EFFECT OF A SULFUR DIOXIDE CONTAMINATED

ATMOSPHERE ON BREAKING STRENGTH OF

FABRICS OF DIFFERENT FIBER CONTENT

By

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ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

All facets of modern mass media are steadily proclaiming air
pollution as one of the major problems of today's world. Pollution
alerts, results of temperature inversions which impede the regular
circulation of air, and vital health statistics are attracting world-
wide attention. A consequence of refined and complex societies appears
to be a greater desecration of the atmosphere, one of the fundamental
necessities of life. The outcome of this desecration is that all
aspects of daily living and a majority of the world's population have
been affected.

Action has been started to control this contamination of the atmos-
phere, but much remains to be done. The federal Clean Air Act of 1963
provides for financial assistance to local and regional state air
pollution agencies (12, 13). Nationwide, in 1965, only 15 states had
some form of pollution control agency. California is probably the
leader in air pollution control, spending more than a quarter of a
million dollars yearly on its program (6). A majority of the populace
of the United States still remains largely apathetic and unaware that
air pollution directly affects them.

> The air pollution buildup is developing at a faster rate than
> nature's ability to neutralize it, or man's attempts to combat it.
> The gap between the intensification of the problem and the response
> to it becomes wider all the time (3).

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Although the primary concern associated with air pollution revolves around the nation's health, the problem is not confined to the human body alone. A recent committee report cited by Herber (6) attributes a high economic loss to air pollution.

> At the present time, air pollution probably costs the United States about 11 billion dollars in property damage annually. To state this staggering price in more meaningful terms, the annual bill for damage to clothing, home furnishings, buildings, machinery, roads, and public installations caused by air pollutants, such as sulphur dioxide and ozone, is equal to about half the yearly funds collected by the Internal Revenue Service in corporation taxes. If this damage could be avoided and the corresponding funds made available to the public, a family of four people would have its yearly income boosted by over $250.

The effects of air pollution on the fabrics we wear and use are relatively unknown, but a beginning has been made in the study of these effects. Much of the past research has been concerned with fabrics which are used in the home and which are exposed daily to both sunlight and atmospheric elements. However, even in the air-conditioned, humidity-controlled buildings of today, clothing, whether worn or stored, is constantly exposed to the elements of the atmosphere.

The positive correlation between an atmospheric contaminant and fabric deterioration from a recent study (14) of curtain marquisettes at Oklahoma State University led to interest in further investigation of this topic.

This particular investigation of air pollution and fabric deterioration probes the effect of a sulfur dioxide contaminated atmosphere on the deterioration of cotton, Dacron, Dacron-cotton, nylon, and rayon clothing fabrics. The objectives of this study were to:

1. Devise a method for the reproduction of a constant sulfur-dioxide contaminated atmosphere.

2. Determine the effectiveness of a test chamber for uniform
    dispersion of the air and sulfur dioxide mixture.

3. Determine the deteriorative effect of the sulfur dioxide
    atmosphere on breaking strength of the fabrics at various
    exposure periods in a test chamber.

4. Evaluate the methods and procedures used in the study in terms
    of recommendations for future research.

CHAPTER II

REVIEW OF LITERATURE

Polluted air may contain either natural or man-made foreign substances. Ladd (8) has defined it as "any deviation of the normal atmosphere of:

Nitrogen	78.08
Oxygen	20.95
Carbon dioxide	0.03
Argon	.93
Trace amounts of	
He, H_2, O_3, N_2O, etc.	.01"

Recognition of atmospheric pollution as a major threat to the world has focused attention upon the sources and types of air pollutants in an attempt to control the purity of the atmosphere. There are a multitudinous number of man-made sources, but the three identified below contribute most of the contamination:

1. Large industrial operations such as steel mills, metallurgical plants, petroleum refineries, chemical plants, and power plants (9).

2. Small industrial and commercial installations such as dry-cleaning plants, asphalt-mixing plants, junkyards, etc. (9).

3. Motor vehicles which in the use of 1,000 gallons of gasoline discharge 17 pounds of SO_2 (sulphur dioxide), plus 18 pounds of

aldehydes, 25-75 pounds of oxides of nitrogen, and more than 3,000 pounds of carbon monoxide (6).

The combined effects of numerous small installations may contribute as significantly to the pollution problem as the large operations.

Lewis (9) has classified five basic types of air pollution represented by odor, dust, smoke, motor exhaust, and toxic substances. He also states that all pollutants are caused by burning, vaporizing, or dividing but that the highest proportion of pollutants comes from burning fuels. As a result of nationwide combustion of coal, 50,000 tons of SO_2 are discharged daily. "The sheer process of burning materials causes the emission into the air of smoke, fumes, dust, acids, organic substances, nitrogen dioxide, sulfur dioxide, and carbon monoxide."

Meetham (11) has grouped pollution materials into three somewhat different categories:

1. The reactive substances which include, among others, SO_2 and SO_3 (sulfur trioxide), SO_2 being one of the most important in ordinary town air.

2. Fine particles which remain suspended in the air for a long time and are then deposited as dirt (smoke).

3. Coarse particles which quickly fall to the ground (mineral matter and grit - ash).

Much attention will be given to SO_2, smoke, and ash, not only because they are most important but because they serve jointly as prototypes: any other form of pollution when released into the atmosphere will behave similarly to one or other of them.

Smog is also an indication of atmospheric impurities, and two distinct types have been categorized according to composition. The London-type, which is of an acidic and reductive character, has a high SO_2 and H_2SO_4 (sulfuric acid) content. It holds smoke, soot, dust, and

aerosols and is highly corrosive to nylon, paper, and other textiles. The Los Angeles-type contains ozone produced by photochemical reactions between olefinic hydrocarbons and nitrogen oxides. Ozone is known for attacking rubber but is usually not considered as dangerous to textiles as the London-type smog (17).

Atmospheric impurities have been said to be the second largest single influence on textiles exposed to air. Meetham (11) and Lewis (9), along with other authorities, are proclaiming SO_2 as one of the major and most plentiful impurities in the atmosphere. The combustion of sulfur forms this invisible gas which contains one atom of sulfur and two atoms of oxygen. Sulfur is an element that comprises one per cent to six per cent of most of the coal and oil burned but may also be found in automobile gasoline.

Sulfur trioxide is formed when another atom of oxygen is attracted to the SO_2 molecule. This new molecule combines with moisture in the air to form H_2SO_4, and it is the latter substance which accounts for the highly corrosive nature attributed to SO_2.

The oxidation process of sulfuric acid formation from SO_2 in the atmosphere was recently studied (7). A comparison was made between the oxidation of SO_2 in the air and the oxidation of SO_2 in the presence of NO_2 (nitrogen dioxide), O_3 (ozone), and H_2O_2 (hydrogen peroxide). It was found that the presence of other airborne particulate matter in the air increased the production of H_2SO_4.

Sulfur dioxide has a distinguishable odor and "Like smoke, ... penetrates indoors, where it tarnishes metals and makes fabrics tender and easily torn after washing" (11). Meetham further reports that less than one fifth of the SO_2 in the atmosphere falls to the ground with

rain; and the average time during which the SO_2 remains in the air is approximated at less than 12 hours. One could deduce from these facts that the SO_2 must then settle elsewhere, and it evidently does so within a relatively short time. Wool, cotton, and leather have been found to rot in polluted atmospheres. The SO_2 absorbed by the fabrics was oxidized to form H_2SO_4, which then attacked the proteins in the materials.

Lewis (9) says that not only leather deteriorates but paper becomes brittle and textiles are likewise affected. He specifically mentions color change due to ozone and nitrogen oxides, and in addition states that SO_2 decreased the strength of cotton, wool, and nylon. Particles consisting of SO_2-originated sulfuric acid are thought to be a cause of runs in nylon hosiery. "In 1948, many women in Jacksonville, Florida, were partly undressed on the street when acid in the air suddenly disintegrated their nylon blouses and stockings."

Race (16) detected that of fabrics exposed to an industrial atmosphere in Leeds, England, during the winter and summer months, those exposed during the winter showed the greater loss in breaking strength. Because there is less sunlight during the winter, this occurrence could only logically be attributed to the increased acidity of atmospheric moisture.

> One of the primary causes of the high acid content of rain and atmosphere in winter appears to be fog... Contributing factors to both fog and acid formation are undoubtedly the lower winter temperatures, favouring greater condensation of volatile acids, and, more especially, the much greater consumption of domestic fuel in winter than in summer.

Moisture, acting both chemically and physically, is known to be an important deteriorative agent, and it plays a large role in the effectiveness of other deteriorative agents. "In the usual case, the more water and the easier the access to it the more serious the detrimental

effect on materials. Ordinarily, the more severe the moisture condi-

tions the more rapid the degradative effect" (5).

The U. S. Public Health Service operates the Continuous Air

Monitoring Program (CAMP) to provide up-to-date information on levels

of gaseous air pollutants in several larger cities of the U. S. A

recently published report (10) concerns air monitoring over a two-year

period in Cincinnati, Chicago, New Orleans, Philadelphia, Washington,

D. C., and San Francisco. Chicago and Philadelphia, due to their heavy

industrialization and consumption of coal, had the highest levels of

SO_2. The two-year means were as follows:

> Chicago   - 0.135 ppm with 618 days of valid data
>
> Philadelphia - 0.076 with 604 days of valid data

Although the over-all means appear low, a look at the maximum level for

shorter periods of time shows higher amounts of SO_2 pollution:

	Month	Day	Hour	5-Min.
Chicago	0.344	0.79	1.36	1.64
Philadelphia	0.150	0.46	1.03	1.25

The study also showed diurnal variation patterns of SO_2 concentra-

tion with similar morning and evening peaks emerging in all of the

cities. This variation, with a low level of concentration in the after-

noon, is explained by the dilution capacity of the atmosphere. The

morning peak is caused by increased human activity, while the evening

hours are usually characterized as having lighter winds than the after-

noon hours. A similar study (4) conducted in St. Louis showed peak

levels of SO_2 to be in agreement with those in Chicago and Philadelphia.

The amount of SO_2 varies from area to area, and some cities of more

than one million population have reported a level as high as 8 ppm (6).

Cotton fabrics were exposed in St. Louis during the Continuous
Air Monitoring Program, and tests conducted on the fabrics resulted in
these observations:

1. A significant relationship existed between air pollution and
   the degradation of cotton fabrics. Fabrics exposed at the
   three sites with the highest levels of air pollution had the
   greatest strength loss.

2. The economic aspects of air-pollution-induced cloth degradation
   could be considerable. If a fabric article is serviceable
   until it still has one third of its original strength, air
   pollution can reduce its effective service life to one sixth or
   less of that of a similar article exposed in a clean area (4).

A major problem in laboratory work involves the simulation of a
real situation. Apparatus was recently constructed by Amtower (18)
which would reproduce known gas mixtures in any desired concentration
and complexity. This apparatus produced a dynamic mixture by combining
filtered air with the gas.

> Dynamic mixtures are preferable to static mixtures. The latter
> have been used extensively in plastic bags, but they have the
> disadvantage that the pollutant reacts slowly with the container,
> introducing some uncertainty into the value for the concentration.

Peters (14, 15), in a study conducted at Oklahoma State University
in 1966, produced an ozone-contaminated atmosphere in the laboratory.
Using a wood and glass frame test chamber, she exposed curtain marqui-
settes of acetate, cotton, Dacron, Fiberglas, and nylon for a period of
9 to 45 days. The loss of strength was statistically significant for
nylon and Dacron; the loss in strength of acetate was almost signifi-
cant; cotton showed no significant strength loss; and no conclusions
could be drawn about Fiberglas strength because of its high variability.

CHAPTER III

MATERIALS AND METHODS

Outdoor exposure of fabrics is one of the best methods for
obtaining knowledge regarding atmospheric weathering. However, due to
the complexity of the atmosphere it is impossible to state explicitly
which of the elements has the greatest effect on fabrics. Therefore, in
this experiment an atmosphere contaminated with SO_2 was used in a con-
trolled laboratory situation to determine the specific effect of this
major atmospheric pollutant on fabric strength.

Fabrics

Although the majority of past investigations have been conducted
with sheer transparent fabrics, many of today's clothing fabrics could
not be classified as such. Even so, they are constantly being exposed
to the elements of the atmosphere. It is for this reason that white
opaque fabrics such as those used for blouses, shirts, and uniforms were
chosen for the experiment. Standard test fabrics woven of cotton,
Dacron polyester, Dacron (65%)-cotton (35%), nylon, and rayon were
selected.[1]

Fabric similarity was taken into consideration as much as possible
with respect to weight, yarns per inch, yarn size, and fabric

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[1]Testfabrics Catalog Number 21; March, 1965. Testfabrics Incorpor-
ated; 55 Vandam Street; New York, New York; 10013.

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construction (Table I). All fabrics with the exception of nylon were woven from spun yarns in a plain weave. The nylon taffeta, a plain weave variation, was woven from filament yarns. A double-ply yarn was used in the warp direction of the Dacron fabric; all other fabric yarns were single ply.

TABLE I

DESCRIPTIVE ANALYSIS OF THE FABRICS

Fabric	Yarns per Inch		Weight per Square Yard (Oz.)	Yarn Number (Tex System)		Yarn Twist (Turns per inch)	
	W	F		W	F	W	F
Cotton	87	77	3.2	17.6	14.5	20	25
Dacron Polyester	65	56	3.8	21.3	20.7	25	18
Dacron-cotton	98	63	2.4	12.2	14.4	25	27
Nylon	141	67	2.6	8.1	16.4	5	5
Rayon	72	59	4.0	19.7	31.5	19	18

Test Chamber

The wood and glass frame test chamber designed by Peters (14, 15) was utilized for the experiment. The chamber was 61½ inches long, 10 inches wide, and 31¼ inches deep with approximately 11 cubic feet of space. There were four removable side glass panels and a removable wooden top.

The following modifications of the chamber were made for this study:

1. Holes one inch in diameter were drilled in either end of the
   chamber, one near the top and the other near the bottom, to
   allow for the continuous flow of air through the chamber.

2. Three rows of wire were restrung in the chamber with two
   parallel lines equidistant from the center in each row. This
   gave a total of six wires from which to hang the specimens.

3. Two solid baffles were placed in the chamber dividing the
   length into three sections. The baffles were used to aid in
   distribution and flow of the air. The following diagram
   illustrates the location of the baffles and the air movement
   through the chamber.
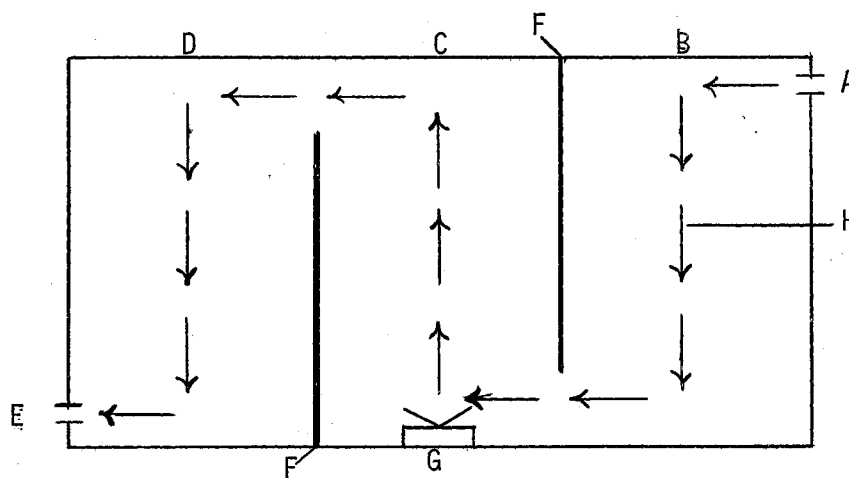
Scale: 3/8" = 6"

Figure 1. Air Flow Through Chamber

A. Air Entrance   E. Air Exit
B. Chamber Section I   F. Baffles
C. Chamber Section II   G. Electric Fan
D. Chamber Section III   H. Air Flow

4. The edges of the glass panels and top opening were sealed with
   masking tape to prevent as much air loss as possible.

The electric fan in the center bottom of the chamber was run throughout the experiment to avoid settling of the SO_2 mixture.

Humidity was increased inside the chamber by placing two containers of distilled water on the chamber floor between the fan and the air entrance wall. Hygrometers hung on the inside wall at each end of the chamber were used as a daily check on the temperature and humidity; a sling psychrometer was used to measure room temperature and humidity. These readings were recorded daily between 10:30 a.m. and 12:30 p.m.

No attempt was made to darken the room in which the chamber was placed. Distance overhead lighting was the only source of light present in the windowless room.

Gas Dilution Apparatus

The apparatus which diluted and circulated the SO_2-contaminated atmosphere through the chamber (Figure 2) operated in several phases. A small blower[2] attached to the end of a galvanized metal duct started the process by drawing air from the room. Ideally the blower was capable of a volume of 490 cubic feet of air per minute. The T-shaped duct was built to specifications necessary to handle the air flow from the blower. The air was not filtered for contaminants since Stillwater does not lie in a heavily polluted area.

The air velocity was measured in feet per minute with an "Alnor" type 8500 Thermo-Anemometer. Two one-inch holes were placed in the duct to take this reading, but due to the high turbidity of the air it was possible to obtain an average reading from the top hole only.

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[2]Blower obtained from W. W. Grainger, Inc.; 316 East Sheridan Avenue; Oklahoma City, Oklahoma.

Pure SO_2 was dispensed from a No. 3 Matheson cylinder, and after entering the metal duct through a small section of copper tubing mixed with the air flow. The flow of the SO_2 was controlled with a gas regulator and a calibrated flowmeter.[3] Steps used in the calculation of the flow rate of SO_2 were as follows:

1. Area of duct in sq. ft. x rate of air in ft./min. = cu. ft. of air/min.

2. Cu. ft. of air/min. x 472 cc/min. x 60 sec. = cc. of air/min.

3. $\frac{\text{Desired conc. of gas in ppm}}{\text{cc. of air/min.}}$ = flow rate of SO_2

4. Flowmeter reading obtained from Calibration Chart.

Two baffles placed at approximately 45-degree angles within the duct, 3 inches and 6 inches from the T-joining, were used to insure the mixing of the air and the SO_2. Because the dilution of the SO_2 required a specific velocity of air, one end of the T-joining was vented with a metal gate.

The T-joining of the metal duct had six gas valves which could be used as outlets for the gas mixture. Of the four half-inch valves and the two one-inch valves, only a one-inch valve connecting the duct to the chamber (Figure 2) was used for the experiment. The gas mixture was forced through the one-inch valve and into the chamber through plastic tubing.

After circulating through the chamber the mixture was routed to an air exhaust system. The foreground of the photograph (Figure 3) shows the tube leading to the chamber; the tube in the background came from

[3]Regulator and flowmeter obtained from Matheson Scientific, Inc.; Post Office Box 908; La Porte, Texas, 77571.

PLASTIC TUBING
TO CHAMBER

BAFFLES

SCALE: 1" = 1'-0"

① – CYLINDER SO₂
② – MATHESON REGULATOR 13-660
③ – MATHESON FLOWMETER 621BS1
④ – ⅛" COPPER TUBING
⑤ – DAYTON BLOWER 2C962
⑥ – AIR FLOW DISTRIBUTOR
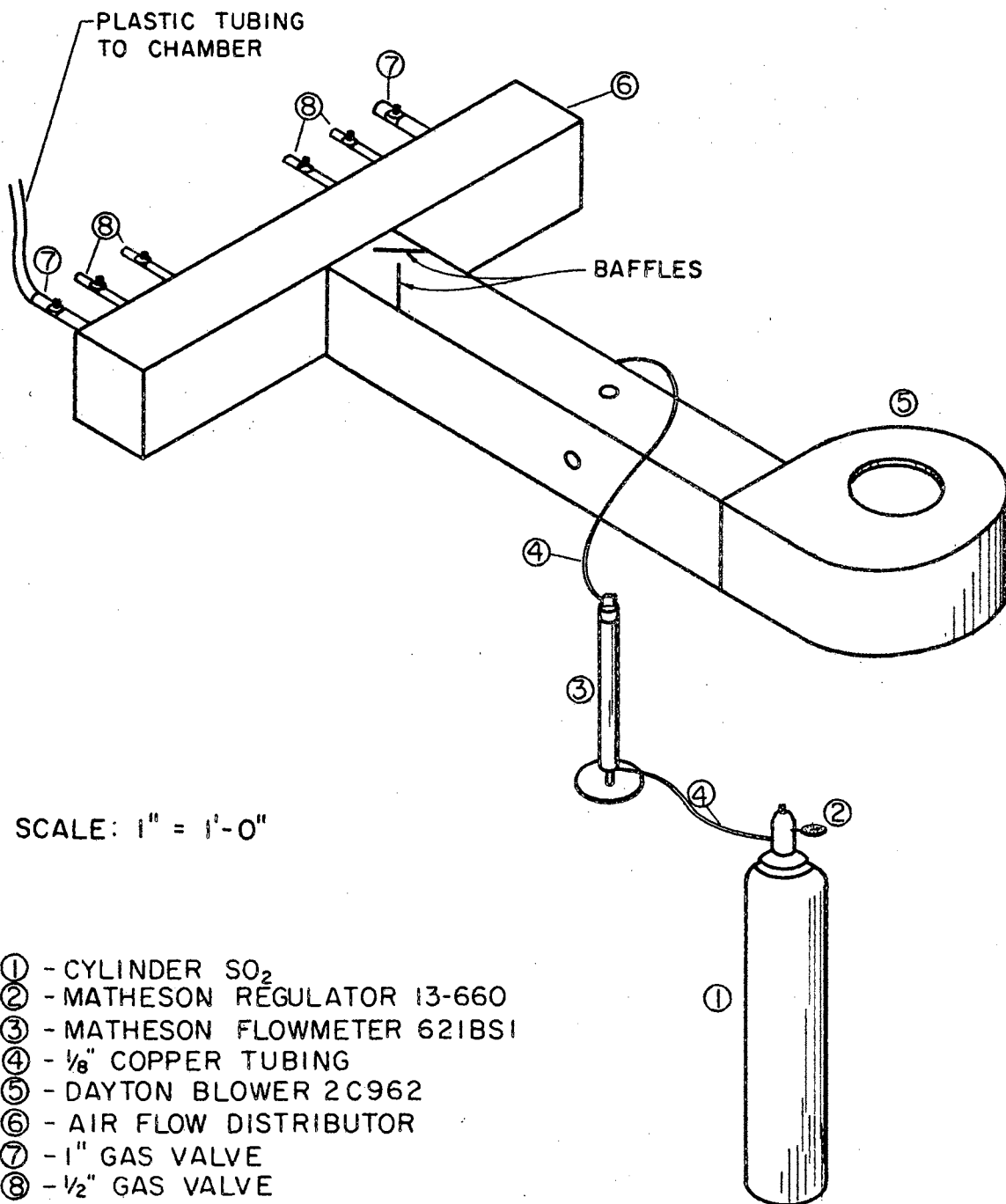⑦ – 1" GAS VALVE
⑧ – ½" GAS VALVE
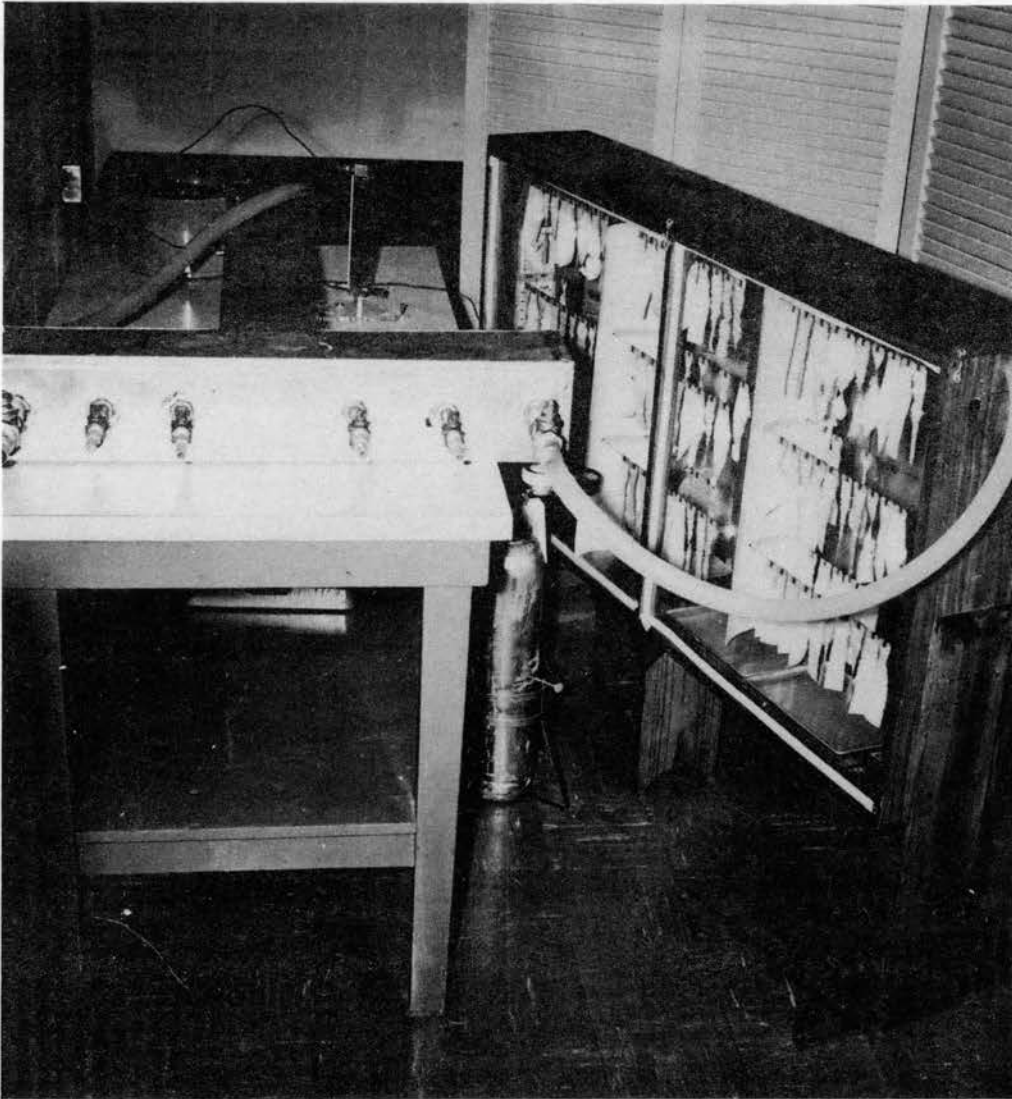
Figure 2. Gas Dilution Apparatus

Figure 3. Gas Dilution Apparatus Connected to Test Chamber.

the lower end of the chamber, crossed over the duct, and stopped at the air exhaust pipe in the upper left of the photograph.

Experimental Procedure

Sampling

The specimens for breaking strength, ravelled strip method, were cut according to ASTM Standards (2) from both the warp and filling directions of 1½ yards of continuous length fabrics ranging in width from 36 inches to 47 inches. A total of 240 specimens (120 warp and 120 filling) was used in the experiment with 48 specimens (24 warp and 24 filling) from each length of fabric. All specimens were randomly assigned to an exposure period; and those specimens which were to be placed in the chamber were further assigned to a chamber section and a wire position. To readily identify each sample, a coding system was used which designated fabric, yarn direction, exposure period, duplicate, chamber section, row number, and row position.

Exposure

The specimens were exposed to a constant flow of air which had been polluted with SO_2 in the ratio of two parts SO_2 to a million parts of air. The maximum exposure period was 30 days with fabrics tested at four different intervals of 0, 10, 20, and 30 days.

With 12 specimens (6 warp and 6 filling) of each fabric used as a control (0 exposure), 36 specimens (18 warp and 18 filling) of each fabric were placed in the chamber. Of the total number of specimens, 180 were exposed to the contaminated atmosphere and 60 were used to determine initial breaking strength.

Prior to placing the fabrics in the chamber, several checks were made to insure uniform exposure of all specimens. A vapor formed from the reaction of ammonia and hydrochloric acid was circulated within the chamber by using the blower system previously described. Beginning with chamber section I and proceeding to section III there appeared to be a lack of vapor two inches from the right side of each section. Therefore, specimens were not hung within the two-inch dead air space.

A six-day uniformity trial was conducted in a concentrated SO_2 atmosphere for further assurance that all specimens would receive uniform exposure. The results showed no significant differences between chamber location or wire placement of fabrics; thus, it was concluded that air circulation was uniform throughout the chamber.

One more consideration was given to the placement of specimens to obtain further information on a possible gradient from chamber section I to chamber section III. Of the 12 specimens of each fabric for each of the 3 exposure periods, 4 specimens (2 warp and 2 filling) were placed in each of the 3 chamber sections. This gave a total of 60 specimens per section with duplicate warp and filling specimens in each section. Ten specimens were hung approximately 1/8-inch to 1/4-inch apart on each of the 6 wires within a section.

Determination of Breaking Strength

At the end of each exposure period air circulation was stopped and 12 specimens (6 warp and 6 filling) of each fabric were removed and tested for breaking strength under standard conditions and according to ASTM (2) recommended procedures.

The ruptured specimens were returned to the test chamber to keep the quantity and condition of fabric within the chamber as uniform as

possible throughout the experiment.

Analysis of Data

Each of the three chamber sections represented a complete block which led to the analysis of the breaking strength data as a randomized block design with factorial arrangement of treatments with duplicate samples within each block. The combination of five fabrics with four exposure periods gave the factorial arrangement of treatments. Warp and filling specimens were analyzed separately.

CHAPTER IV

RESULTS

Evaluation of Gas Dilution Apparatus

The flowmeter which controlled and recorded the flow of SO_2 was checked daily to insure a constant mixture of air and SO_2. No major fluctuations occurred over the three exposure periods; therefore, it was assumed that all specimens over all time periods had been exposed to an atmosphere which contained the same level of SO_2.

Evaluation of Test Chamber

The mean temperature inside the test chamber coincided with that in the room (Table II). This was to be expected since air for the SO_2 mixture was drawn from the room.

TABLE II

MINIMUM, MAXIMUM, AND MEAN TEMPERATURE FOR EACH
EXPOSURE PERIOD, APRIL 7-MAY 9

Expo- sure Per- iod	Temperature in Degrees Farenheit								
	Air Entrance			Air Exit			Room		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
1	71	82	77	72	82	78	71	85	78
2	68	80	74	68	80	75	67	89	75
3	75	81	78	77	82	79	76	82	79

Relative humidity within the chamber was increased from seven per cent to 23 per cent over the room humidity (Table III). This was a small increase, but it was thought that additional moisture would cause more reaction with the SO_2 and consequently lead to more severe fabric deterioration. A white precipitant along the edges of the water containers indicated that some reaction was taking place between the contaminated atmosphere and the moisture in the chamber.

TABLE III

MINIMUM, MAXIMUM, AND MEAN HUMIDITY
FOR EACH EXPOSURE PERIOD
APRIL 7 - MAY 9

	Relative Humidity in Per Cent								
Exposure Period	Air Entrance			Air Exit			Room		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
1	51	71	60	52	71	62	38	64	50
2	48	70	58	49	70	59	39	64	52
3	44	72	60	39	69	54	25	68	46

Statistical analysis of the breaking strength data (Table IV) showed the mean square for Blocks, Duplicates, and the Experimental Error to be of about the same magnitude. Therefore, blocking and duplication of specimens did not contribute significantly to the variance of the over-all experiment. This indicated that blocking and duplicating of specimens were unnecessary and further verified the uniformity of the chamber.

TABLE IV

ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square Warp	Mean Square Filling
Total	119		
Fabric	4	32,619.1094**	21,004.4885**
Linear in Cotton	1	0.1687	97.2022**
Quadratic in Cotton	1	2.3435	6.4062*
Cubic in Cotton	1	11.1020**	13.3331**
Linear in Dacron	1	13.3327**	29.0093**
Quadratic in Dacron	1	4.1669	5.0415*
Cubic in Dacron	1	13.3327**	0.5335
Linear in Dacron-cotton	1	0.0750	0.4440
Quadratic in Dacron-cotton	1	1.0419	1.0005
Cubic in Dacron-cotton	1	12.6750**	4.7605*
Linear in Nylon	1	46.2523**	58.1032**
Quadratic in Nylon	1	0.5103	0.8438
Cubic in Nylon	1	9.3513**	2.0022
Linear in Rayon	1	9.0750**	60.2069**
Quadratic in Rayon	1	2.6670	2.6667
Cubic in Rayon	1	0.6750	3.3337
In Chamber			
Blocks	2	2.8583	0.6308
Experimental Error	28	3.7065	6.5695
Duplicate	45	3.8333	8.7837
In Control			
Samples in Fabric	25	5.0233	6.3183

Coefficient of Variability   Warp - 2%   Filling - 4%

*Significant at the 5% level
**Significant at the 1% level

Breaking Strength

Breaking strength means for each exposure period for cotton, Dacron, Dacron-cotton, rayon, and nylon are presented in Table V. Statistical analysis of the data for the warp and filling directions of all fabrics indicated that the fabrics behaved significantly differently at the one per cent level.

TABLE V

BREAKING STRENGTH MEANS FOR ALL FABRICS,
ALL EXPOSURE PERIODS

	Cotton	Dacron	Dacron-Cotton	Nylon	Rayon
			Pounds		
WARP					
Control	61.0	125.8	46.8	115.8	52.5
Period 1	60.3	127.3	47.6	115.3	52.1
Period 2	62.1	124.7	45.6	112.4	53.1
Period 3	60.2	124.5	47.3	112.6	54.0
FILLING					
Control	41.2	63.6	33.2	109.8	61.9
Period 1	39.7	65.8	32.1	108.5	62.0
Period 2	35.9	66.3	33.4	106.3	64.4
Period 3	36.4	66.7	33.1	105.8	65.8

Both directions of the fabrics were further analyzed by using orthogonal comparisons in regression over exposure time. The linear, quadratic, and cubic responses were obtained for each fabric. This was an attempt to explain which fabrics showed significant differences by

fitting a curve to the data for each fabric. The Analysis of Variance (Table IV) gives the orthogonal comparisons for all of the fabrics.

The error term used to make the F test was that of the Experimental Error as it was the more conservative of the three error items.

As a result of this breakdown the linear response due to time exposure for cotton filling, Dacron warp and filling, nylon warp and filling, and rayon warp and filling were significant at the one per cent level. Cotton warp and Dacron-cotton warp and filling showed no significant effect over time.

This information when used with the Graphs of Breaking Strength Means (Figures 4 and 5) indicated whether the response was negative or positive. The graphs show a significant decrease in loss of strength for cotton filling, Dacron warp, and nylon warp and filling. The cotton warp did not weaken significantly, and perhaps this was due to differences in characteristics of the warp and filling yarns and to more yarns per inch in the warp direction.

It would appear from the graphs that Dacron filling and rayon warp and filling became significantly stronger. The author can offer no logical reason for this increase in strength of the fabrics. A more detailed analysis of the fiber, yarn, and fabric structures both before and after exposure to the contaminated atmosphere might offer explanation for the fabric behavior.

Fabric variation in the chamber and in the control group was low and very similar as indicated by the error terms for each.
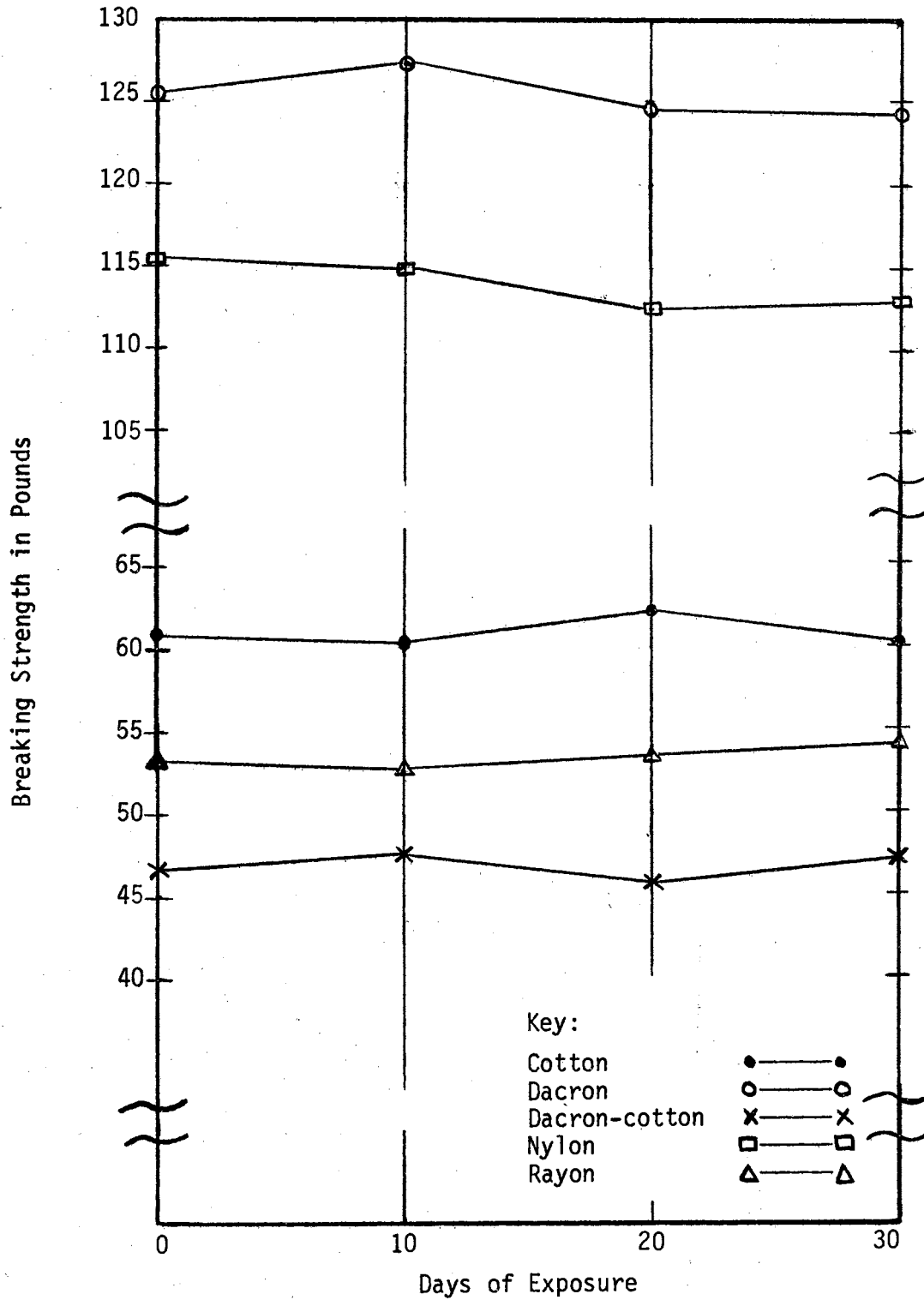
Figure 4. Graph of Warp Breaking Strength Means, All Fabrics, All
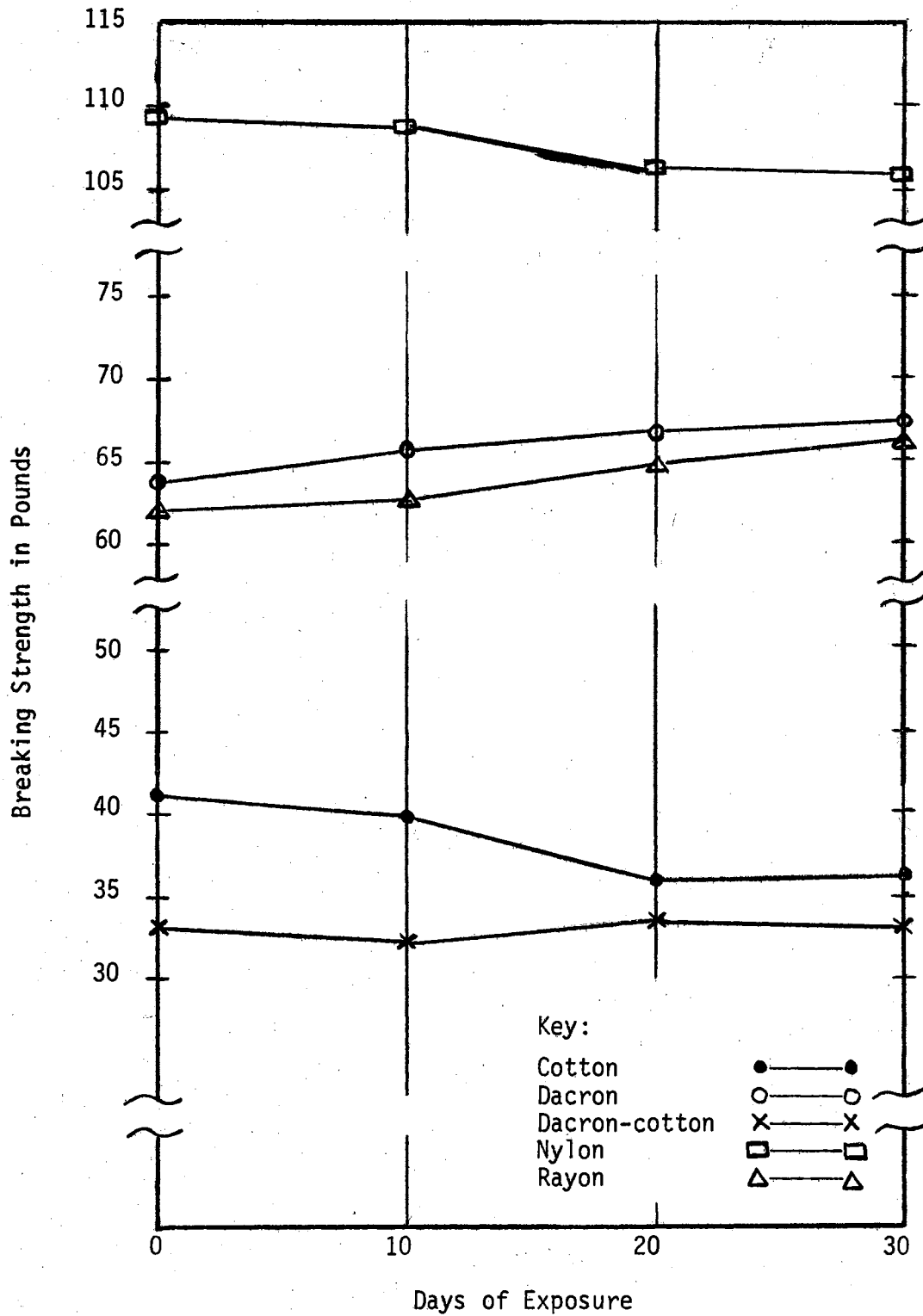   Exposure Periods

Figure 5.   Graph of Filling Breaking Strength Means, All Fabrics, All Exposure Periods

CHAPTER V

SUMMARY AND CONCLUSIONS

Specimens from both the warp and filling directions of white cotton, Dacron, Dacron-cotton, nylon, and rayon clothing fabrics were exposed from 10 to 30 days to a sulfur dioxide contaminated atmosphere. A gas dilution apparatus, especially designed for the project, produced a contaminated atmosphere containing two parts SO_2 to a million parts of air. The gas mixture was circulated through a glass-enclosed test chamber in which the specimens had been hung.

According to a pre-determined random order, specimens were removed from the test chamber every 10 days over the 30-day period. The ASTM ravelled strip method was used to test the specimens for breaking strength. Following this test, the specimens were placed back in the chamber to keep the quantity and condition of fabric within the chamber as uniform as possible.

The data were statistically analyzed as a randomized block design with factorial arrangement of treatments with duplicate samples within each block. The combination of five fabrics and four exposure periods gave the factorial arrangement of treatments for each yarn direction.

The error terms revealed that blocking and duplication of specimens within a block would not have been necessary. Neither the blocking nor the duplication contributed significantly to the variance of the experiment. It was assumed then that all sections of the test chamber were

uniform. Cotton filling, Dacron warp, and nylon warp and filling showed a significant loss of strength. Dacron filling and rayon warp and filling showed a significant increase in strength. Cotton warp and Dacron-cotton in both the warp and filling directions showed no significant change.

The author would recommend several changes for consideration in future research on fabric deterioration in a contaminated atmosphere:

1. Expose fabrics over a longer period of time. A longer exposure of fabrics may give a better over-all picture of the fabrics which showed no change or which appeared to become stronger.

2. Maintain a uniform relative humidity and preferably a high humidity within the chamber.

3. Add another atmospheric contaminant to the SO_2 mixture as SO_2 serves as a prototype for other contaminants.

4. Give more consideration to the contaminants already present in the atmosphere.

5. Make a more detailed analysis of the fiber, yarn, and fabric structure before and after exposure.

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