked by. . . . . .

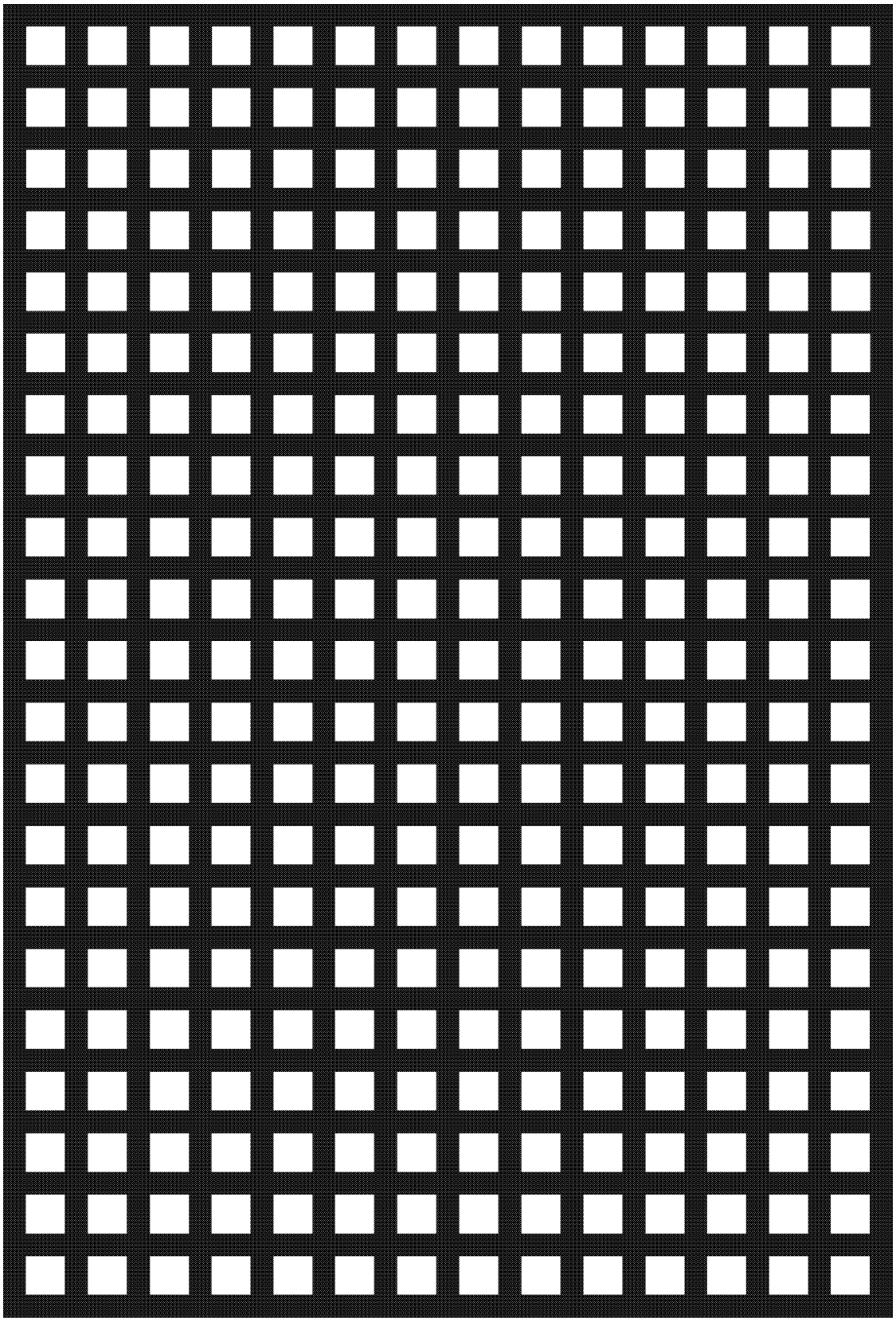
INT.-BU. OF MINES, PGH., PA. 10992



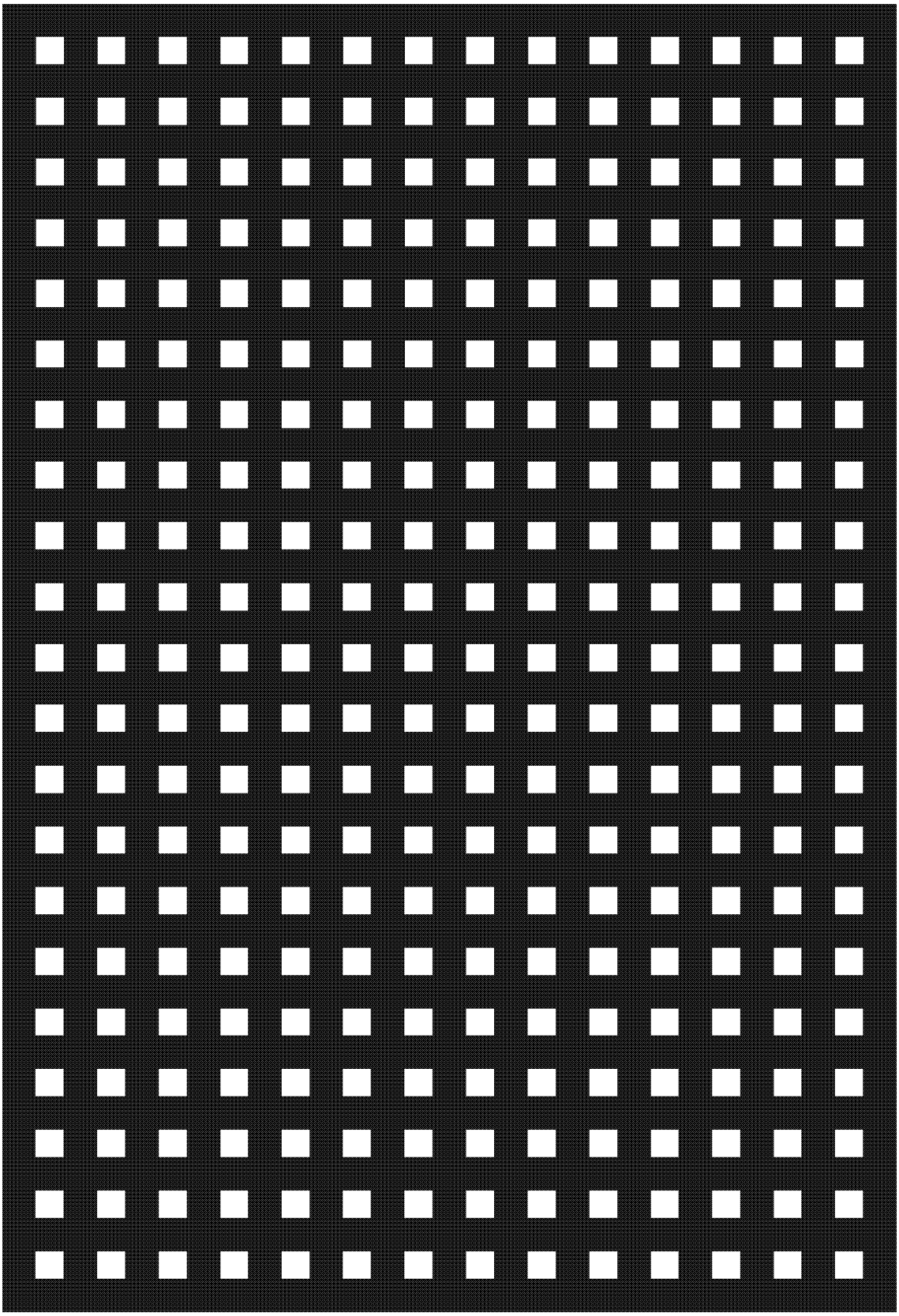
1. EQUIVALENT TO 20 PERCENT BLACK



2. EQUIVALENT TO 40 PERCENT BLACK



3. EQUIVALENT TO 60 PERCENT BLACK



4. EQUIVALENT TO 80 PERCENT BLACK