

EFFECT OF A HUMID SULFUR DIOXIDE CONTAMINATED
ATMOSPHERE ON THE BREAKING STRENGTH
OF FIVE CLOTHING FABRICS

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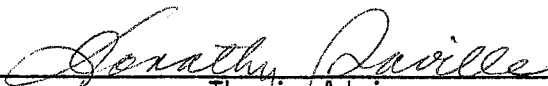
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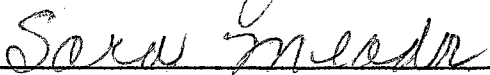
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CHAPTER I

INTRODUCTION

Economic expansion and technological progress are hallmarks of America's modern society. They have enabled Americans to enjoy the highest standard of living man has ever achieved. But the prosperity of the twentieth century has brought with it one serious unplanned, unwanted side effect - air pollution.

Air pollution has often been referred to as "the fallout of affluence" (3). No city or town is entirely without some degree of air pollution. John W. Gardner, as Secretary of the Department of Health, Education, and Welfare, recently said, "There is no major metropolitan area in the nation today without an air pollution problem. And the problem is getting worse" (20).

The causes of air pollution are numerous and varied. The major causes are the burning of fuel to produce heat and electricity, the use of motor vehicles, the burning of refuse, and the manufacture and use of such things as steel, metals, paper, and chemicals (23). Meetham (11) states that our habit of polluting the air with waste products has become a great social evil.

The rain water loses its purity; ash and other solids fall continuously to the ground; the air contains a suspension of fine particles which penetrate indoors to be deposited on walls, ceilings, curtains, and furniture; our clothing, our skin, our lungs are contaminated; metals corrode, buildings decay, and textiles wear out; germs multiply; our natural resistance to disease is lowered.

Air pollution costs Americans about \$12 billion a year. This is approximately \$65 per person (16). Appropriations for air pollution activities authorized under the Air Quality Act of 1967 (22) for the fiscal year 1968 were \$74 million, \$95 million for 1969, and \$134 million for 1970. In 1966, one half of the appropriated funds were used for research directed toward solving the pollution problem. Currently, Federal research efforts are concentrated in two broad areas, the harmful effects of air pollution on health and property and the development of methods for measuring and controlling pollution (23). Air pollution research is also being carried out by other government agencies, industries, and universities.

Research by Peters (14, 15) and Fye (6) showed a significant relationship between ozone and sulfur dioxide contaminated atmospheres and fabric deterioration. These two studies created a background for further investigation in the area of air pollution and its effect on fabrics.

This investigation of the effect of sulfur dioxide, a major component of industrial air pollution, on the deterioration of fabrics of cotton, wool, Dacron-cotton, nylon, and rayon, had two major objectives.

1. To develop an effective method of creating and maintaining a constant relative humidity in the test chamber.
2. To determine the effect of a sulfur dioxide contaminated, high humidity atmosphere, and time on the breaking strength of fabrics of different fiber content.

CHAPTER II

REVIEW OF LITERATURE

The harmful effects of atmospheric pollution are widespread and varied. Economic losses from air pollution are measured in the billions of dollars each year. Air pollution may be associated with chronic respiratory diseases such as bronchitis, emphysema, and lung cancer (23). Air pollution damages property and vegetation and also decreases the serviceability of many textile fabrics.

Most of the gases and particles of air pollution are emitted directly from man's activity. Some 300,000 manufacturing establishments, 82,000,000 motor vehicles and countless dwelling units pollute the air each in a different way. According to Lewis (8) the sources of contamination employ three basic processes, burning, vaporizing, and dividing. Each process contributes one or more of the five basic types of air pollution. These types are characterized by the emission of odor, dust, smoke, motor exhaust, or toxic substances. Most air pollution contains more than one of these contaminants.

Among the most toxic substances that pollute the atmosphere are the gases, such as nitrogen, oxide, carbon monoxide, ozone, and sulfur dioxide, which result from combustion.

Sulfur dioxide is a relatively stable, non-flammable, non-explosive, colorless gas that most people can smell or taste in the air at concentrations from 0.3 to 1.0 parts per million (ppm) (1). "Sulfur dioxide

in concentrations of two parts per million annoys human beings" (7). In 1963, 23 million tons of sulfur dioxide were emitted into the atmosphere. This pollution resulted primarily from the combustion of coal and petroleum products for heat and power, the refining of petroleum, the smelting of ores containing sulfur, and the burning of refuse (10). The Continuous Air Monitoring Program (CAMP) indicated that the average annual sulfur dioxide concentration in cities of the United States ranges from near zero to 0.16 ppm (1). Public Health Service air pollution chief John T. Middleton (17) believed the evidence against the effects of SO_2 was so strong that air-quality criteria should be determined, and in 1967 a suggested criteria of acceptable air-quality level for SO_2 was set at 0.05-0.08 ppm for a 24-hour average.

Geographically, concentrations of SO_2 are highest in the industrialized northeastern quarter of the United States (23). The levels are highest during the winter months with peak concentrations usually occurring around eight o'clock in the morning.

The most destructive feature of sulfur dioxide is its ability to react photochemically or catalytically with oxygen and materials in the atmosphere to form sulfur trioxide which reacts rapidly with moisture to form sulfuric acid (1, 11).

Gartrell and associates found that moisture in the air is apparently the primary factor affecting the rate of oxidation of SO_2 to H_2SO_4 . Caste reported that the highest ratio of H_2SO_4 to SO_2 was on a misty day. Bushtueva deduced from a study on the relationship of windspeed and relative humidity to the formation of sulfuric acid that "calm days, high humidity, and especially foggy weather were associated with high concentrations of sulfuric acid" (1).

The National Air Sampling Network has made studies (1) in various cities of the concentration of sulfur dioxide and suspended sulfates in the air. The analysis of the data showed that as relative humidity and metals (manganese and iron as suspended particles) increased, so did the suspended sulfate. Temperature had no effect on the suspended sulfate concentration.

Field studies in a number of geographical locations indicate that there is a relationship between sulfur dioxide and sulfuric acid concentration in the air.

The relationship is partly dependent upon the amount of moisture in the air, upon the time the sulfur contaminants have been in the atmosphere, the amount of catalytic particulate matter present in the air, the amount (intensity and duration) of sunlight...as well as recent precipitation (1).

It is a well-known fact that textile fabrics deteriorate when subjected to unprotected outdoor exposure. Researchers attribute most of the degradation to the attack of sunlight and microorganisms. Recently, air pollutants have been suspected of contributing to the degradation of fabrics when weathered in the atmosphere.

Cotton is attacked by microorganisms. The mechanisms involved in the degradation of cellulose by sunlight are not completely known (12). Cotton has been found to be sensitive to some products of coal and petroleum combustion (9). Nylon is resistant to microorganisms but sensitive to sunlight and combustion products. Polyester is weakened by sunlight but is quite resistant to acid fumes and microbial attack (9). Wool is made brittle by excessive weathering, and its fiber strength and moisture regain are decreased (26).

The Western Regional Research Cooperative Project (12) dealt with the effects of atmospheric conditions on cotton fabrics. The results

implied that traces of air pollutants in the atmosphere may have been a factor contributing to the degradation of exposed fabrics.

Little and Parson (9) weathered cotton, nylon, and Terylene (polyester) at eight different sites in the United Kingdom. They found cotton to be as resistant to atmospheric conditions as Terylene and more resistant than nylon at the semi-rural sites where "clean" or unpolluted atmosphere was expected to exist. In the urban areas where polluted atmosphere was a common occurrence, nylon showed the greatest decrease in breaking strength, followed by cotton, then Terylene.

Cotton fabrics were exposed to filtered and unfiltered air by Morris (13) in California where the major air pollutants were organic compounds and oxides of nitrogen. Breaking strength results indicated that samples exposed to unfiltered air deteriorated more than those exposed to filtered air.

Several years ago the United States Public Health Service launched a project to assess the degrading effect of air pollution on various materials, including textiles (25). The objective was to explore the relationship between the degree of damage to the exposed fabrics and the corresponding quality of the ambient air. The results of the project as reported by Brysson and others (5) showed a significant relationship between air pollution of the industrial areas of Chicago and St. Louis and the strength degradation of cotton fabrics. Specifically, sulfur dioxide air contamination showed the best degree of correlation with fabric degradation and soiling.

Investigators have shown an interest in the effects of specific pollutants and the atmospheric conditions under which they are most destructive.

Bogaty and others (4) have reported that dry ozone (a common pollutant in the Los Angeles area) has no effect on the strength of cotton, whereas moist ozone causes a significant loss in strength.

Salvin (18) has established that ozone and other contaminants under certain atmospheric conditions, particularly high humidity, fade fabrics. The dyes on acetate and polyesters change at low humidities, whereas dyes on cotton, nylon, and rayon changed at high humidities (75-85 per cent). The atmosphere of Chicago, which is often rich in sulfur dioxide, showed specific examples of color change in cotton fabrics (19).

Peters (14, 15) at Oklahoma State University exposed nylon, Dacron, acetate, cotton, and Fiberglas marquissette curtain samples to ozone and ultraviolet light from 9 to 45 days in a test chamber. The mean temperature and relative humidity for the exposure periods were between 82 and 90 degrees F. and 60 -70 per cent, respectively. Nylon and Dacron showed a significant loss in breaking strength over time. Acetate did not quite have a significant loss of strength, cotton did not show a significant strength loss, and no conclusions were drawn about Fiberglas, due to its high variability.

Eye (6) at Oklahoma State University subjected cotton, nylon, Dacron-cotton, rayon, and Dacron clothing fabrics to a SO₂ contaminated atmosphere containing two parts per million. Mean temperature and relative humidity for the exposure periods were 76 degrees F. and 58 per cent, respectively. Following exposure periods of 10, 20, and 30 days, the fabrics were tested for breaking strength. The cotton filling, Dacron warp, and nylon warp showed a significant loss of strength. Cotton warp and Dacron-cotton warp and filling showed no significant change. Dacron warp and rayon warp and filling showed an increase in

strength, a result which could not be explained.

The Czechoslovak Knitting Industries Research Institute (24) established a laboratory to study the effects of air pollution on synthetic fibers such as polyamids (nylon), polyesters, and polyolefins. The laboratory was equipped with a custom-made smog simulator for studying the effects of exhaust gases (natural, de-tarred, modified in air by light, with added sulfur dioxide, and added nitrogen dioxide) on the various fibers. Laboratory experiments indicated that SO₂-laden soot had a destructive effect on fine nylon fibers. When activated charcoal is saturated, by adsorption, with sulfur dioxide and then brought in contact with the fiber, it damages the fiber-forming polymer. The soot must be activated by either heat or light to produce the damage. The best form of activation was found to be SO₂-saturated steam at high temperatures, thus indicating that high humidity favors the destruction of nylon fibers by SO₂-laden soot. A field study done by the same laboratory found that acidic soot is the prime destroyer, apart from light, of textile fibers that are easily damaged by sulfuric acid. The damage done to more acid-resistant fibers like wool, polyester, and polyolefins is likely but is less pronounced as shown in the laboratory studies.

Brysson (5) has pointed out the possible effect of air pollution on the serviceability of fabrics.

The economic aspects of air contamination induced degradation are considerable. By arbitrarily assuming that a fabric article retains serviceability up to the point where it retains one-third of its original strength, it can be seen that heavy air pollution can reduce the effective service life to one-sixth or less than that of a similar article exposed in a clean or low contamination area.

CHAPTER III

METHODS AND MATERIALS

The degree of fabric degradation caused by individual components of air pollution, climate, or a combination of both is difficult to assess when fabrics have been weathered outdoors. Therefore, in this investigation an attempt has been made to create in the laboratory a humid sulfur dioxide contaminated atmosphere in order to determine specifically the effect of such an atmosphere on the breaking strength of clothing fabrics.

Fabrics

Five white standard test fabrics woven of cotton, wool, Dacron (65 per cent)-cotton (35 per cent), nylon, and rayon were selected for the study.¹ The fabrics were considered suitable for such garments as blouses, dresses, and shirts.

The weight, yarns per inch, yarn size, and construction of the fabrics were as similar as possible to obtain. The cotton, Dacron-cotton, and rayon were woven from spun yarns in a plain weave, and the nylon was woven from filament yarns in a variation of a plain weave. These four fabrics were the same as those described by Fye (6) and were assumed to be made to the same specifications. However, the specimens

¹Testfabrics Catalog Number 27; April, 1967. Testfabrics Incorporated; 55 Vandam Street; New York, New York 10013.

were not taken from the same yardage. The wool fabric was woven from single ply yarns in a plain weave. The yarns per inch were -warp 56 and filling 46; yarn number was (indirect system) -warp 9.9 and filling 9.5; yarn twist (turns per inch) was -warp 18.7 and filling 15.2; and the weight was 3.8 oz./sq. yd.

Experimental Apparatus

Test Chamber

A wood and glass test chamber designed and constructed by Peters (14) for a previous study was used 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 two removable glass panels on each side of the chamber and a removable wooden top. During the experiment the edges of the glass panels and removable top were sealed with tape to prevent air leakage.

The modifications of the chamber made by Fye (6) to facilitate a continuous flow of contaminated atmosphere were utilized. These modifications included two holes for atmosphere entrance and exit and three rows of two parallel wires strung the lengthwise direction of the chamber. This gave six lines from which to hang the test specimens.

The small electric fan positioned in the center at the bottom of the chamber was run throughout the experiment to improve circulation in the chamber.

Hygrometers were hung on the inside wall at each end of the chamber to indicate the temperature and relative humidity in the chamber.

The apparatus was located in a room approximately 12 feet wide, 15 feet long, and 13 feet high. One window was located on the north

wall about seven feet above floor level directly above the apparatus. The window served as an exhaust for the contaminated atmosphere and provided the main source of daytime light. Due to the height, exposure of the window, and the position of the chamber, the chamber received no direct sunlight and a relatively small amount of indirect light. A hygrothermograph recorded the temperature and relative humidity in the room.

Gas Dilution Apparatus

The apparatus which diluted and circulated the SO₂ contaminated atmosphere was the same as that used by Fye (6) and is shown in Figure 1. It operated in several phases. A small blower attached to the end of a T-shaped galvanized metal duct started the process by drawing air from the room. The blower was capable of a volume of 490 cubic feet of air per minute.

The air velocity was measured in feet per minute with an "Alnor" type 8500 Thermo-Anemometer through a one-inch hole in the metal duct.

Pure SO₂ was dispensed from a No. 3 Matheson cylinder through a small copper tube into the metal duct where the gas was mixed with the air. The gas flow was controlled with a gas regulator and a calibrated flowmeter. The following calculations were made to determine the flow rate of SO₂ to obtain a concentration of approximately two parts per million.

1. Area of duct in sq. ft. x rate of air in ft./sec. = cu. ft. of air/sec.
2. Cu. ft. of air/sec. x 472 cc/ft.³ x 60 sec./min. = cc. of air/min.
3. $\frac{\text{Desired conc. of gas in ppm}}{\text{cc. of air/min.}} = \text{flow rate of SO}_2$

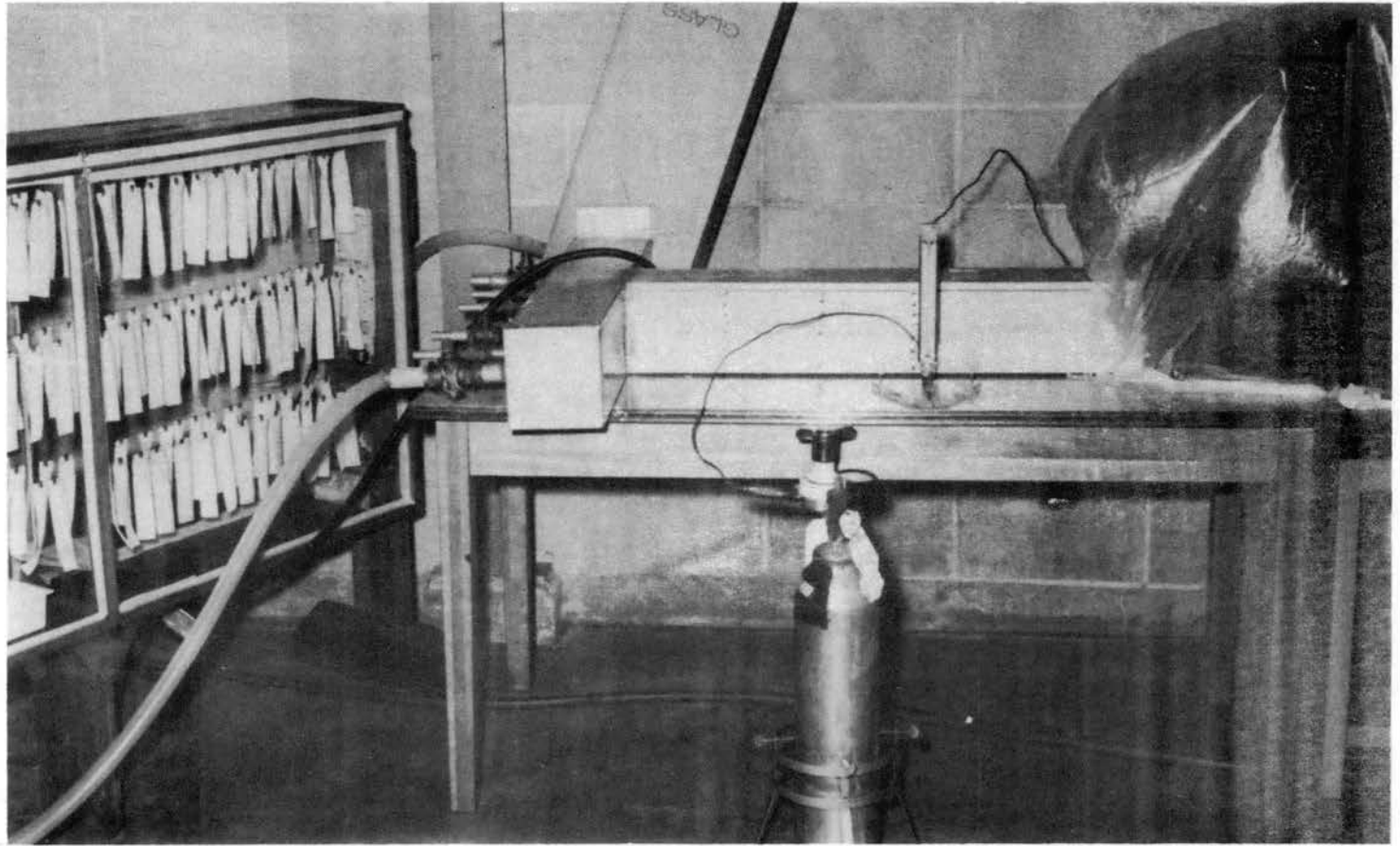


Figure 1. Test Chamber, Humidifier and Gas Dilution Apparatus

4. Flowmeter reading obtained from Calibration Chart.

Two baffles within the metal duct aided in mixing the SO_2 and the air. One end of the T-joining was vented with a metal gate to aid in acquiring the specific velocity of air for the correct dilution of the SO_2 .

The gas mixture was forced through a one-inch valve and into the chamber through plastic tubing. The atmosphere passed through the chamber and out through tubing which was vented into a cardboard stack which lead to the partly open window.

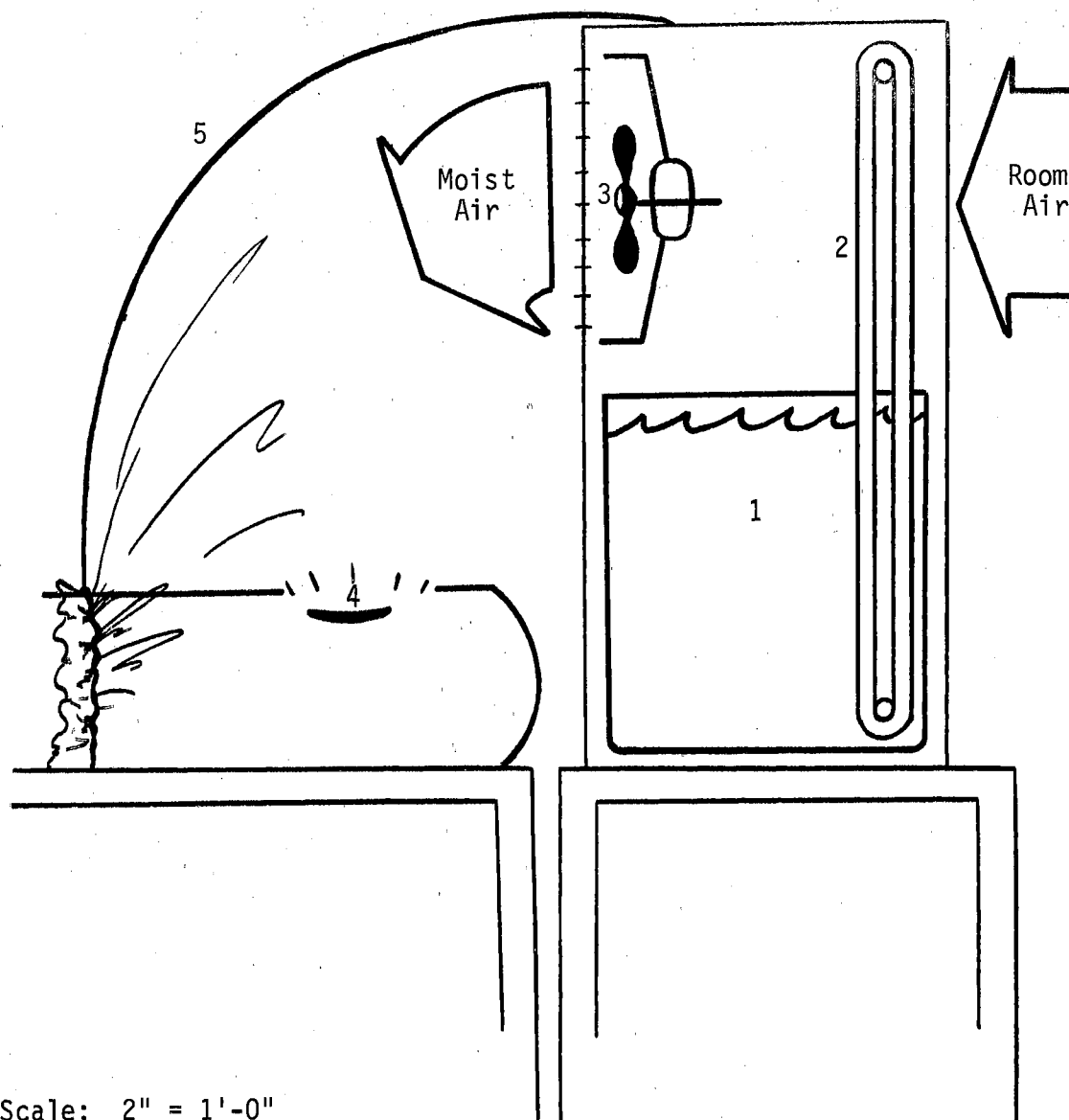
Humidifier

The relative humidity of the atmosphere within the chamber was increased by the use of a room humidifier (Figure 2) which had a possible output of 15 gallons of water per 24 hours.² The air from the room was drawn through the back of the humidifier by means of a 10-inch circulation fan. This air passed through a revolving porous pad which rotated through an 8½-gallon capacity water reservoir.

The humidifier was placed on a table next to the blower in the metal duct. A piece of polyethylene plastic was taped around the frame of the humidifier, extended over the blower, and gathered around the duct to form a hood. Thus, the air drawn into the duct by the blower passed through the humidifier first.

Two plastic containers of water were placed in the first section of the test chamber to further increase the humidity. The containers were filled every five days.

²Sears, Roebuck and Co. Kenmore home humidifier, 2 speed control, Automatic humidistat, 115 volts, 60 cycle, Model No. 758.72790.



Scale: 2" = 1'-0"

- | | |
|------------------------------|----------------------|
| 1. 8½-Gallon Water Reservoir | 4. Blower |
| 2. Rotating Porous Belt | 5. Polyethylene Hood |
| 3. 10-Inch Circulation Fan | |

Figure 2. Atmosphere Humidifying System

The humidifier ran continually on a high setting for the duration of the experiment. Every day between 12:00 p.m. and 2:00 p.m. the humidifier was filled with water and the temperature and humidity in the room and in the test chamber were read and recorded.

Experimental Procedure

Sampling

A total of 240 breaking strength specimens were used in the experiment. ASTM Standard Methods of Test for Breaking Load and Elongation (2), ravelled strip method, were used for the preparation and breaking of samples. The specimens were taken from one to one and one-half-yard lengths of each of the test fabrics. The specimens were coded as to fiber content, yarn direction, exposure period, duplicate (fiber content, and yarn direction the same), chamber section (block), line number and line position. The following method was used to randomize the specimens and to determine the location of each in the test chamber.

Twenty-four warp and 24 filling specimens were cut from each of the test fabrics and grouped into four sets of warp and four sets of filling (each set included six specimens). One set of warp and one set of filling of each fabric were randomly assigned to the control group and to the three exposure periods. This procedure designated 60 specimens (30 warp and 30 filling) to the control group and each exposure period. The chamber was divided into three horizontal sections to facilitate the analysis of data. The two parallel wire lines in the top, middle, and bottom were designated as chamber section 1, 2, and 3, respectively.

Within each exposure period, specimens 1 and 2 (duplicates) of each of the 10 sets were assigned to the first chamber section, 3 and 4 to

the second section and 5 and 6 to the third section, thus giving 20 specimens for each exposure period in each section. The 60 specimens per section were randomly assigned a line number (1 or 2) and a line position (1-30).

Analysis of Chamber Atmosphere

Further information was desired concerning the concentration of SO_2 in the chamber atmosphere. Therefore, a gas analysis was performed on air samples taken from the chamber before the specimens were placed in the chamber and during the first and second exposure periods. The West-Gaeke (21) method for the determination of sulfur dioxide was used.

The air samples were drawn from the test chamber through a length of rubber tubing inserted into the chamber through a small hole in the lid. Three samples were drawn consecutively from five different parts of the chamber by a sequential sampler at the rate of one liter per two minutes. The samples were bubbled through 10 ml. of absorbing reagent (sodium tetrachloromercurate) and treated with pararosaniline hydrochloride and formaldehyde. Following a 20-minute period for color development, the samples were randomly read for light absorbance at $560 \text{ m}\mu$ in a spectrophotometer.³ The absorbance was plotted on a calibration curve, and the parts per million of SO_2 in each air sample was determined.

Exposure of Fabrics

A white vapor formed by a reaction between hydrochloric acid and ammonium hydroxide was circulated through the chamber prior to exposure

³Model-B, Beckman Spectrophotometer, No. 245432.

of the specimens to determine the air flow and to detect any dead air spaces. The vapor appeared to fill the chamber and form a flow pattern which crossed the top of the chamber from the air entrance to the center then swirled and dropped into the fan which circulated the air up into both ends of the chamber. No dead air spaces were visible.

One hundred and eighty specimens were exposed in the test chamber, 60 for 30 days, 60 for 60 days, and 60 for 90 days. The contaminated atmosphere was calculated to contain two parts SO₂ to a million parts of air. The specimens were hung vertically by a 3/8-inch metal clip about 1/4-inch apart on the six lines in the chamber. The 60 specimens in the control group were not exposed and were used to determine initial breaking strength.

Determination of Breaking Strength

After each exposure period of 30, 60, and 90 days, 60 specimens were removed from the test chamber. This included 20 specimens from each of the three sections of the chamber among which there were 12 specimens (6 warp and 6 filling) of each of the five fabrics.

Each specimen was tested for breaking strength under standard conditions. After the data were recorded, the broken specimens were returned to the chamber to keep the quantity and condition of fabric within the chamber as uniform as possible.

Analysis of Data

A randomized complete-block design with a factorial arrangement of the treatments was used for the fabrics exposed in the test chamber. Each section of the chamber represented a complete block containing specimens of all five fabrics and duplicates of each specimen. The

combination of five fabrics, three exposure periods, and duplicates gave a factorial arrangement of treatments. The control group, which was not exposed in the chamber, was also considered in the analysis. Linear, quadratic, and cubic effects were obtained for each fabric in both warp and filling directions.

CHAPTER IV

RESULTS AND DISCUSSION

Evaluation of the Atmosphere Humidifying System

The humidifying system had the capacity to increase the relative humidity inside the chamber a maximum of 33 per cent over the relative humidity of the room. When the relative humidity in the room was high, such as 66 to 74 per cent, the humidifier was capable of increasing the humidity within the chamber only 6 to 13 per cent, depending on the temperature of the room. The mean increase in relative humidity in the chamber over that of the room for the duration of the three exposure periods was 24 per cent. The pans of water in the chamber contributed about 3 to 5 per cent of the increase in humidity.

The air cooling effect of the humidifier dropped the temperature within the chamber an average of three degrees below that of the room during the three exposure periods. Temperature and humidity means and standard deviations for the chamber and room for each exposure period are shown in Table I.

TABLE I
TEMPERATURE AND RELATIVE HUMIDITY MEANS AND
STANDARD DEVIATIONS FOR EACH EXPOSURE
PERIOD, JANUARY 1 - APRIL 1

Exposure Period	\bar{x}^*	Chamber s^{**}	\bar{x}^*	Room s^{**}
<u>Temperature in Degrees Fahrenheit</u>				
1	66	2.040	70	1.913
2	65	1.149	68	1.338
3	67	2.598	70	3.317
<u>Relative Humidity in Per Cent</u>				
1	74	4.266	49	9.219
2	73	4.278	46	4.690
3	76	4.701	55	13.675

*Mean

**Standard Deviation

Evaluation of SO₂ Contaminated Atmosphere

The flowmeter which controlled and recorded the flow of SO₂ gas was checked daily to insure the proper mixture of SO₂ with the air drawn from the room by the blower. The gas and air mixture was precalculated to contain approximately two parts SO₂ to a million parts of air. However, the analysis of the chamber atmosphere indicated the over-all mean for each chamber section was 2.5 - 2.7 ppm (Table II). The SO₂ content of the individual air sample readings fluctuated between 1.5 and 4 ppm. This may have been caused by uneven mixing of the gas in the air due to the turbulence of the air flow in the metal duct. Since the mean gas concentration in each chamber section was quite uniform, it appeared that SO₂, which is heavier than air, was not settling to the

bottom of the chamber. Apparently the fan in the bottom of the chamber aided in the circulation of the contaminated atmosphere.

TABLE II
SULFUR DIOXIDE CONCENTRATION IN THE TEST CHAMBER ATMOSPHERE

Chamber Section	Mean Concentration in Parts Per Million			Over-all Mean
	<u>Dec. 20</u>	<u>Jan. 27</u>	<u>Feb. 8</u>	
1	3.0	3.2	1.9	2.7
2	3.0	3.5	1.5	2.7
3	3.2	2.7	1.7	2.5

Breaking Strength

A statistical analysis of the breaking strength data (Table III) showed the mean squares for Blocks, Duplicates, and Experimental Error to be about the same magnitude. This indicated that blocking and duplication of specimens were unnecessary and that the test chamber was uniform. The variation among the samples in the chamber and those in the control was about the same as indicated by the error terms for each.

Mean breaking strengths for all fabrics and exposure periods are shown in Table IV. Analysis of the warp and filling data showed that all fabrics behaved significantly different at the one per cent level. Since Fabric by Time interaction was significant, each fabric was analyzed over Time. Orthogonal contrasts were used to derive the linear, quadratic, and cubic responses on all fabrics in each direction as shown in the analysis. The orthogonal comparisons partitioned the sum of squares so the simple effect of each fabric could be observed and tested

TABLE III
ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square Warp	Mean Square Filling
Total	119		
Fabric	4	25793.4023**	28554.8525**
Linear in Cotton	1	9.0750	.8670
Quadratic in Cotton	1	.3750	.1350
Cubic in Cotton	1	1.8750	2.5230
Linear in Wool	1	4.1070	7.5000
Quadratic in Wool	1	1.8150	10.0000
Cubic in Wool	1	7.8030	10.8000
Linear in Dacron-Cotton	1	3.0720	6.3480
Quadratic in Dacron-Cotton	1	8.6400	.9600
Cubic in Dacron-Cotton	1	13.0680	.4320
Linear in Nylon	1	39.6750**	46.8750**
Quadratic in Nylon	1	6.6150	33.1350*
Cubic in Nylon	1	9.0750	.6750
Linear in Rayon	1	.0570	5.5470
Quadratic in Rayon	1	9.3750	27.7350*
Cubic in Rayon	1	.3600	.0030
In Chamber			
Block	2	7.5586	10.3043
Experimental Error	28	5.0599	4.9618
Duplicate	45	7.8140	8.2947
Control			
Samples in Fabric	25	5.7234	12.9850

*Significant at the five per cent level

**Significant at the one per cent level

for significance. The Experimental Error found in the chamber was used as the denominator in the F test on each comparison.

TABLE IV
BREAKING STRENGTH MEANS FOR ALL FABRICS,
ALL EXPOSURE PERIODS

	Breaking Strength in Pounds				
	Cotton	Wool	Dacron-Cotton	Nylon	Rayon
WARP					
Control	55.6	25.5	45.1	115.3	49.8
Period 1	56.4	24.3	42.9	112.0	50.7
Period 2	56.2	26.2	45.2	112.5	50.9
Period 3	57.5	26.1	45.4	111.3	49.3
FILLING					
Control	37.0	21.8	35.1	109.5	58.3
Period 1	37.9	18.8	35.6	110.4	56.6
Period 2	37.2	20.1	35.4	109.6	57.0
Period 3	37.8	19.7	36.7	105.7	59.6

The effects of the treatments over time on cotton, wool, Dacron-cotton, and rayon warp were not significant. Significant linear effects are shown for nylon warp and filling at the one per cent level. A quadratic effect was shown for rayon filling at the five per cent level. The graphs of breaking strength means (Figures 3 and 4) show a loss in strength over time for nylon warp and filling. The quadratic effect observed for rayon filling indicated a parabola fit the data best.

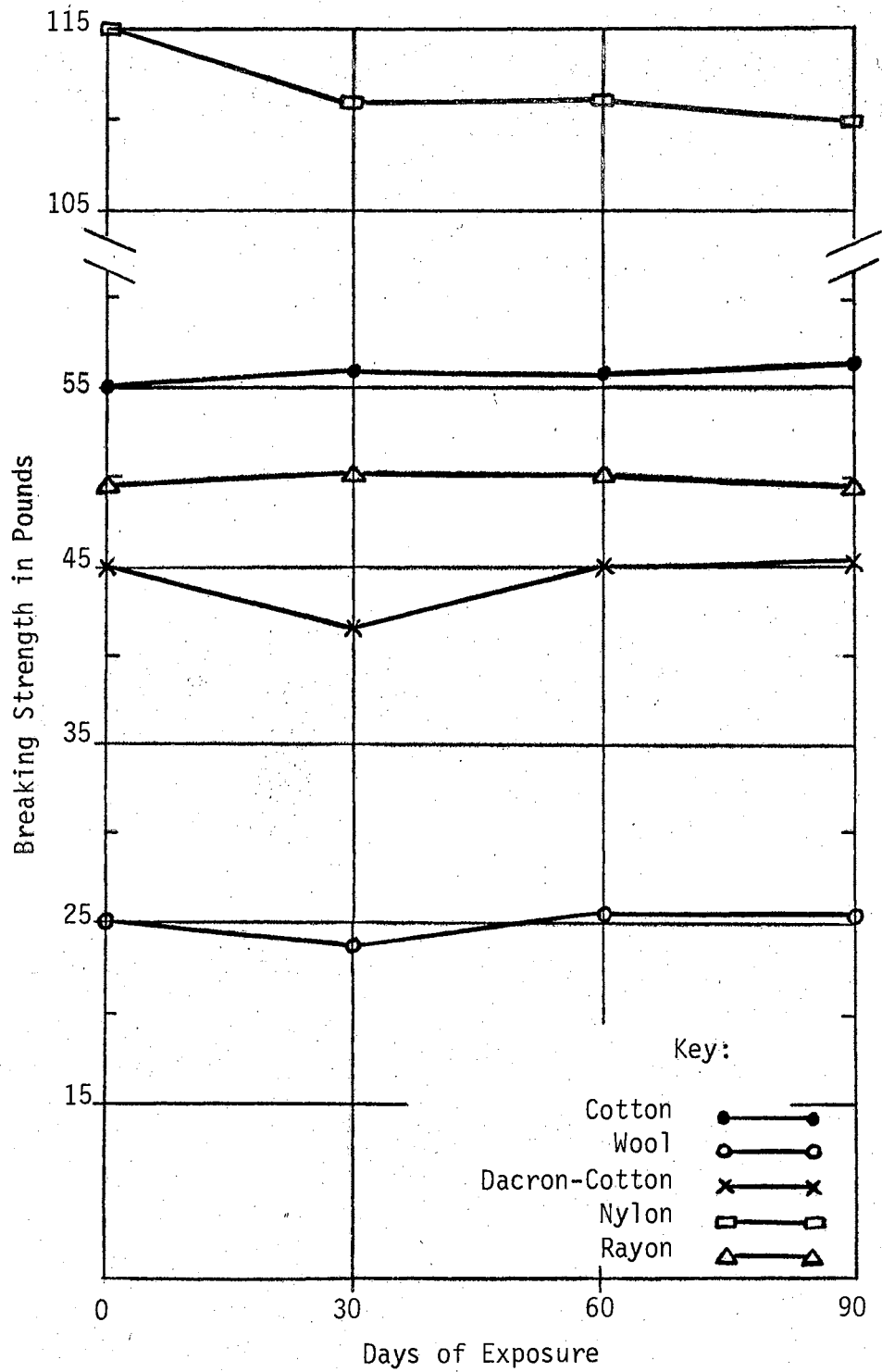


Figure 3. Graph of Warp Breaking Strength Means, All Fabrics, All Exposure Periods

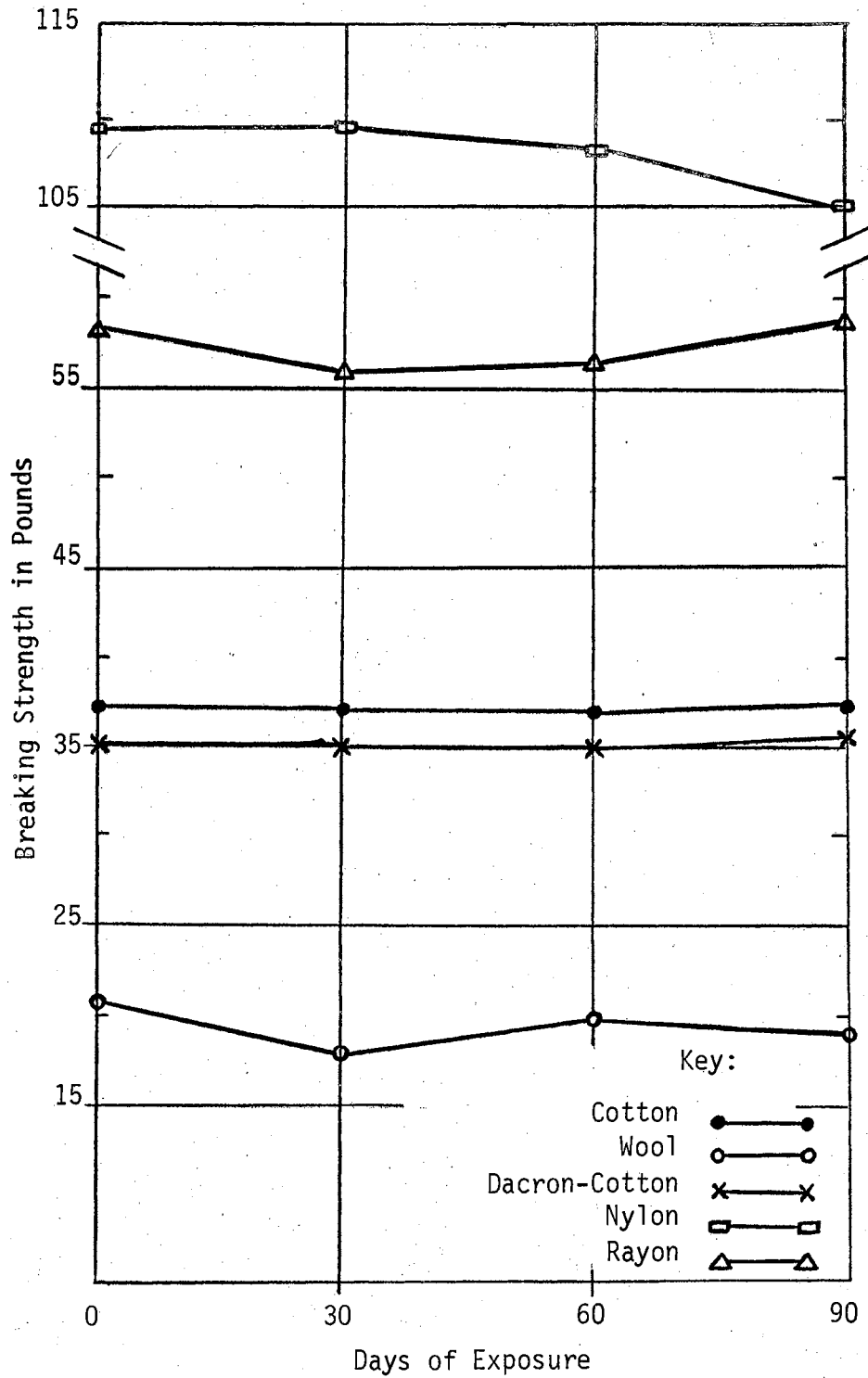


Figure 4. Graph of Filling Breaking Strength Means, All Fabrics, All Exposure Periods

The significant decrease in strength for nylon agrees with the results on nylon in the study done by Fye (6). Since the treatment showed no observable effect on the other fabrics, it may be assumed that sulfuric acid was not present in the atmosphere or in the fabric during the exposure of the fabrics in the chamber. If sulfuric acid had been present in the chamber atmosphere, cotton and rayon would have been expected to show loss of strength, since cellulosic fibers are sensitive to sulfuric acid. Therefore, it may be assumed that sulfur dioxide, not necessarily sulfuric acid, affected the breaking strength of nylon.

Sulfur dioxide is oxidized to sulfuric acid in the atmosphere by two processes - catalytic and photochemical. The rate of conversion in sunlight was found to be one to two per cent per hour and this rate was not affected by relative humidity in the range of 30 to 90 per cent (1).

CHAPTER V

SUMMARY AND CONCLUSIONS

Specimens of cotton, wool, Dacron-cotton, nylon, and rayon clothing fabrics taken from both warp and filling yarn directions were exposed to a humid SO₂ contaminated atmosphere in a wood and glass test chamber.

The fabrics were exposed for 30, 60, and 90 days to an atmosphere containing approximately 2.0 parts SO₂ per million parts of air. The atmosphere was produced by a gas dilution apparatus. A humidifying system added moisture directly to the contaminated atmosphere and increased the relative humidity a mean of 24 per cent over that of the room during the three exposure periods.

Following each exposure period, a predetermined number of specimens were removed from the chamber and tested for breaking strength according to the ASTM Standard Method for Breaking Load and Elongation, ravelled strip method.

The data were analyzed as a randomized complete-block design with a factorial arrangement of treatments. The control group, which was not exposed in the chamber, was also considered in the analysis.

The analysis of the data showed that the SO₂ contaminated atmosphere had no significant effect on cotton, wool, Dacron-cotton, and rayon warp. The treatment over time significantly decreased the strength of nylon warp and filling. There was a significant quadratic effect shown for rayon filling.

The nature of the results indicated that sulfur dioxide may not have been converted to sulfuric acid. Therefore, the author recommends further research on the combined effect of sunlight, which affects the conversion, and sulfur dioxide on the deterioration of fabrics.

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