NATIONAL BUREAU OF STANDARDS REPORT

8001

PERFORMANCE CHARACTERISTICS OF FOUR MODELS OF
"DRI-PAK" DEEP-BED AIR FILTERS

manufactured by
American Air Filter Company
Louisville, Kentucky

by

Carl W. Coblentz and Paul R. Achenbach

to

General Services Administration
Public Buildings Service
Washington 25, D.C.

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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Carl W. Coblentz and Paul R. Achenbach
Mechanical Systems Section
Building Research Division

Report to

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1. Introduction

At the request of the Public Buildings Service, General Services Administration the performance characteristics of four deep-bed dry media air filters, type Dri-Pak Models 1060, 2060, 2090, and 2100 manufactured by the American Air Filter Company, Louisville, Kentucky were determined. The scope of this examination included the determination of the arrestance of the particulate matter in the laboratory air and measurement of the pressure drop at different dust loads when the filters under test were operated at their rated air flow rate.

2. Description of Test Specimen

The test specimens were supplied by the American Air Filter Company of Louisville, Kentucky and were stock samples of their Dri-Pak series 1000 and 2000 filters, i.e., designed for nominal air flow rates 1000 cfm and 2000 cfm, respectively. The approximate arrestance of the various media used in these filters, when tested by the NBS Dust Spot Method, using the particulate matter in the laboratory air as the aerosol, was indicated by the three digits following the initial series number as a percent, 060, 090, and 100.

All specimens had identical steel face plates 24 in. square with 36 stamped square holes, symmetrically arranged. The sides and corners of these holes were well rounded for reducing the entrance air turbulence and to provide rigidity to the plate. The holes were arranged in six rows with a

bag of filter media bonded to the downstream side along each row of holes. In order to avoid direct contact of adjacent bags, when they were inflated by the air pressure, the bags were stapled so that it appeared as if there was a pocket of media extending downstream from each inlet hole and the pockets of each row were connected. The media consisted of fiber glass mats about 1/4 in. thick and supported on the downstream side by a flexible mesh. A microscopic examination of the different media indicated that the glass fibers in the model 1060 and 2060 media were about 5 microns in diameter, whereas the fibers of the model 2090 and 2100 media were less than 3 microns in diameter. The useful media area was approximately 90 sq. ft. for the 2000 series specimens and 45 sq. ft. for the 1000 cfm filters, indicating a net media velocity of about 22 ft/min.

The test specimens were furnished folded and occupied a space of about 24 x 24 x 4 in. The weights of the test specimens were as follows:

Model 1060	2240 grams	(5 lbs.)
Model 2060	2750 grams	(6 lbs. 1 oz.)
Model 2090	2550 grams	(5 lbs. 9 oz.)
Model 2100	2420 grams	(5 lbs. 5 oz.)

A holding frame made of sheet steel was provided with rubber seals and steel springs to hold the face plate as well as a panel type pre-filter, if such was to be used. The assembly of filter banks is accomplished by riveting together these holding frames. Some 2-inch Amer-Glass throw-away type panel filters were also furnished by the manufacturer in order to determine the effect of pre-filters on the dust holding capacity of these deep-bed filters.

3. Test Method and Procedure

The arrestance determinations were made with the NBS Dust Spot Method as described in a paper by R. S. Dill entitled "A Test Method for Air Filters" (ASHVE Transactions, Vol. 44, p. 379, 1938). The filter under test was installed in the air filter test apparatus and carefully sealed to prevent bypass of air or inward leakage into the test apparatus except through the measuring orifice. After establishing the correct air flow rate through the filter, samples of air were drawn from the center points of the test duct 2 feet upstream and 8 feet downstream of the test specimen at equal rates and passed through known areas of Whatman No. 41 filter paper. Arrestance determinations were made with the particulate matter in the laboratory air as the aerosol and also with Cottrell precipitate injected into the air stream at a ratio of 1 gram per 1,000 cu. ft. of air.

The light transmission of the sampling papers was measured on the same area of each paper before and after the test and the two sampling papers used for any one arrestance determination were selected to have the same light transmission when clean.

For determining the arrestance of the particulate matter in the laboratory air, equal sampling areas were used in the upstream and downstream samplers. A similar increase of the opacity of the two sampling papers was obtained by passing the sampling air only part of the time through the upstream paper while operating the downstream sampler continuously. This was accomplished by installing one solenoid valve in the upstream sampling line and another one in a line bypassing the sampler. The solenoid valves were operated by an electric timer and a relay so that one was open while the other one was closed during any desired percentage of the 5-minute timer cycle, reversing the position of the two valves during the remainder of the cycle. The arrestance, A (in percent), was then determined with the formula:

$$A = 100 - T \times \frac{\Delta D}{\Delta U}$$

where T is the percentage of time during which air was drawn through the upstream sampler, and ΔU and ΔD are the observed changes in the opacity of the upstream and downstream sampling paper, respectively.

For determining the arrestance of the filter with Cottrell precipitate as the test dust, different size areas of sampling paper were used upstream and downstream of the filter in order to obtain a similar increase of opacity on both sampling papers. The arrestance was then calculated by the formula:

$$A = \left(1 - \frac{S_D}{S_U} \times \frac{\Delta D}{\Delta U}\right) \times 100$$

where the symbols A, ΔU, and ΔD are the same as indicated above and S_U and S_D are the upstream and downstream sampling areas. Only a few arrestance determinations were made using Cottrell precipitate. These arrestance determinations were made with Cottrell precipitate only, while cotton linters were added during the loading process in a ratio of 4 parts to every 96 parts Cottrell precipitate, including that amount of Cottrell precipitate used for arrestance measurements. The lint used had been previously prepared by grinding No. 7 cotton linters through a Wiley mill with a 4-millimeter screen while the Cottrell precipitate had been sifted through a 100-mesh screen, eliminating all particles larger than about 150 micron size.

The pressure drop across each filter was recorded at the beginning and at the end of the test, after each arrestance determination, and after every 20-gram increment of Cottrell precipitate that was introduced into the test apparatus to load the filter. The models 1060 and 2060 were loaded until the pressure drop had increased 0.5 in. W.G. above that of the clean filters, whereas the models 2090 and 2100 were loaded until the final pressure drop reached 1 in. W.G. One model 1060 specimen was operated without pre-filter and a second specimen was tested with three Amer-Glass pre-filters, successively.

Some arrestance determinations were made with Cottrell precipitate as the aerosol on models 2060 and 2090. Since these values approached 100 percent, they were not considered significant for this series of filters, therefore, all arrestance determinations on the two other models were made with the particulate matter in the laboratory air, only.

4. Test Results

All test specimens were furnished folded to the downstream side of the face plate, held together by a strip of paper. When a filter was introduced in the holding frame the paper strip was cut and the filter media unfolded due to the air pressure. No damage to any of the test specimens was noticed during the installation, however, a number of pockets in the bags of each filter did not open up immediately, causing an increased air flow through those pockets which had opened up. It was then necessary to cover the inlet of a large number of the inflated pockets to raise the pressure drop across the remainder. This procedure was repeated until all of the pockets were inflated.

The performance of the four different models was as follows:

A. Model 1060

The performance data of this model are shown in Table 1, indicating that the pressure drop of the clean filter at the rated air flow rate of 1,000 cfm was 0.200 in. W.G. The arrestance for the particulate matter in the laboratory air was initially 37.2 percent and it increased to 61.7 percent when the pressure drop reached 0.578 in. W.G. and the dust load was 1413 grams. The dust load is reported as the weight of Cottrell precipitate and lint introduced into the test apparatus diminished by the percentage of fallout upstream of the filter. The fallout was determined at the conclusion of the test by sweeping out the test duct upstream of the filter and calculating the ratio of fallout to the dust introduced into the system.

The data in Table 1 are shown graphically in Figure 1 where the arrestance and pressure drop values are plotted against the dust load and smooth lines drawn to approximate the curves of least mean distances. The dust load corresponding to 0.700 in. W.G. pressure drop was 1,610 grams and the average arrestance during the loading of the filter was approximately 57 percent.

The performance of the Model 1060 filter with an Amer-Glass prefilter is shown in Table 2. Three prefilters were loaded during this test and the initial pressure drop and arrestance was determined with a fourth one. About 400 grams of Cottrell precipitate and lint was introduced for each of the first three prefilters. This dust load increased the combined pressure drop across prefilter and Dri-Pak about 0.45 in. W.G. for the first two prefilters and about 0.61 in. W.G. for the third prefilter as compared to the initial pressure drop with both filters clean. It will be noted that the arrestance of the combination with clean prefilters was not significantly different from that determined when the Dri-Pak filter was operated without a prefilter. The arrestance of the combination increased by 6 percent to 11 percent as the prefilters loaded up. After a dust load of 1206 grams had been added to the system, the pressure drop of the combination with a clean prefilter had increased from 0.288 in. W.G. to 0.423 in. W.G. Assuming that each prefilter had the same initial pressure drop, the pressure drop across the Dri-Pak deep-bed filter increased 0.135 in. W.G. during this loading period. In Figure 1 it is shown that a dust load of about 700 grams increased the pressure drop of the Dri-Pak filter the same amount when operating without a prefilter.

Figure 2 indicates that the average arrestance of the two filters in series was about 43 percent during the addition of the 1200 grams of Cottrell precipitate and lint. The average arrestance of the Dri-Pak filter operating by itself was about 53 percent during the addition of the first 1200 grams of the same aerosol, as shown in Figure 1.

However, the Dri-Pak filter was probably between one-third and one-half loaded after the addition of 1200 grams of dust when the prefilter was used. The average arrestance of the Dri-Pak filter, operating by itself, was about 49 percent during the first third of the loading period, as shown in Figure 1. Thus it appears that the arrestance of the combination of the two filters might be lower than for the Dri-Pak filter by itself during a full loading period. It should be recognized, however, that the effect of a prefilter in a given installation would depend somewhat on the distribution of particle size in the dust and the amount of lint involved at that installation. The results described above are related specifically to the performance with Cottrell precipitate and lint as the aerosol.

Table 1

Performance Characteristics of
the Dri-Pak Model 1060 without Prefilter

Pressure Drop in. W.G.	Dust Load grams	Arrestance %
0.200	0	37.2*
0.243	202	49.3
0.277	404	53.6*
0.319	606	55.6*
0.330	646	57.5
0.358	808	61.2*
0.442	1009	59.5
0.520	1211	60.1*
0.578	1413	61.7*
0.712	1615	58.7*

*Average of two tests

Table 2

Performance Characteristics of the
Dri-Pak Model 1060 with Amer-Glass Prefilter

Pressure Drop in. W.G.		Dust Load, grams		Arrestance, %
Combination	Dri-Pak Only	Combination	Prefilter Only	Combination
0.288	----	0	0	39.5
0.434	----	203	203	43.5
0.740	----	388	388	45.1
0.392	0.294	388	0	36.8*
0.750	0.300	797	409	44.8
0.421	0.300	797	0	39.5
0.903	0.308	1206	409	50.6
0.423	0.308	1206	0	43.1

*The Dri-Pak filter was removed from test apparatus and the collected dust was dislocated in the pockets.

AMERICAN AIR FILTER COMPANY, DRI-PAK MODEL 1060

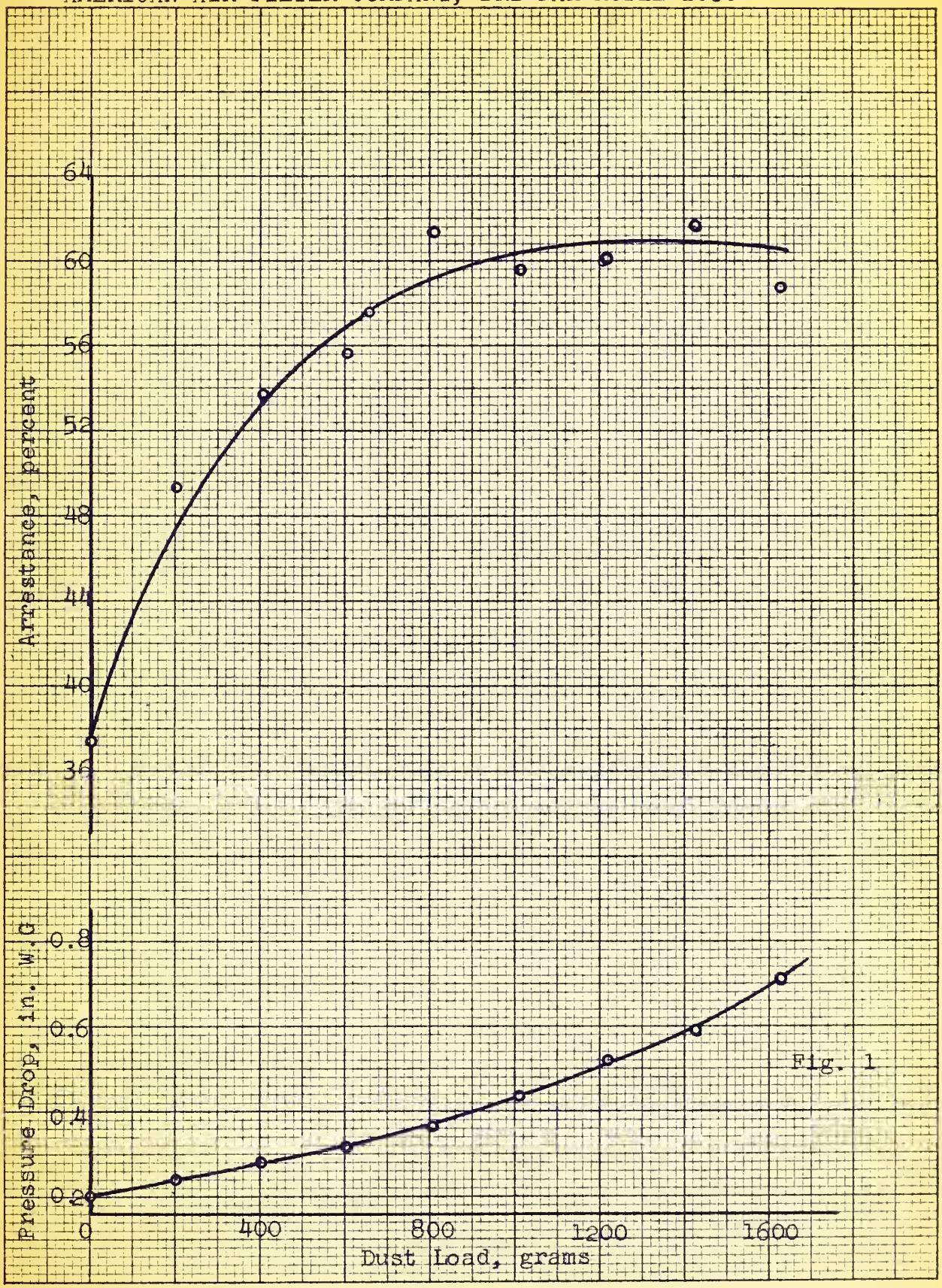

Fig. 1

AMERICAN AIR FILTER COMPANY, DRI-PAK MODEL 1060 WITH PREFILTERS

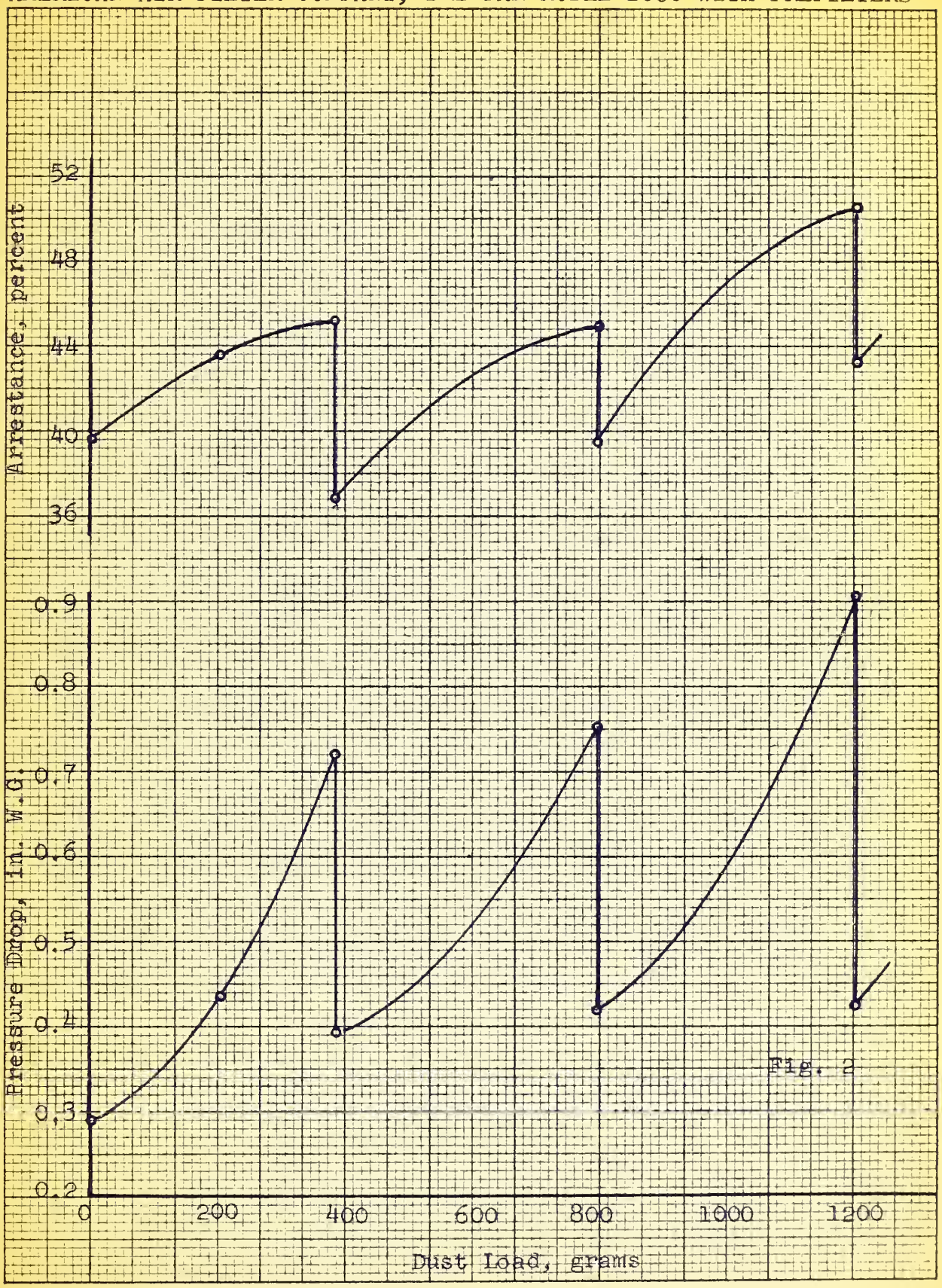

Fig. 2

B. Model 2060

The pressure drop, dust load, and arrestance values determined with the Dri-Pak Model 2060 are shown in Table 3. The initial pressure drop of this filter was 0.342 in. W.G. and it increased to 0.594 in. W.G. when the dust load had reached 1,666 grams. At that time it was noticed that a number of pockets in the filter had not opened up. By closing up the inlet openings of some of the operating pockets temporarily, these pockets were opened up by the force of the increased air pressure. As a result of the increase in filter area the pressure drop decreased to 0.485 in. W.G., i.e., by 0.109 in. W.G. It can be assumed that the initial pressure drop of the test specimen would have been lowered by a similar amount if all pockets had opened up at the beginning of the test. The final dust load of 3,937 grams at a pressure drop of 0.485 in. W.G. was based on a 0.5 in. W.G. increase above the 0.342 in. W.G. initial pressure drop. The final pressure drop recommended by the manufacturer was only 0.7 in. W.G. From Figure 3, in which the arrestance and pressure drop values of Table 3 for the Model 2060 filter have been plotted against the dust load, it can be determined that the dust load of this filter at 0.7 in. W.G. pressure drop was 3,100 grams.

The initial arrestance of the filter was 43.8 percent and the average value for the entire loading period was about 57 percent.

The upper curve of Figure 2 shows a considerable scattering of the individual arrestance values, which was caused in part by the dislocation of the dust in the filter pockets that occurred every time the air flow was cut off. Also evident in the lower curve of Figure 3 is the decrease in pressure drop that resulted from forcing open several pockets of the filter media which had remained closed during the early part of the operation of this specimen.

Two arrestance determinations made with Cottrell precipitate as the aerosol indicated 97.6 percent when the filter was clean and 98.5 percent with a dust load of 1,458 grams.

Table 3

Performance Characteristics of
the Dri-Pak Model 2060 without Prefilter

Pressure Drop in. W.G.	Dust Load grams	Arrestance %	
0.342	0	43.8	97.6*
0.359	208	53.7	
0.388	417	59.6	
0.418	625	58.9	
0.455	833	55.6	
0.500	1042	66.6	
0.535	1250	55.5	
0.560	1458	56.4	98.5*
0.594	1666	--	
0.485**	1666	54.8	
0.560	1875	58.5	
0.584	2083	62.2	
0.607	2291	59.2	
0.634	2500	57.9	
0.652	2708	57.7	
0.678	2916	64.9	
0.708	3125	57.2	
0.729	3333	62.2	
0.750	3541	56.3	
0.794	3749	56.5	
0.845	3937	56.8	

*Cottrell precipitate as the aerosol.

**Forced open closed filter pockets.

AMERICAN AIR FILTER COMPANY, DRI-PAK MODEL 2060

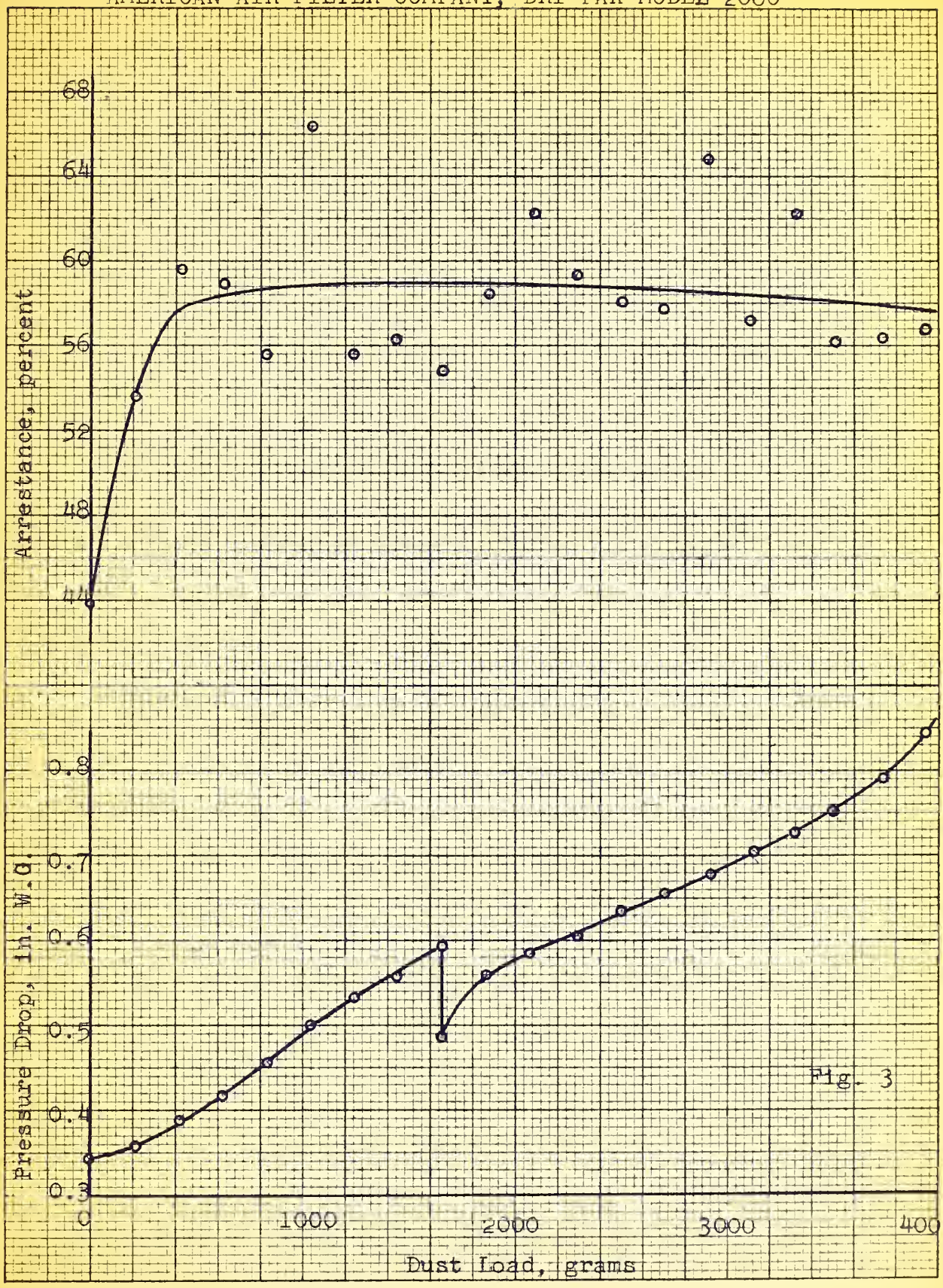

Fig. 3

C. Model 2090

The performance of Model 2090 Dri-Pak filter is indicated by the values for pressure drop, dust load, and arrestance shown in Table 4. The initial pressure drop of this specimen was 0.268 in. W.G., its dust-holding capacity at a final pressure of 1.005 in. W.G. was 2,789 grams. The arrestance of the clean filter determined with the particulate matter in the laboratory air was 56.5 percent; it reached 90.0 percent for the first time with a dust load of 417 grams and a maximum of 93.7 percent with a dust load of 1937 grams. The arrestance of Cottrell precipitate showed values of 99.1 percent and 99.5 percent during the early part of the loading period.

The dust-holding capacity of this model based on the recommended final pressure drop of 0.8 in. W.G. was 2,500 grams and the average arrestance approximately 90 percent.

The performance data for the Model 2090 Dri-Pak filter from Table 4 were plotted in Figure 4 and smooth curves were drawn through the observed values.

Table 4

Performance Characteristics of
the Dri-Pak Model 2090 without Prefilter

Pressure Drop in. W.G.	Dust Load grams	Arrestance %	
0.268	0	56.5	99.1*
0.312	208	82.0	
0.342	417	90.0	
0.372	625	89.2	99.5*
0.398	833	85.3	
0.421	1042	91.1	
0.453	1250	90.6	
0.471	1354	92.6	
0.511	1562	92.6	
0.544	1729	93.0	
0.604	1937	93.7	
0.660	2145	91.3	
0.740	2354	92.1	
0.813	2476	92.3	
1.005	2789	90.4	

*Cottrell precipitate as the aerosol.

AMERICAN AIR FILTER COMPANY, DRI-PAK MODEL 2090

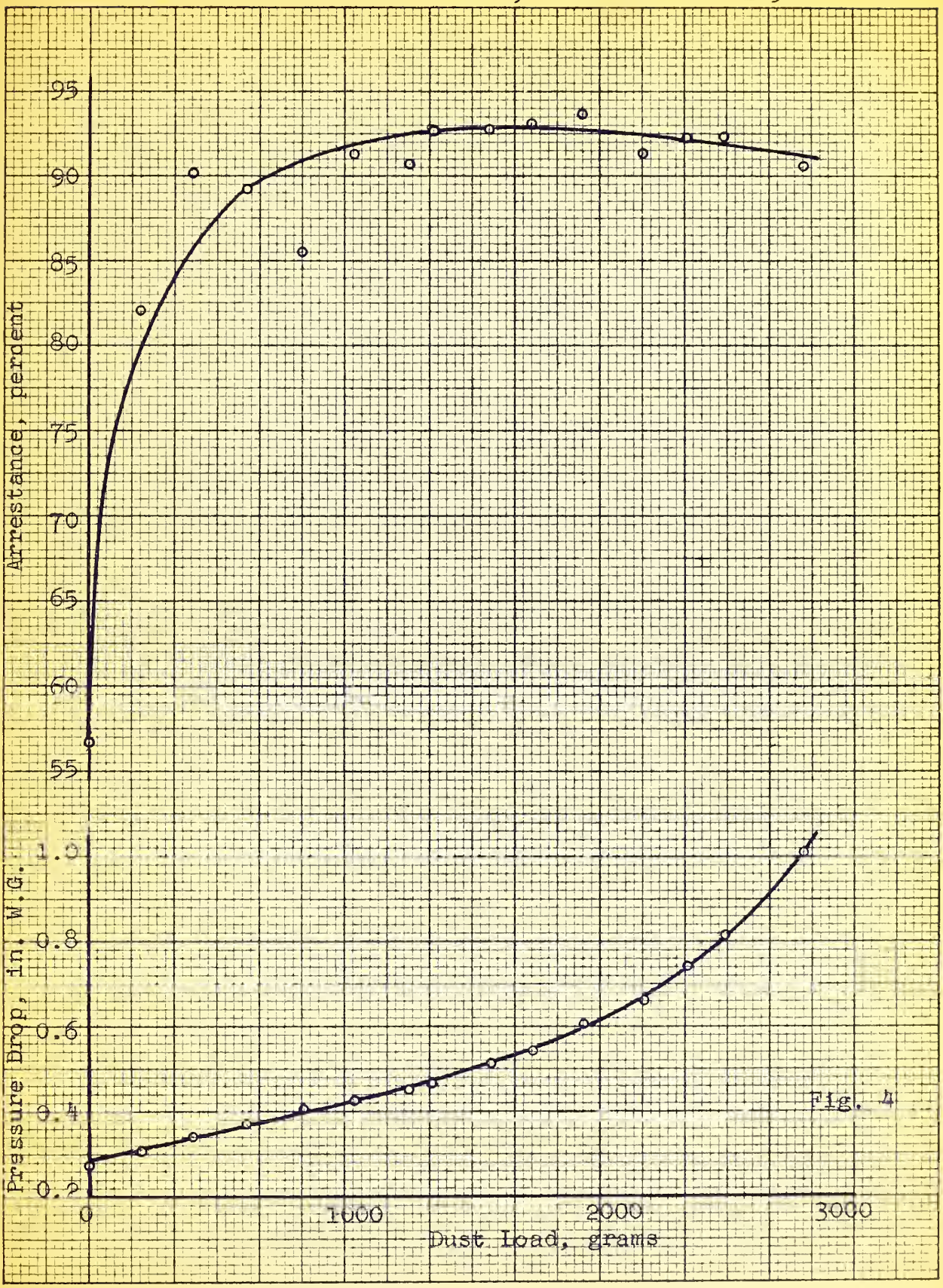

Fig. 4

D. Model 2100

The first two specimens of the Dri-Pak Model 2100 were found to have holes in the media, the cause of which could not be determined. The manufacturer's representatives stated that these two specimens had not been assembled in the regular production line and had received no quality control inspection. The three replacement filters then furnished by the manufacturer did not reveal any holes after being installed into the test apparatus. Only one of these three filters was loaded to capacity, identified as Specimen A in Table 5. The initial pressure drops and arrestances of the two other specimens are also presented in Table 5.

It will be noted that the initial pressure drop of the three specimens ranged from 0.400 in. W.G. to 0.425 in. W.G. and the arrestance values were between 87.9 percent and 89.5 percent. These differences in the initial performance of deep-bed filters of this type do not seem excessive. Specimen A had a maximum arrestance of 98.7 percent at a dust load of 416 grams and a pressure drop of 0.480 in. W.G.

The performance data for Specimen A, shown in Table 5, were plotted in Figure 5 and smooth curves approaching the lines of least mean distances were drawn. The average arrestance of this specimen was approximately 97.5 percent and the dust-holding capacity based on a recommended final pressure drop of 1.0 in. W.G. was 1350 grams.

Table 5

Performance Characteristics of
the Dri-Pak Model 2100 without Prefilter

Pressure Drop in. W.G.	Dust Load grams	Arrestance %
	Specimen A	
0.400	0	89.5
0.437	208	98.2
0.480	416	98.7
0.546	667	96.6
0.646	937	98.0
0.905	1271	97.8
1.03	1355	97.5
	Specimen B	
0.425	0	87.9
	Specimen C	
0.412	0	89.3

AMERICAN AIR FILTER COMPANY, DRI-PAK MODEL 2100

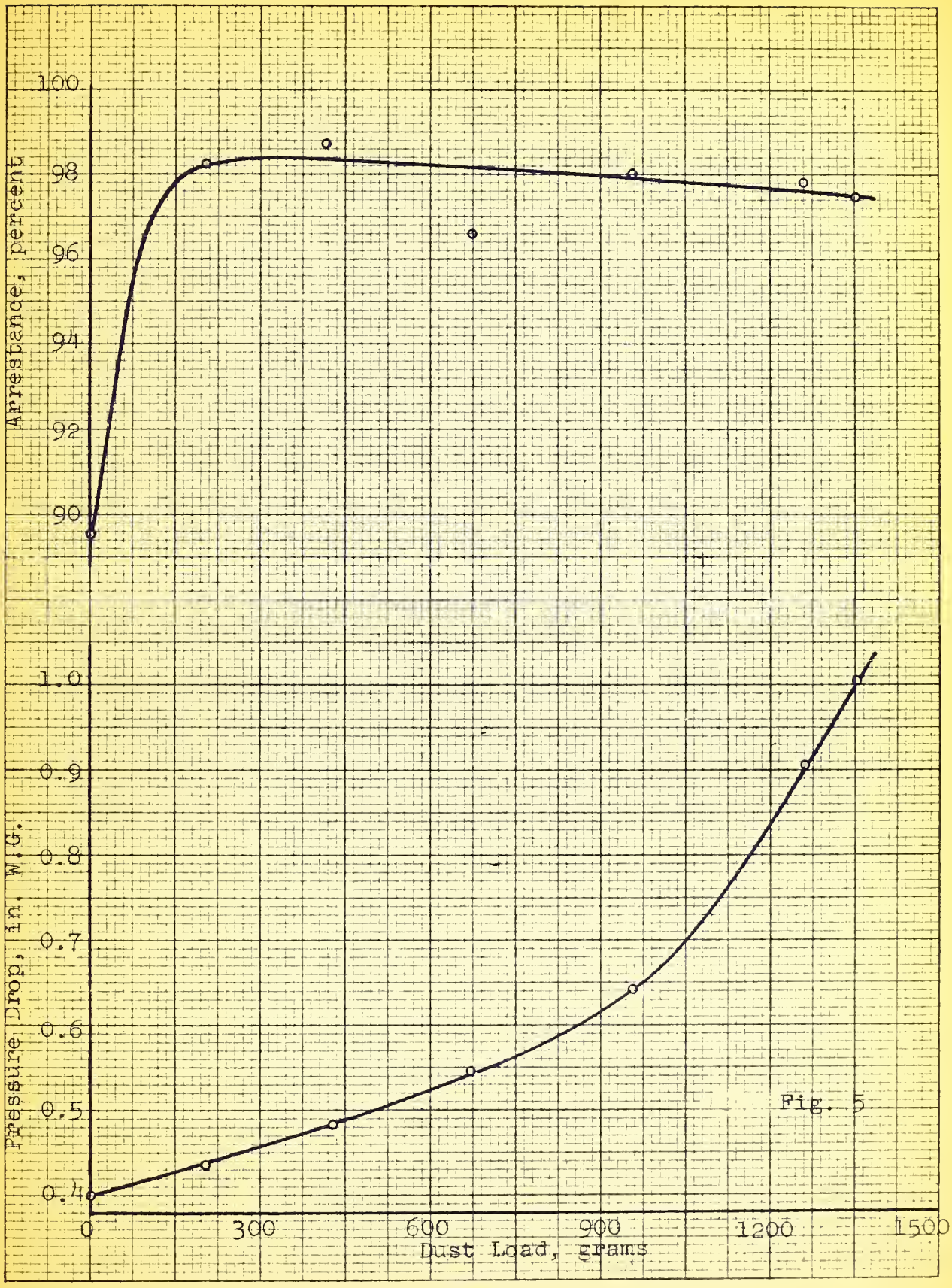

Fig. 5

Summary

Table 6 summarizes the pertinent data determined in the tests of the four models of the Dri-Pak filter. It shows the air flow rate, initial pressure drop, the final pressure drop recommended for each model by the manufacturer, and the dust load of the filters corresponding to the final pressure drop. Also shown are the arrestance of the particulate matter when the filters were clean and the average arrestance values for the entire loading period. It should be noted that the initial pressure drop of the Model 2060 filter would have been lower than the observed value of 0.342 in. W.G. if all of the pockets had been opened at the time of installation of this filter. Although the initial arrestance of the Model 2060 filter was higher than that of Model 1060 it was found that the average arrestance, 57 percent, was the same for both models and the dust load for the Model 2060 at the final pressure drop of 0.7 in. W.G. was close to double that of the other filter which had about half as much media area.

Figure 6 shows the observed arrestance values plotted against the pressure drop for the four filter models. It will be noted that the increase in pressure drop from the initial value to that at which the filters first reached the average arrestance, shown in Table 6, differed considerably with the four models. This increase in pressure drop is shown in Table 7, which also presents the corresponding values of the dust loads that had been introduced into the filters when the average arrestance was first reached. These latter values were taken from Figures 1, 3, 4, and 5, respectively.

Table 6

Summary of Performance of
Four Dri-Pak Deep-Bed Air Filters

Model Number	1060	2060	2090	2100
Rated Air Flow Rate, cfm	1000	2000	2000	2000
Initial Pressure Drop, in. W.G.	0.200	0.342	0.268	0.400
Recommended Final Pressure Drop, in. W.G.	0.7	0.7	0.8	1.0
Dust Load at Final Pressure Drop, grams	1600	3180	2570	1350
Initial Arrestance, %	37.2	43.8	56.5	89.5
Average Arrestance, %	57	57	90	97

Table 7

Pressure Drop Increase and Dust Load
that First Produced the Average Arrestance

Model Number	1060	2060	2090	2100
Pressure Drop Increase, in. W.G.	0.12	0.04	0.10	0.02
Dust Load, grams	600	310	700	110
Pressure Drop Increase, % of Total Increase	24	11	19	3
Dust Load, % of Total Load	37	10	28	8

A comparison of the data in Table 7 on the Models 1060 and 2060 air filters indicates the effect of the unopened pockets in the latter specimen during the early part of the test. It will be noted that the amount of dust load required to increase the arrestance of the Model 2060 filter to the average arrestance value of 57 percent was only half that required for the Model 1060 even though the latter had only half as much filter area if both were fully expanded. The increase in pressure drop accompanying the initial rise in arrestance to 57 percent was only 0.04 in. W.G. for the Model 2060 as compared to 0.12 in. W.G. for the Model 1060. Since the design air velocities through the media in both filters were equal, the failure of some pockets to open initially in the Model 2060 filter caused the air velocity to be higher in this filter at the beginning of the test. This probably accounted for some of the observed difference in initial loading characteristics and rate of increase in arrestance.

AMERICAN AIR FILTER COMPANY, DRI-PAK SUMMARY

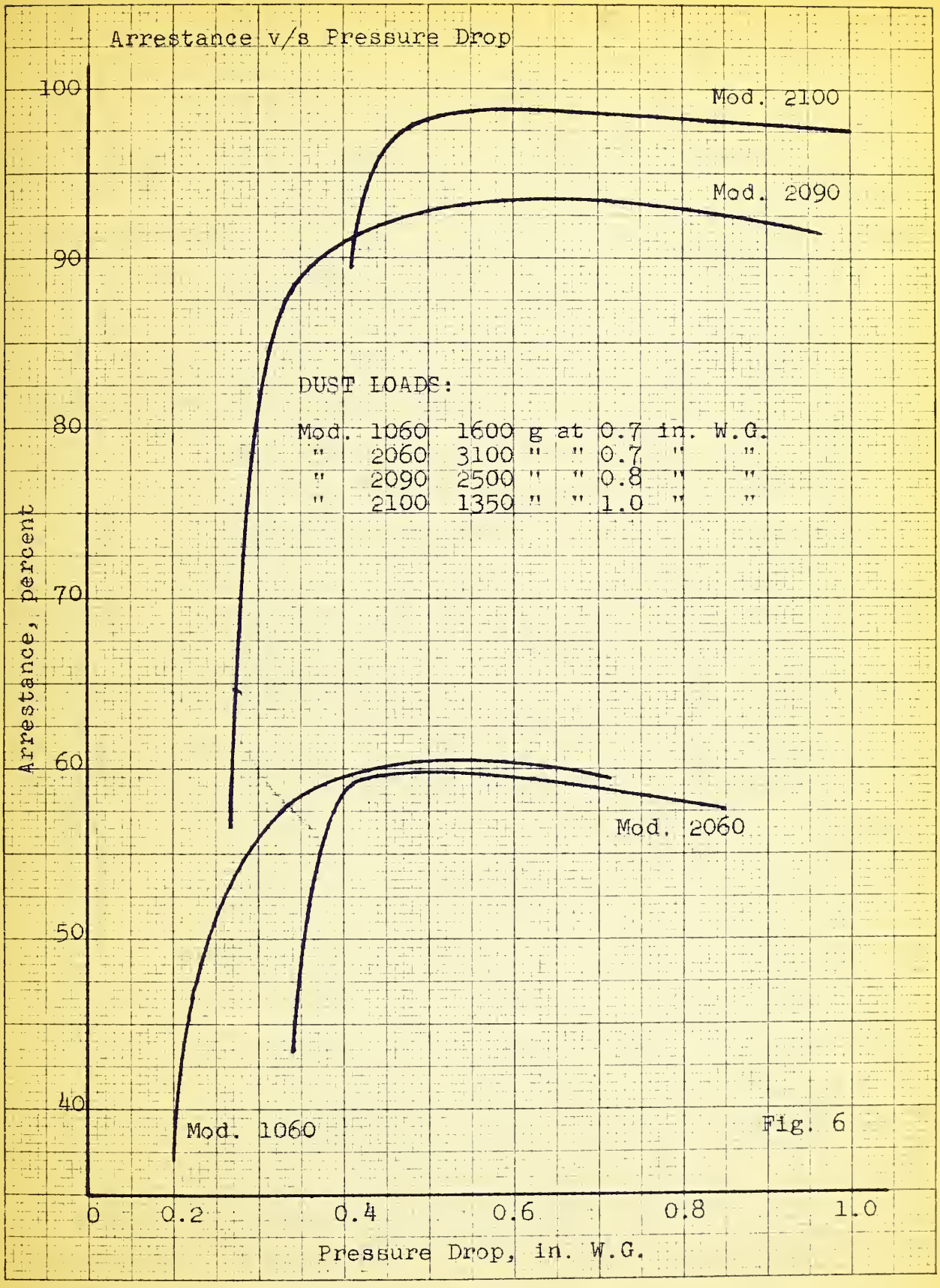

Fig. 6

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Tropospheric and Space Telecommunications. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Spectrum Utilization Research. Radio-Meteorology. Lower Atmosphere Physics.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Frequency Utilization. Modulation Research. Antenna Research. Radiodetermination.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. High Latitude Ionosphere Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

RADIO STANDARDS LABORATORY

Radio Standards Physics. Frequency and Time Disseminations. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Radio Plasma. Microwave Physics.

Radio Standards Engineering. High Frequency Electrical Standards. High Frequency Calibration Services. High Frequency Impedance Standards. Microwave Calibration Services. Microwave Circuit Standards. Low Frequency Calibration Services.

Joint Institute for Laboratory Astrophysics - NBS Group (Univ. of Colo.).

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