NATIONAL BUREAU OF STANDARDS REPORT

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DEVELOPMENT OF A LABORATORY TEST

FOR

EVALUATION

OF THE

EFFECTIVENESS OF SMOKE SIGNALS

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1. INTRODUCTION

The United States Coast Guard has the duty of approving devices carried on vessels as life-saving equipment. One such device is a smoke signal for daytime use.

The effectiveness of a smoke signal depends upon the opaqueness, color, and duration of the smoke. The color of a smoke signal can be determined satisfactorily by comparison with Munsell color chips. However, the opaqueness of a smoke has been judged simply by observation and is therefore a matter of individual opinion. The present work was undertaken to devise a laboratory method for evaluating the relative transmittance of the smoke emitted by any signal, thereby evaluating its effectiveness.

Several manufacturing companies were invited to suggest methods of test and to cooperate by supplying samples of signal smokes. The companies were: Aerial Products, Inc., Kilgore, Inc. (International Signal Division), Superior Signal Company, Inc., and the Universal Match Corporation.

In addition to signals assumed to be acceptable, smoke signals known to be defective in various ways were also supplied by the manufacturers. Additional samples of various age and condition were supplied by the United States Coast Guard.

The test method suggested by the manufacturers was essentially as follows: ignite the smoke signal in a large enclosure; by a sampling technique, determine the volume of the smoke cloud, measure the optical density of a sample, and thereby evaluate the effectiveness of the signal. This suggested static test method would require a relatively large enclosure. Also it would be relatively difficult to determine the average smoke density. Furthermore, the rate of smoke formation would be difficult to evaluate. These factors together with cost and space considerations indicated the desirability of developing a different type of test method.

2. TEST METHOD

The test method selected for evaluating smoke signals was based on the measurement of the transmittance of the smoke when drawn through a stack at a known rate. The attenuation of a beam of light in the stack and the lapse of time provided a measure of opaqueness and duration of the smoke.

3. TEST APPARATUS

The test apparatus consisted of the following: a water tank with circulating tap water in which to float the smoke pot; a chemical hood, with adequate air flow, in which the smoke is generated; an optical system installed in the exhaust stack; and a photometric system that together with the optical system measures the transmittance of the exhausted smoke. A Vel-O-Meter (Illinois Testing Laboratory) was used to measure the intake air velocity.

3.1 Hood

The general arrangement and dimensions of the hood are shown in Figure 1. The sliding door of the hood was equipped with spacers to provide an inlet of reproducible size. The essential dimensions are the inlet opening of one square foot area (approx. 27" x 5-1/2") at the bottom of the sliding door and the exhaust stack diameter of 7-1/2 inches. The exhaust blower produced an average intake air velocity of 650 feet per minute, with or without the production of smoke.

3.2 Optical System

On an extension of a diameter of the stack are arranged an optical system and a photoelectric receiver. The source, a 20-diopter collimating lens, and a removable window are on one side of the stack. On the other side are, in order, a removable window, a 20-diopter lens forming an image of the source, a 6.5 mm circular stop in the focal plane of the lens, and a phototube. This lens and stop combination permits the receiver to register rays departing from parallel by plus or minus 3.7 degrees.

The light source is a 6-8-volt, 50-candlepower marine service lamp, trade number 1184. The removable windows are provided to permit removal of precipitated smoke particles. This optical system reduces to a negligible amount the effect of "beam broadening" caused by smoke particles scattering light from the original beam.

A glass tube installed earlier in the exhaust stack permitted visual observation of the distribution of the smoke and together with an examination of the smoke deposit on the tube surface indicated that the distribution was sufficiently uniform for the purpose. A metal tube was used for all measurements.

Experience indicates that the windows need not be cleaned after each signal. In fact the drift of the 100 percent reading is less when smoke from a previous deposit is allowed to remain.

3.3 Photometric System

The photometer was a Densichron Densitometer (W. M. Welch Scientific Co.), equipped with a phototube having an S-1 surface. The output was connected to a 10-ohm load resistor and a Brown recorder. The recording instrument is a single variable, strip-chart recorder with 4 1/2 second full scale travel time.

4. TEST PROCEDURE

The voltage on the light source was adjusted together with the volume control on the Densichron to produce a full scale deflection on the recorder.

The recorder drive was started, the smoke pot was ignited and placed in the water tank in the hood, and the hood door was lowered onto the inlet spacers.

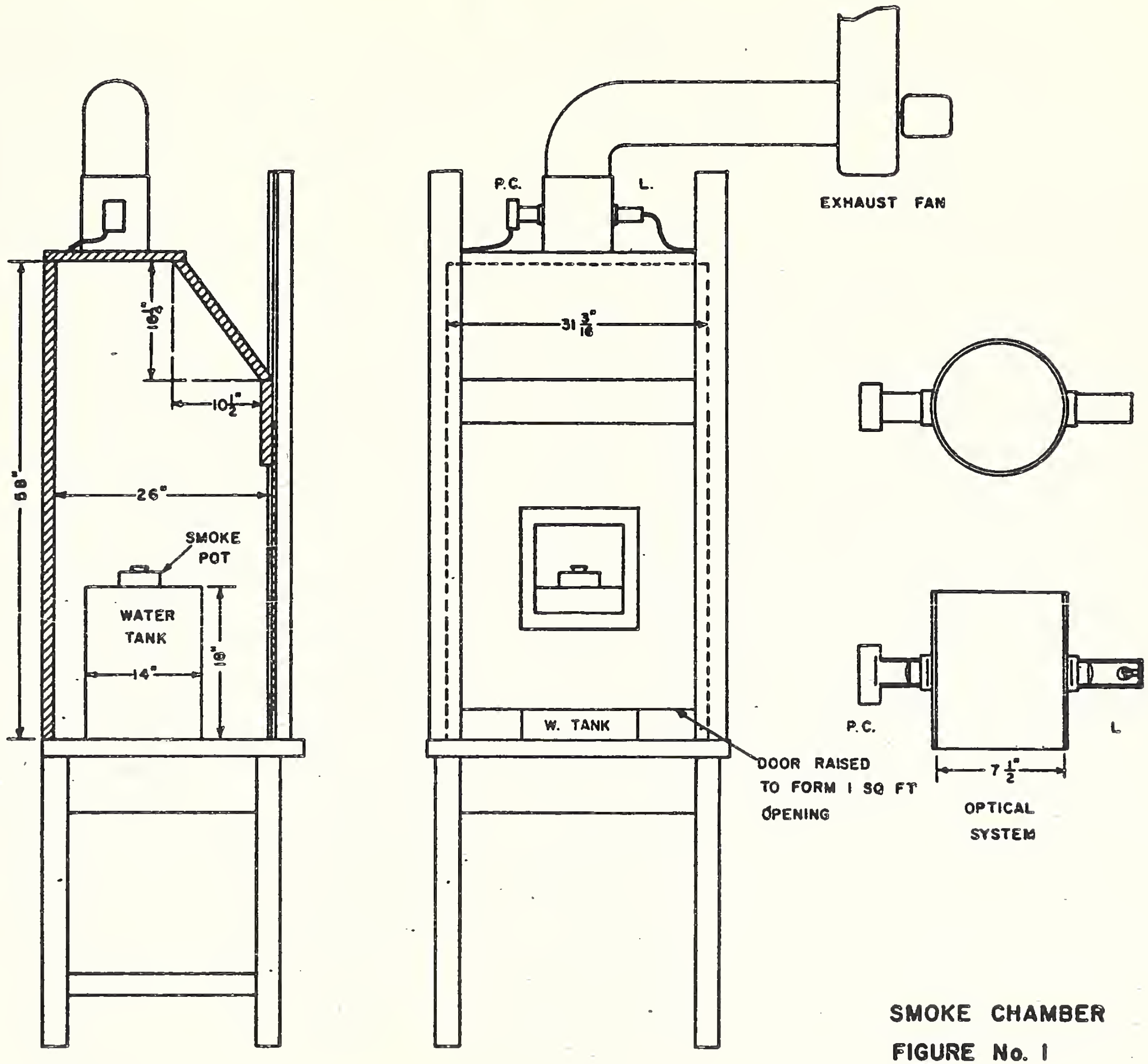
5. RESULTS

Figures 2 through 5 are photocopies of representative chart records from about 15 smoke signals tested. These records were made at a chart speed of two inches per minute. Note that the pen moved from right to left across the chart. Figures 2 and 3 are for smoke signals classed as "satisfactory". Note that the transmittance is well below 20 percent throughout most of the smoke emitting period. In Figure 2 the average transmittance for three minutes is of the order of two percent; in Figure 3, five percent. Note also that at least one minute is required after the initial appearance of smoke for the signal to provide sufficient smoke to attenuate the beam appreciably.

Figures 4 and 5 are records of smoke signals classed as "inadequate" by the cooperating manufacturer. Note from Figure 4 that the smoke started and then nearly stopped twice before the steady rate became established. This figure shows a smoke emitting period of about seven minutes, but the relatively high transmittance of 20 to 50 percent indicates that the smoke signal would be inadequate. Figure 5 indicates a similar signal performance but shows a period of about 2 minutes when there was sufficient smoke to produce less than 20 percent transmittance.

6. SUGGESTED DEFINITION FOR SATISFACTORY SMOKE SIGNAL

A satisfactory smoke signal, judging from the results of the measurements of the samples used in this report, might be defined as one that has less than 20 percent transmittance for 3 minutes when measured with apparatus operated as here described. The essential parameters of this apparatus are a light path of 7 1/2", an optical system aperture of ± 3.7 degrees and an entrance air flow of 650 cubic feet per minute. For other parameters the transmittance, the duration, or both might be different.



SMOKE CHAMBER
FIGURE No. 1

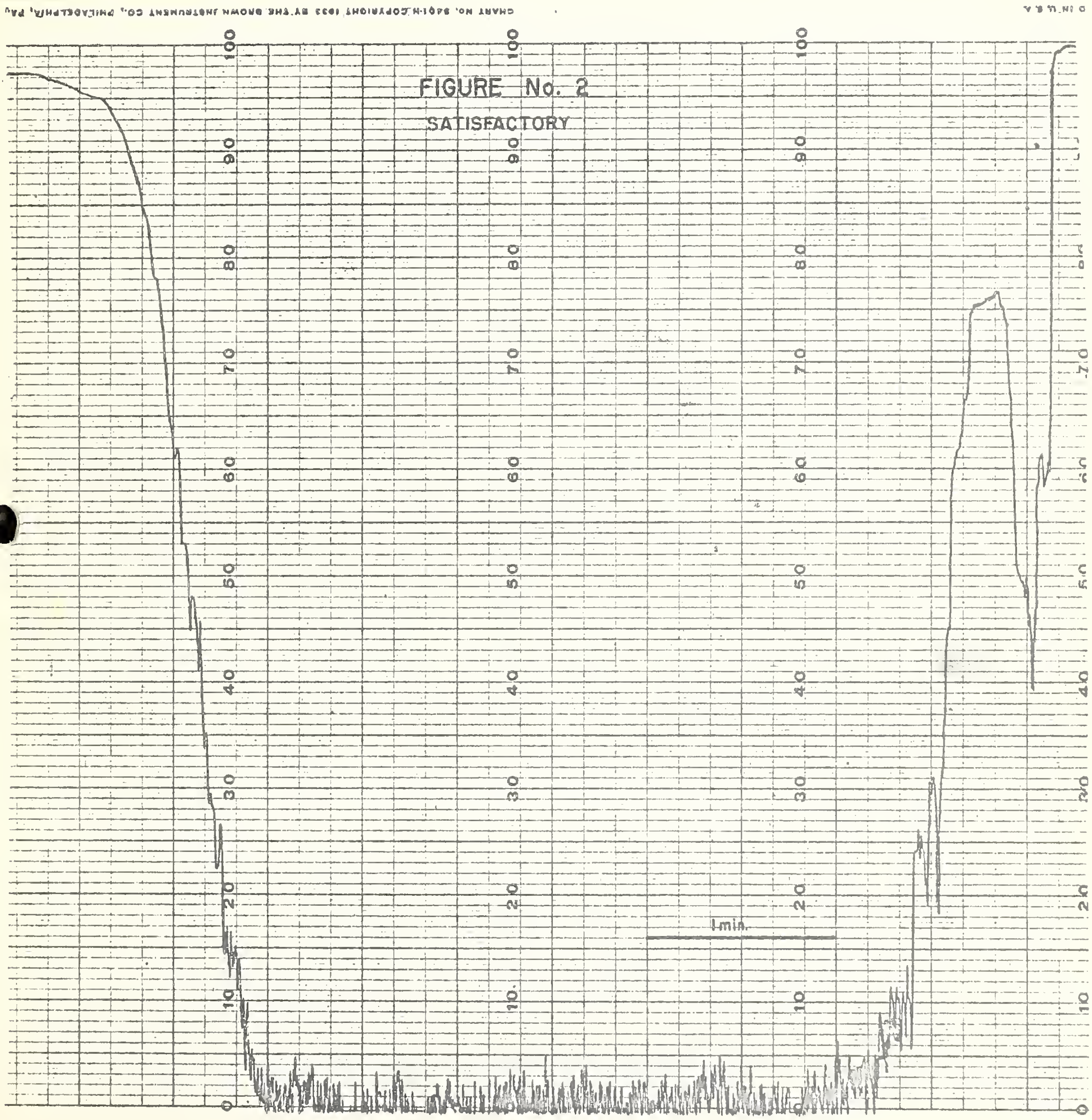
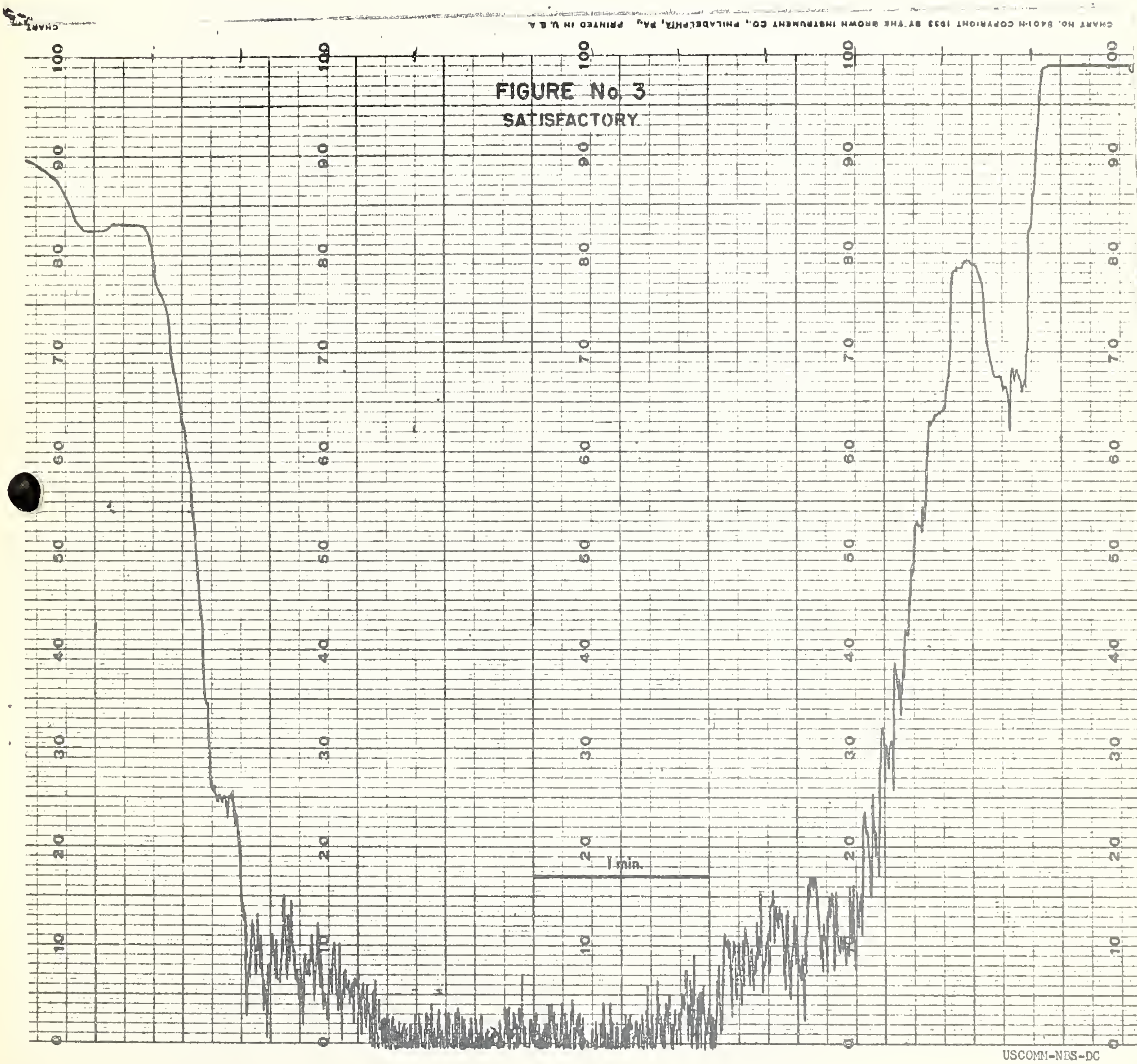


FIGURE No. 2

SATISFACTORY



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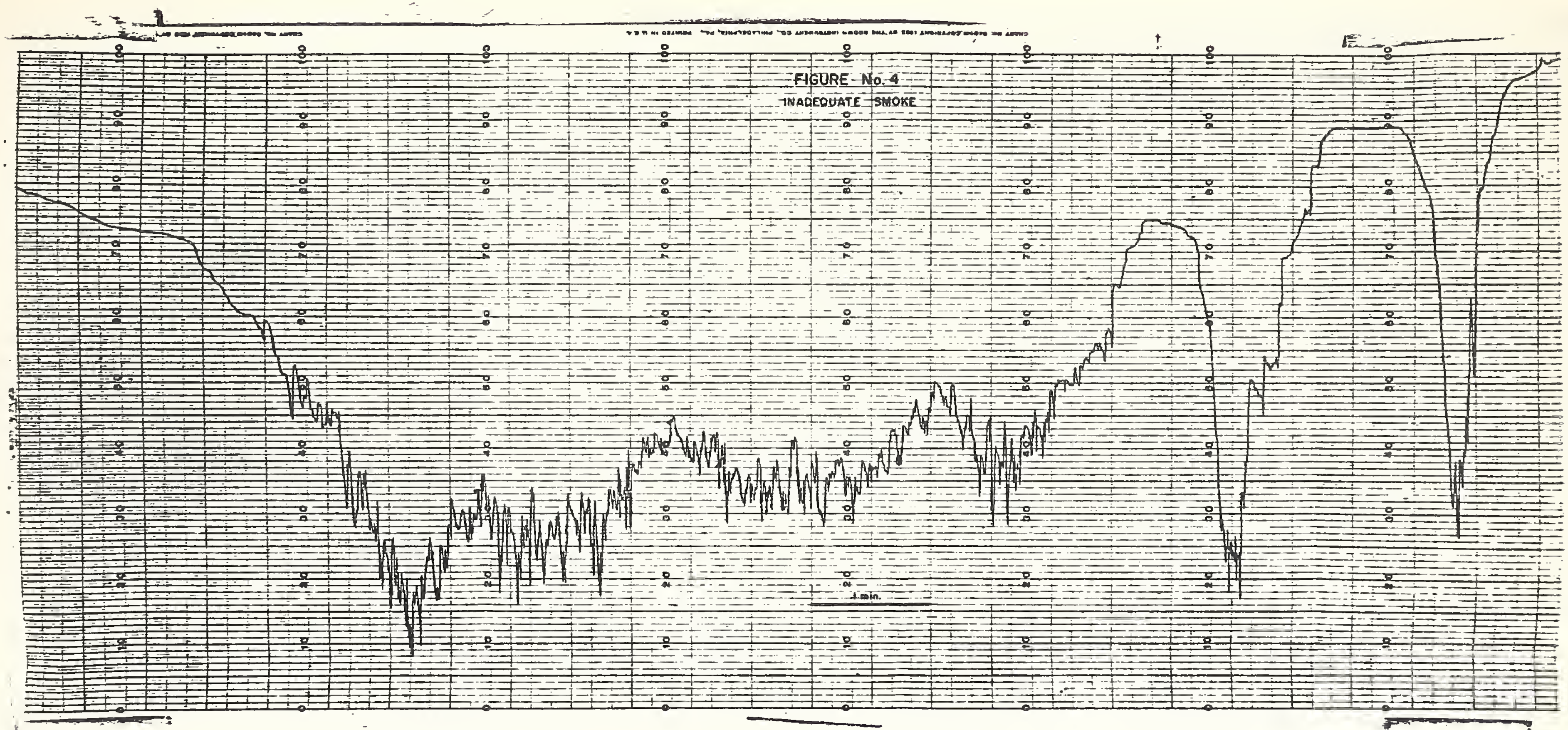
FIGURE No. 4
INADEQUATE SMOKE
1 min.

FIGURE No. 5

INADEQUATE SMOKE