AN INVESTIGATION OF FABRIC DESTRUCTION

BY RADIANT HEAT FLUX

By

RAJAGOPAPAN RAVI

Bachelor of Technology

Osmania University

Hyderabad, India

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AN INVESTIGATION OF FABRIC DESTRUCTION

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Thesis Approved:

Kenneth J. Bell
Thesis Adviser

Robert L. Robinson, Jr.

John H. Erbar

Norman N. Durham
Dean of the Graduate College

PREFACE

In the search for more fire-resistant clothing materials, a study of fabric ignition is essential. Prior work has commonly used the ignition of fabrics as a measure of fire safety. In this work, the smoke initiation point as a correlating basis for fabric destruction has been studied.

In order to develop correlations between smoke initiation time and the irradiance, data were collected using different fabrics. The experimental equipment, the experimental procedure, and the results obtained from the correlation of the data are discussed in this thesis.

I wish to record my grateful thanks to Dr. Kenneth J. Bell and Dr. Don Adams for the guidance and encouragement given in attempting this project. I also express gratitude to my cousin Sreenivasan and parents for watching my dreams turn into reality.

I am indebted to the Edgewood Arsenal, U. S. Army for providing the financial assistance received during the course of this research project.

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CHAPTER I

INTRODUCTION

Fire is a word embracing in its widest sense any manifestation of glowing heat. Early human civilization saw fire as a natural manifestation and apotheosized it. At a later stage of human knowledge it was believed to be an element of nature. However, its original use was as a defense against wild beasts, later extended constructively to warming the person, cooking, hardening implements and utensils, and producing artificial light. Human development has also unfortunately seen fire being used destructively and many a times Mother Nature has been unkind too, resulting in a tragedy. Too often, people are the "things" that burn. So, it is not surprising to find fire as the subject of concentrated research over the centuries.

Heat transfer in fires is predominantly in the form of thermal radiation, which caused investigators to use thermal radiation sources for research. Usually when a textile material is subjected to thermal radiation, it first darkens, smokes, glows and then ignites. All the studies in the past record data based on ignition point as the defeat of the target. However, the work done by Bell and Adams (3) on unwashed fabrics at low thermal radiation intensities shows an interesting behavior wherein the fabric first darkens and then smokes, leaving ashes.

This unusual behavior of fabrics, poses a question, 'What is ignition?' Unfortunately, the terminology used in the literature on 'ignition' is not standardized. Ignition, as defined by the Encyclopedia of Modern Science (5), is the process of raising the temperature of combustible or inflammable substances to the point at which combustion proceeds. The present investigation is a study of the smoke initiation point as a criterion of fabric destruction. The question of the reproducibility of the smoke initiation point is also addressed.

Two other reasons for undertaking this study are:

A. The government standards on non-inflammable fabrics (7). The Flammable Fabrics Act demands that the Secretary of Commerce establish standard tests to be imposed on fabrics so as to protect people from hazards of fabric-related burn injuries.

B. The importance of ignition at low heating rates in flame weapon applications against combustible targets (11).

The parameters affecting the smoke initiation point, can be classified in two categories.

A. PRIMARY VARIABLES: Properties of the fabric

1. Composition
2. Color
3. Fabric surface texture
4. Multiple layers of the fabric
5. Fabric: washed or unwashed
6. Density (weight per unit area)
7. Moisture content

8. Presence or absence of flameproofing materials
9. Contact with backing material, such as wood, metal or skin
10. Fabric pre-exposed to heat or not
11. Thermophysical properties of the fabric

B. SECONDARY VARIABLES: Experimental procedure

1. Mode of ignition: piloted or unpiloted
2. Intensity of radiation
3. Humidity
4. Rate of air flow over the sample surface
5. Self-shielding by smoke

This research project has involved the first six primary variables and some of the secondary ones.

The following goals were set for the project:

A. Construct and operate experimental equipment to obtain heat flux smoke initiation time data for civilian and military fabrics of different colors and surface textures.

B. Using the above data,

1. To develop correlations of smoke initiation time as a function of incident flux
2. To study the effects of color and surface texture on the civilian fabrics.

CHAPTER II

REVIEW OF THE LITERATURE ON IGNITION BEHAVIOR

No work has been reported in the literature on the defeat of a target, based on the smoke initiation point. However, a comprehensive survey of the literature has shown that numerous investigators have studied the ignition process of cellulosic materials, especially wood. These studies have provided background material for the present study.

The investigators have used thermal radiation sources for irradiating cellulosic materials. When combustible solids are exposed to radiant energy, the following sequence of events takes place (4): First, a part of the radiation is absorbed by the solid, part is reflected and the remainder transmitted. Of the incident energy absorbed, a part will be reradiated, a part lost due to convective cooling effects and the rest retained within the target. The amount of energy retained depends on the absorptance of the solid surface, the spectral distribution of the incident energy, thickness and other thermophysical properties of the solid. This fraction of the incident energy that is retained, depending primarily on the level of irradiance (13), produces changes within the solid. Thus at low irradiance the retained energy is conducted through the solid, resulting in the increase in temperature of the solid, thereby eventually causing thermal damage or initiating chemical reactions which lead the sample to darken, smoke liberating volatiles, glow and possibly ignite, leaving behind ashes.

At high irradiance, the temperature of the solid rises to a point where volatiles are liberated which mix with the surrounding air and ignite leaving behind ashes (12).

At intermediate levels of irradiance, the temperature of the solid is high enough to liberate volatiles, but not high enough to spontaneously ignite. However when a pilot source like a hydrocarbon flame or heated wire is placed in front of the sample, the volatiles are ignited and the flames spread to the sample. This is called piloted ignition (6). In the present investigation the pilot sources used were a natural gas flame and a heated platinum wire.

Usually flameproofing materials are added to the fabric, so that upon exposure to heat, the fabric does not flame, but smokes leaving behind ashes. In general, the flameproofing agents decompose at low temperatures and are often poisonous. Stepniczka and Dipietro (14) have dealt with this aspect in greater depth. They concluded that polyester fabrics generate far more smoke than cotton fabrics without the phenomenon of afterglow and that as the temperature increases, the smoke density of cotton fabrics increases as well, but in the case of polyester fabrics the opposite relationship was obtained.

Wulf and Durbetaki (15) have presented a stochastic model on fabric ignition as a potential health hazard and concluded that fabric response to heating under laboratory conditions is highly deterministic.

Keeny (9) has worked on the effect of air velocity upon ignition of multilayer clothing. He concluded that the combination of garment arrangements and increased air velocity increased the afterflaming and the resulting fabric damage, and that the flame retardant treatments were effective in controlling burning of single fabrics but quite ineffective on two layer fabric arrangements.

Finley, et al. (8) has also worked on the effect due to multilayer clothing and concluded that layered garments produced different flammability characteristics arising from combinations of fiber content, garment-torso spacing, and fabrics with and without flame retardant finishes.

For heat transfer mechanisms in the ignition of cellulosic materials by radiant energy Afgan (1) and Martin (10) have concluded that: At low irradiances there is heat loss due to convection primarily and the solid takes a long time to absorb the energy required for ignition. At intermediate levels of irradiance the heat absorbed is high enough but not sufficient to spontaneously ignite the solid and the heat is primarily diffusing through the solid. At high levels of irradiance, the mechanism is ablation controlled as sufficient volatiles are liberated which mixing with the air form an explosive mixture and ignite. Thus at low irradiance levels the mechanism of heat transfer is convection controlled, at intermediate levels of irradiance it is diffusion controlled and at high levels of irradiance it is ablation controlled.

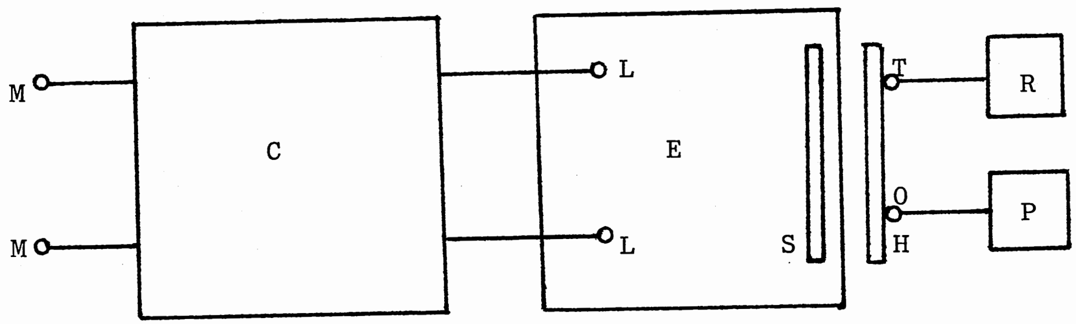
CHAPTER III

EXPERIMENTAL APPARATUS

A block diagram for the test apparatus is shown in Figure 1.

A. TEST ENCLOSURE: The test enclosure is 61 cm wide, 92 cm high and 46 cm deep. The back and the two sides of the enclosure are made of transite (asbestos-cement), which is very hard and highly resistant to temperatures upto 1500 ^{o}C. The back side has a small opening to allow the lamps to be fitted into the enclosure. While the right side is fixed, the left side operates as a door to facilitate manipulations inside the enclosure. In order to alter the irradiance at the sample position, the front side made of aluminum was made adjustable, so as to vary the separation distance between the radiation source and the sample. The front side, Figure 2 has a square opening 10.16 cm on a side, which is closeable on the rear side by the sample holder.

B. SAMPLE HOLDER: The sample holder, Figure 3 made of aluminum, is a square 12.70 cm on a side and 0.953 cm thick. It has two holes, each of 2.54 cm diameter: the left hole for the test specimen and thermocouple and the right hole is threaded hole for the calorimeter. The sample holder is attached to the front side of the test enclosure and opens as a door.



LEGEND:

M	Mains
C	Controller
L	Quartz lamp
S	Shield
E	Test enclosure
H	Sample holder
T	Thermocouple
O	Calorimeter
R	Recorder
P	Potentiometer

Figure 1. Block diagram for the test apparatus

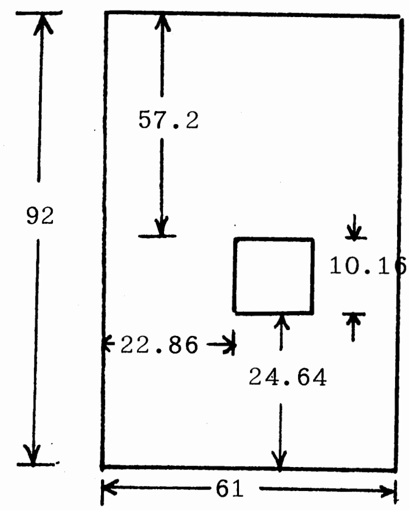


Figure 2. Front side of the test enclosure (all dimensions in cm)

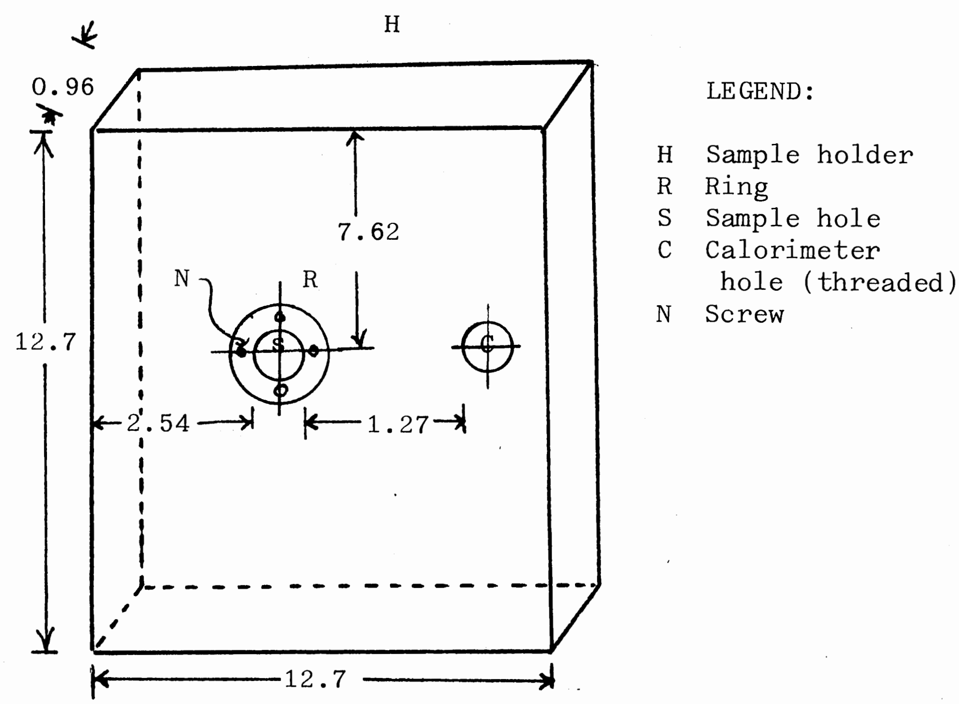


Figure 3. Sample holder (all dimensions in cm)

The thin ring (R), Figure 3, is made of steel and serves to hold the sample. It has an internal diameter of 2.54 cm and an external diameter of 5.08 cm. It is held in place by four screws (N) Figure 3. The test specimen is held in place, by placing a similar ring in front of the sample and tightening it with nuts.

C. THERMOCOUPLE: A chromel-alumel thermocouple made by the Store-room Manager Mr. Eugene McCroskey and diameter 16 mm was used for obtaining the temperature behind the sample, by connecting it to the recorder.

The thermocouple holder consists of two parts. The outer part, Figure 4, is a 15.24 cm long aluminum tube, which fits into the sample hole from the rear. The inner part of the thermocouple holder, Figure 5, is a 6.35 mm copper tubing fitted with a 6.35 mm thick disc to fit inside the aluminum tube. The thermocouple wire passes through the tubing.

D. CALORIMETER: An asymptotic calorimeter, Hy-Cal Engineering Model C-1118-B-15-072, having an absorptivity of 0.89, was connected to the potentiometer, for obtaining a millivolt output of the incident radiant flux.

E. POTENTIOMETER: Leeds and Northup Company Model 8690 millivolt potentiometer having a range from -11 mv to +101 mv was used to measure the millivolt output of the calorimeter response.

F. SHIELD: Inorder to expose the samples to an uniform irradiance of known magnitude and also to protect the test specimen from radiation prior to the test. The sample was shielded during

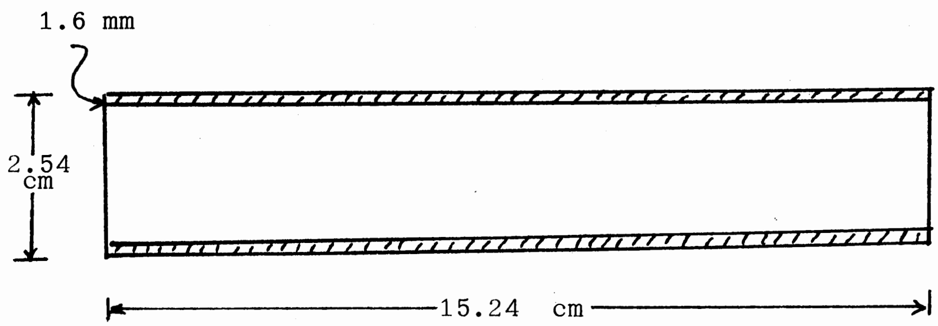


Figure 4. Thermocouple Holder-Outer Part

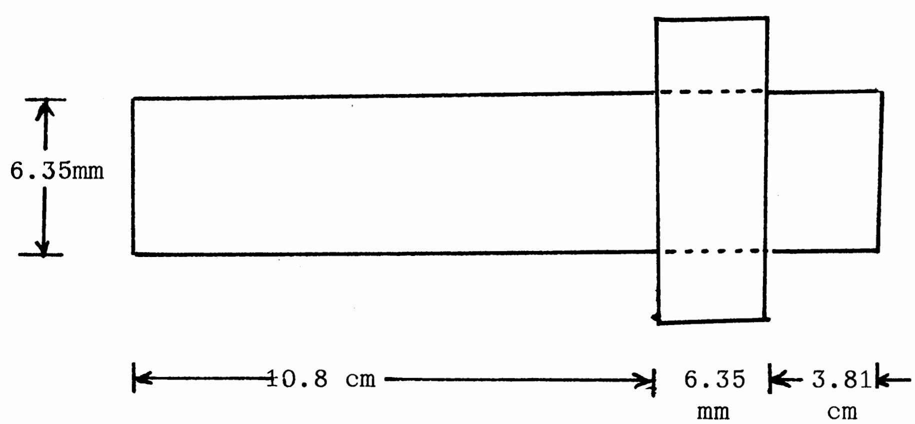


Figure 5. Thermocouple Holder-Inner Part

the transient warm-up period of the quartz lamps by a water-cooled aluminum shield, Figure 6, placed immediately in front of the sample. The shield is movable in a vertical direction by a pulley mechanism.

G. LAMPS: Two Research Inc. Controls Model AUB-612B quartz lamps, each 31.12 cm wide and 15.24 cm high with gold-surfaced reflectors were used as sources of radiant energy. Model 2000T3/CL lamps containing eight 2000 watt tungsten filaments were used. The two lamps were connected in series and cooled by using compressed air.

H. CONTROLLER: Research Inc. Model 5562 temperature/power control system was used to control the input, which included model 5310 Data-Trak card programmer, and Model 624A Thermac temperature controller. The temperature controller could be operated in any one of the following modes: a) Program b) Set point c) Manual.

I. RECORDER: A Gould Brush 2400 recorder was used in conjunction with Model 13461530 d.c. bridge preamplifier to record the thermocouple output. It uses a pressurized ink writing system and has a variable chart speed.

J. OTHER EQUIPMENT: A Brenet Number 65 stopwatch with a 10-second sweep and 1/10 second sub-divisions was used for noting the smoke initiation time.

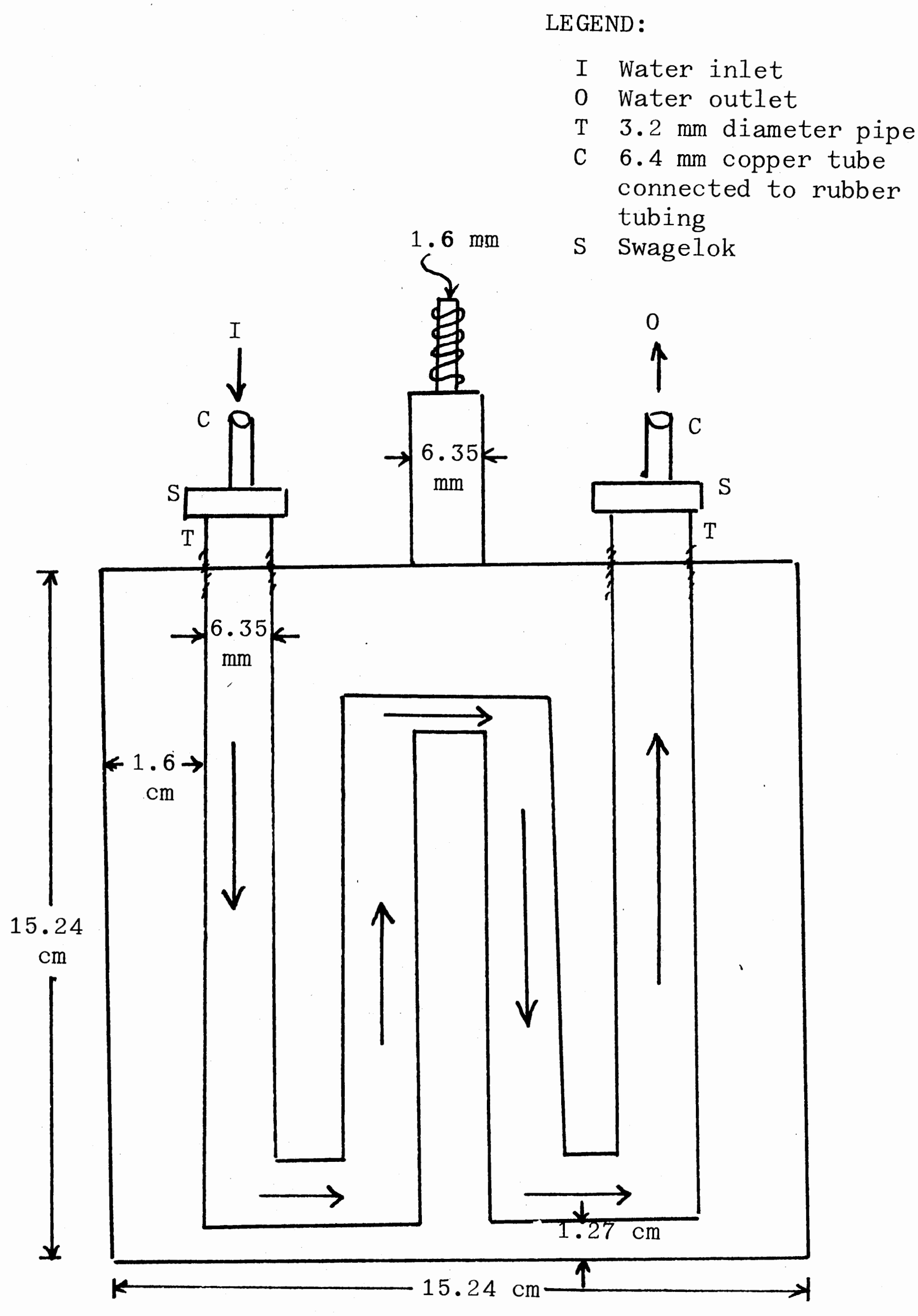


Figure 6. Shield

Piloted ignition was attempted both with a platinum wire and a natural gas flame. The voltage to the platinum wire was varied with the help of a variable autotransformer (Variac) type 116B of Superior Electric company. The natural gas was taken from the regular laboratory gas connections. A hypodermic needle was used to obtain a thin gas flame.

The Lufkin Rule Company Model 1811 micrometer with a least count of 0.0125 inch was used to measure the thickness of the sample.

The Mettler Instrument Corporation weighing balance was used to weigh the sample. Weighings between 0.0001 g and 100 g could be made by using the balance.

For safety purposes, asbestos gloves and goggles were used. A pair of scissors was used to prepare the samples of required size.

CHAPTER IV

EXPERIMENTAL PROCEDURE

A. CALORIMETER CALIBRATION:

Hy-Cal Engineering provided the calibration curve for the calorimeter used. In view of the extensive use of CGS units, a new calibration curve was drawn, after converting the absorbed energy from Btu/ft^2-sec to cal/cm^2-sec. This curve has been reproduced in Appendix C.

B. SAMPLE PREPARATION:

Civilian fabrics of known composition, color and surface texture were purchased. Samples of military cloth for test studies was provided by Edgewood Arsenal, U. S. Army. A disc, 3.81 cm in outer diameter was used to draw a round circle with a marking pencil in the desired cloth. The cloth was then cut along the marked line using scissors to give a test specimen 3.81 cm in diameter. The sample thickness was then measured at three different places using a micrometer. The sample was weighed and then fixed in the sample holder. The effective diameter of the sample exposed to irradiance was 2.54 cm.

C. TEST PROCEDURE:

The fabrics tested are listed in Table I. Appendix B gives

TABLE I

FABRICS INVESTIGATED

FABRIC	COMPOSITION	COLOR	SURFACE TEXTURE
Cotton	100%	White	Corrugated
		Red	Corrugated
		Red Velour	Plane
		Navy Blue	Corrugated
		Marine Blue	Corrugated
Cotton and Polyester	50%-50%	White	Plane
		Red	Plane
		Navy Blue	Plane
		Marine Blue	Plane
Polyester	100%	White	Plane
		Black	Plane
Military		Green	Plane

the rationale for the fabric coding system.

The test is carried out with the sample placed 20.32 cm away from the nearest lamp face. The procedure is as follows:

1. When the experiment is not being performed:
   a) Keep the potentiometer switch in "Galvanometer off" position, and the controller, recorder and main switches in "Off" position.
   b) Keep the coolant air and water supply valves closed.
   c) Keep the radiation shield in "Down" position, so that it covers the sample holder.
2. Keep the exhaust fan on at all times.
3. Before starting the experiment, verify that:
   a) All connections are made correctly.
   b) Insulation is as good as possible.
   c) Cooling water and air are turned on.
   d) Potentiometer switch is in "emf measure" position.
   e) The sample, calorimeter and thermocouple are set in their right positions.
   f) The recorder, potentiometer and stopwatch are set to zero and are ready for use.
4. The experimenter and observers (if any), should wear the proper goggles and gloves at all times that the apparatus is being prepared for operation, is operating, or has just been shut down.
5. The main electrical switch is turned on.

6. The controller is turned on and the output is increased to the desired level and allowed to warm up for 5 minutes.

7. For unpiloted ignition the controller is operated using the manual mode.

8. For piloted ignition using a platinum wire, the variac is also adjusted to the voltage required to make the wire red hot. In the case of piloted ignition using natural gas flame, the flame is started using a lighter, just before the controller is turned on.
   In both cases the pilot source is placed 3 mm away from the sample and about a third of the way down from the top of the sample as shown in Figure 7.

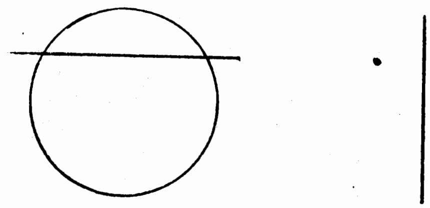
9. The recorder is started, set at the desired speed, and the pointers set in the proper positions at the beginning of the abscissa and ordinate.

10. The shield is opened, simultaneously marking the event on the recorder and starting the stop watch.

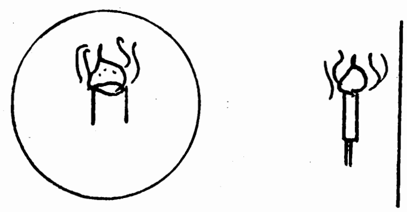
11. While the irradiation is proceeding observe the changes the sample is undergoing.

12. At the first indication of smoke initiation, the stop watch is stopped, and the calorimeter response noted as indicated by the potentiometer.

13. After the sample is reduced to ashes, the sample holder is shielded and the radiant energy source switched off. The recorder is then stopped.



(a)



(b)

Figure 7. Location of the pilot source 3 mm away from the sample

(a) Platinum wire (b) Natural gas flame

14. The sample is removed and the sample holder and lamps are cooled by an air jet.

15. Before starting the next run, verify that:

    a) The lamps, sample holder and thermocouple are back at room temperature.

    b) All the smoke in the thermocouple tube has been driven out.

    c) The rings holding the sample, sample holder and thermocouple are clean.

CHAPTER V

EXPERIMENTAL OBSERVATIONS

100% COTTON:

At lower fluxes, typically between 0.7 to 0.8 cal/cm^2-sec, the sample browns, blackens and then smokes. Smoking stops for some seconds and then smokes again continuously, the sample eventually being reduced to ashes. At higher fluxes, typically between 1.1 to 1.4 cal/cm^2-sec, the sample smokes continuously as it blackens and is reduced to ashes. For fluxes above 1.3 cal/cm^2-sec, the sample continues to smoke, even after shielding, with occasional glowing and bursting into flames, leaving behind ashes.

50% COTTON - 50% POLYESTER:

This fabric is reduced in a similar manner as 100% cotton except that, after the sample blackens, there is bubbling (or fusing) in the sample. The bubbling starts at the center, about a third of the way down from the top of sample, Figure 7, and spreads outwards. The sample left behind in this case is a fragile black mass.

100% POLYESTER:

Independent of the value of the incident flux above the threshold flux, the sample just melts, with bubbling as was observed in the case of 50% cotton - 50% polyester fabrics. Fluxes upto 2.95 cal/cm^2-sec were studied by moving the sample closer to the lamps. The higher the flux, the faster the melting. The sample does not smoke at all. Piloted ignition with platinum wire and natural gas flame yielded the same results as long as the pilot was not in direct contact with the sample: the sample only melted and did not smoke. However when either the platinum wire or the natural gas flame was brought in direct contact with the sample, the sample smoked profusely and ignition was almost instantaneous. The sample smoked and burned, leaving behind a hard, black residue.

MILITARY CLOTH:

The military cloth is reduced exactly as the 50% cotton - 50% polyester fabric when subjected to radiation: the sample blackens, bubbles, smokes and reduces to a fragile black mass.

MULTIPLE LAYERS OF 100% COTTON RED CORDUROY:

When subjected to irradiance, the exposed layer first turned yellow, then blackened, smoked and was destroyed. An ash colored fibrous residue was left behind. At fluxes around 0.8 cal/cm^2-sec the damage in the subsequent layers was almost negligible. At fluxes around 1.2 cal/cm^2-sec, all the layers were destroyed and occasional flaming was observed after shielding; in all the cases the sample glowed.

CHAPTER VI

PRESENTATION, ANALYSIS AND DISCUSSION OF RESULTS

The raw data for the experimental runs are tabulated in Appendix D (tables III through XII) Appendix A gives the nomenclature, Appendix B gives the rationale for the fabric coding system, and Appendix E is the computer program used for the curve fitting.

As reported earlier, no previous work has been reported based on the smoke initiation point as the criterion of defeat of the target. When a fabric is subjected to a low level of irradiance, a very slow reaction occurs between the fabric and oxygen in the surrounding air. This combustion reaction produces heat which tends to raise the temperature of the fabric and thus increases the rate of reaction. Simultaneously opposing this tendency toward increasing the temperature is the energy loss by convection.

At higher levels of irradiance, the rate of reaction between the fabric and the oxygen is high resulting in the rate of heat generated exceeding the rate of heat loss, and the temperature of the fabric rises faster than it would due to external heating effects alone. Thus under favorable conditions the fabric ignites.

In between these two extremes, the ignition is controlled by diffusion of heat. Thus, going from low to high levels of irradiance, the first is controlled by convective energy losses and hence the fabric does not ignite. The second is controlled by diffusion of heat in the fabric and under favorable conditions igintion results; for instance ignition by the use of a pilot source. The third is ablation controlled as the temperature is so high that it predominates over the relatively small diffusion of heat in the fabric. Moreover the increase in temperature of the fabric is so rapid compared to intermediate or low levels of irradiance that the fabric gets reduced before it can lose heat to the surroundings or the diffusion of heat through the solid.

In view of the rapid increase in temperature of the fabric with increasing irradiances, an exponential relation was assumed between the smoke initiation time and the incident flux. The relations assumed were as follows:

$T = a\ \mathrm{Exp}(bF) \qquad T = a\ \mathrm{Exp}(b/F) \qquad \text{and} \qquad T = a(F)^b$

Then, from the data collected, curve fits were run to see if any one of the above forms of the equation is satisfied. The first equation was best satisfied. The computer program used to obtain the equations and the percent error is given in Appendix E. The resulting equations are summarized in Table II and the results are plotted and presented graphically in figures 8 through 17. Figure 18 gives a comparison of all the cotton fabrics while Figure 19 gives the comparison for cctton-polyester fabrics.

TABLE II

CURVE FITS AND THEIR VALIDITY FOR THE FABRICS TESTED

FABRIC	COLOR	DATA POINTS	CURVE FIT	* % ERROR
100% COTTON	WHITE	15	T = 63.58 Exp(-2.50F)	5.06
	RED CORDUROY	21	T = 31.47 Exp(-1.79F)	6.78
	RED VELOUR	16	T = 38.30 Exp(-1.99F)	2.40
	MARINE BLUE	15	T = 28.66 Exp(-1.68F)	5.21
	NAVY BLUE	15	T = 21.70 Exp(-1.29F)	2.77
50% COTTON-50% POLYESTER	WHITE	12	T = 23.92 Exp(-1.42F)	5.44
	RED	14	T = 51.29 Exp(-1.77F)	4.04
	MARINE BLUE	16	T = 43.24 Exp(-2.10F)	5.09
	NAVY BLUE	16	T = 30.82 Exp(-1.82F)	7.02
MILITARY	GREEN	15	T = 29.58 Exp(-1.72F)	3.80

* Average absolute value of the percent error

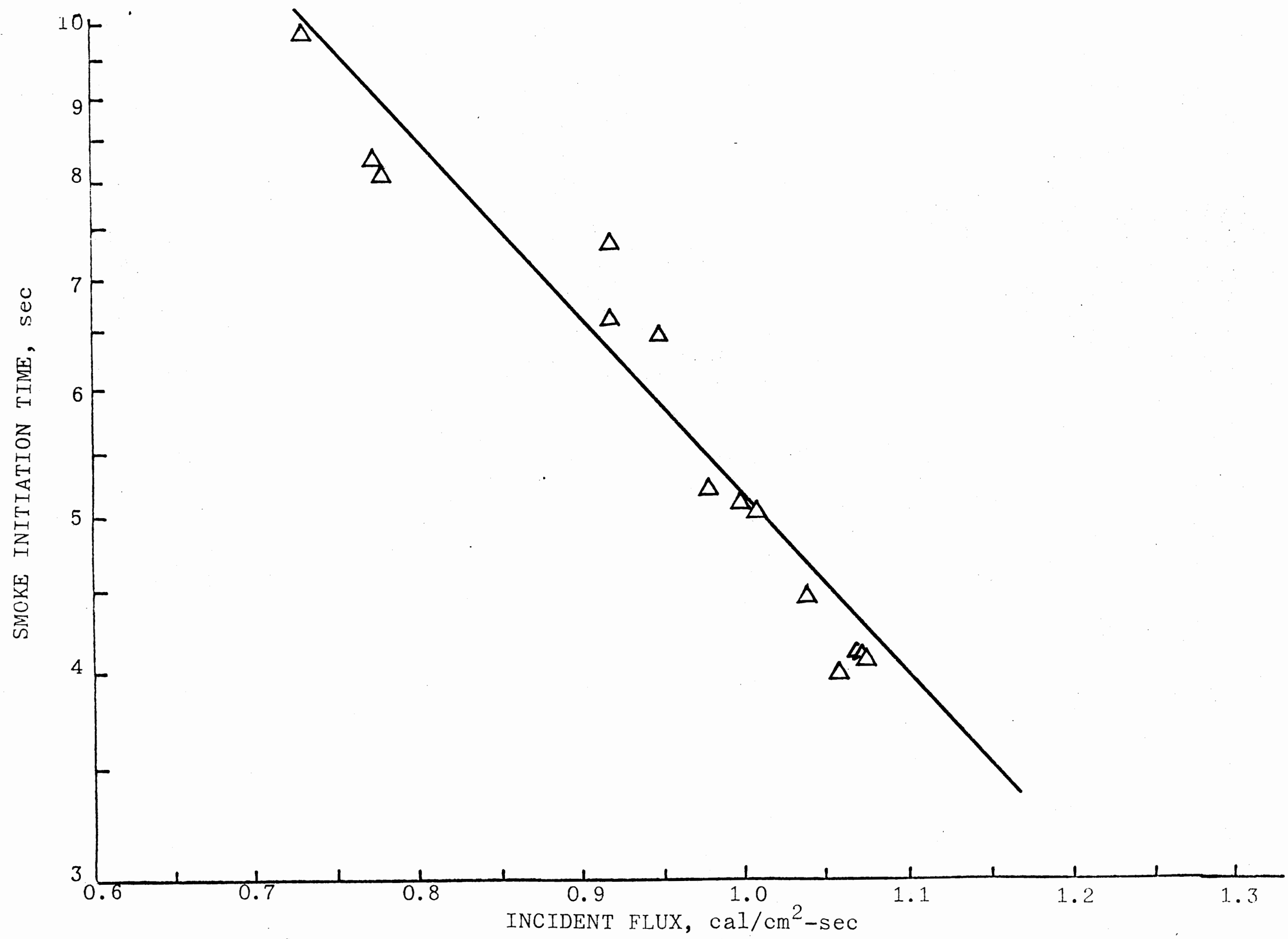


Figure 8. Smoke initiation time vs Incident flux: 100% cotton white corduroy unwashed

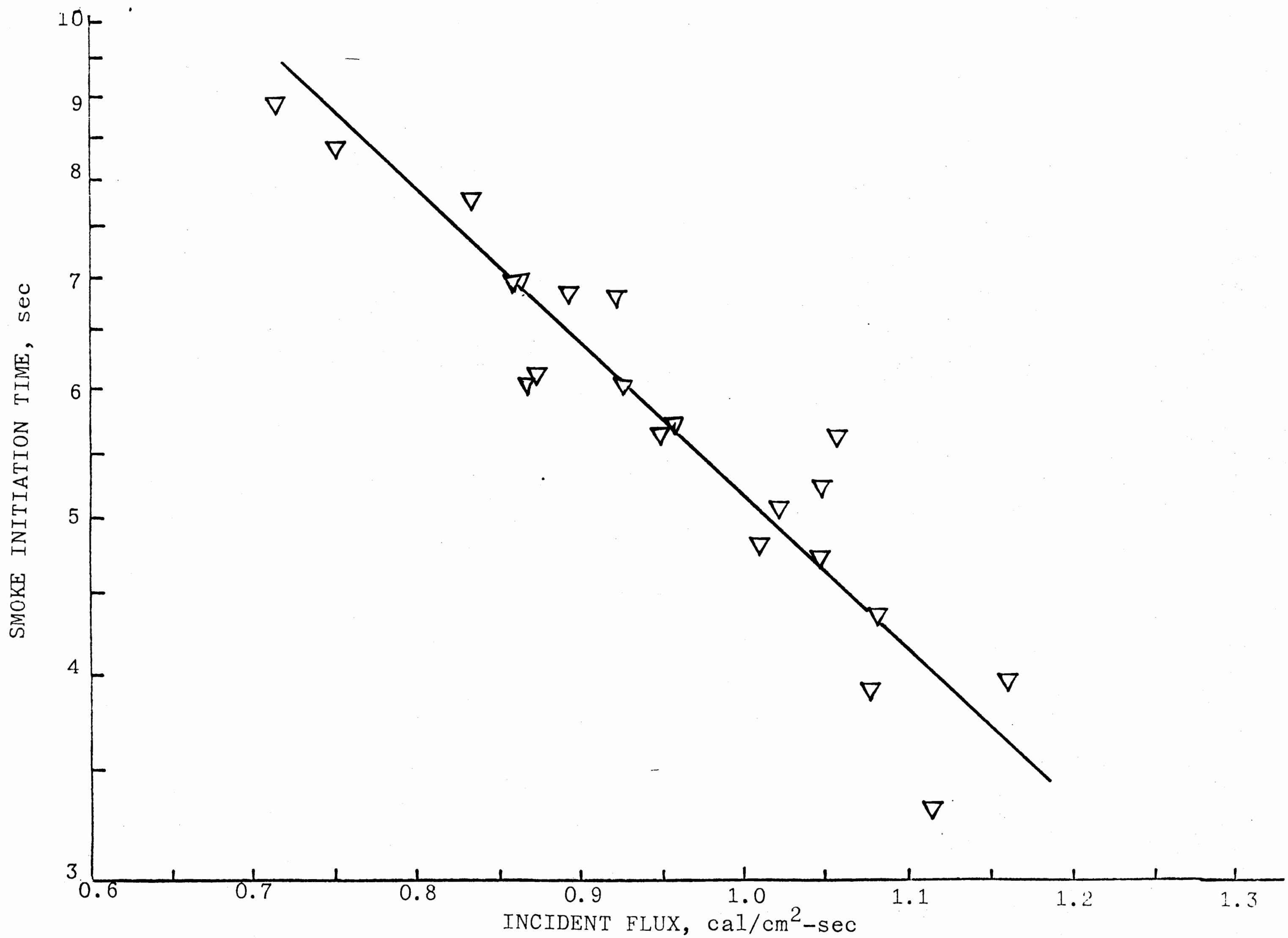


Figure 9. Smoke initiation time vs Incident flux: 100% cotton red corduroy unwashed

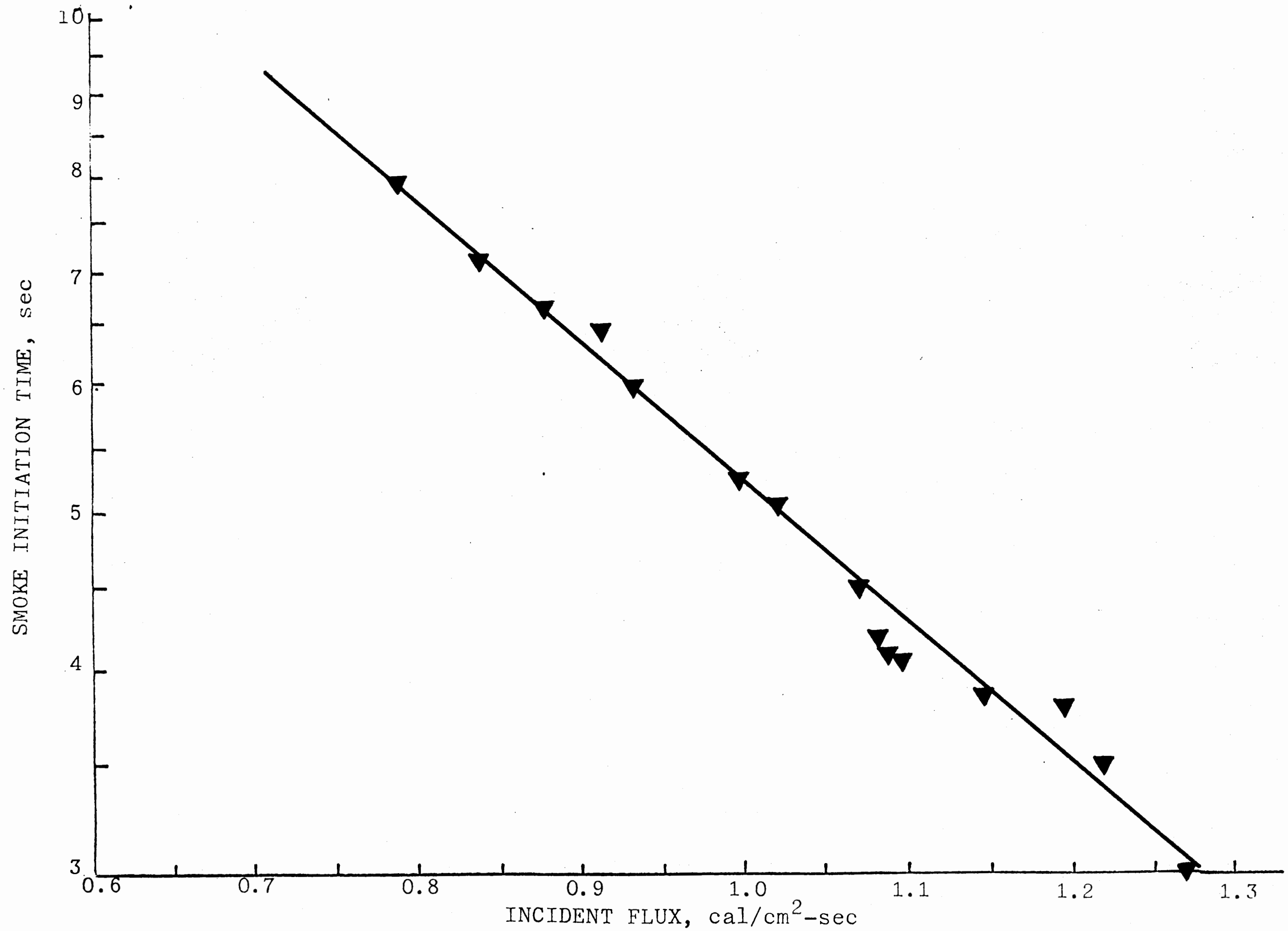


Figure **10.** Smoke initiation time vs Incident flux: 100% cotton red velour unwashed

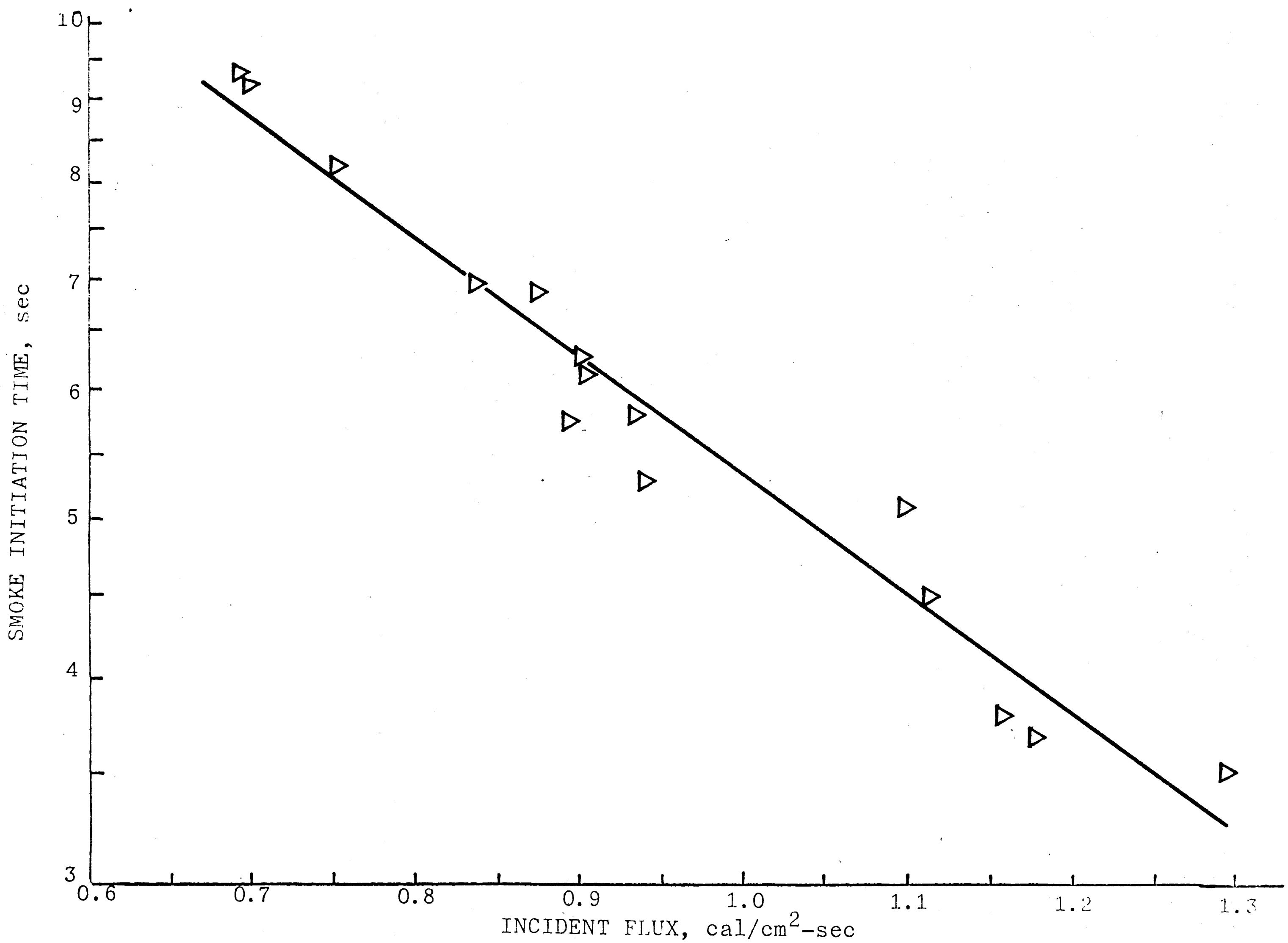


Figure 11 . Smoke initiation time vs Incident flux: 100% cotton marine blue unwashed

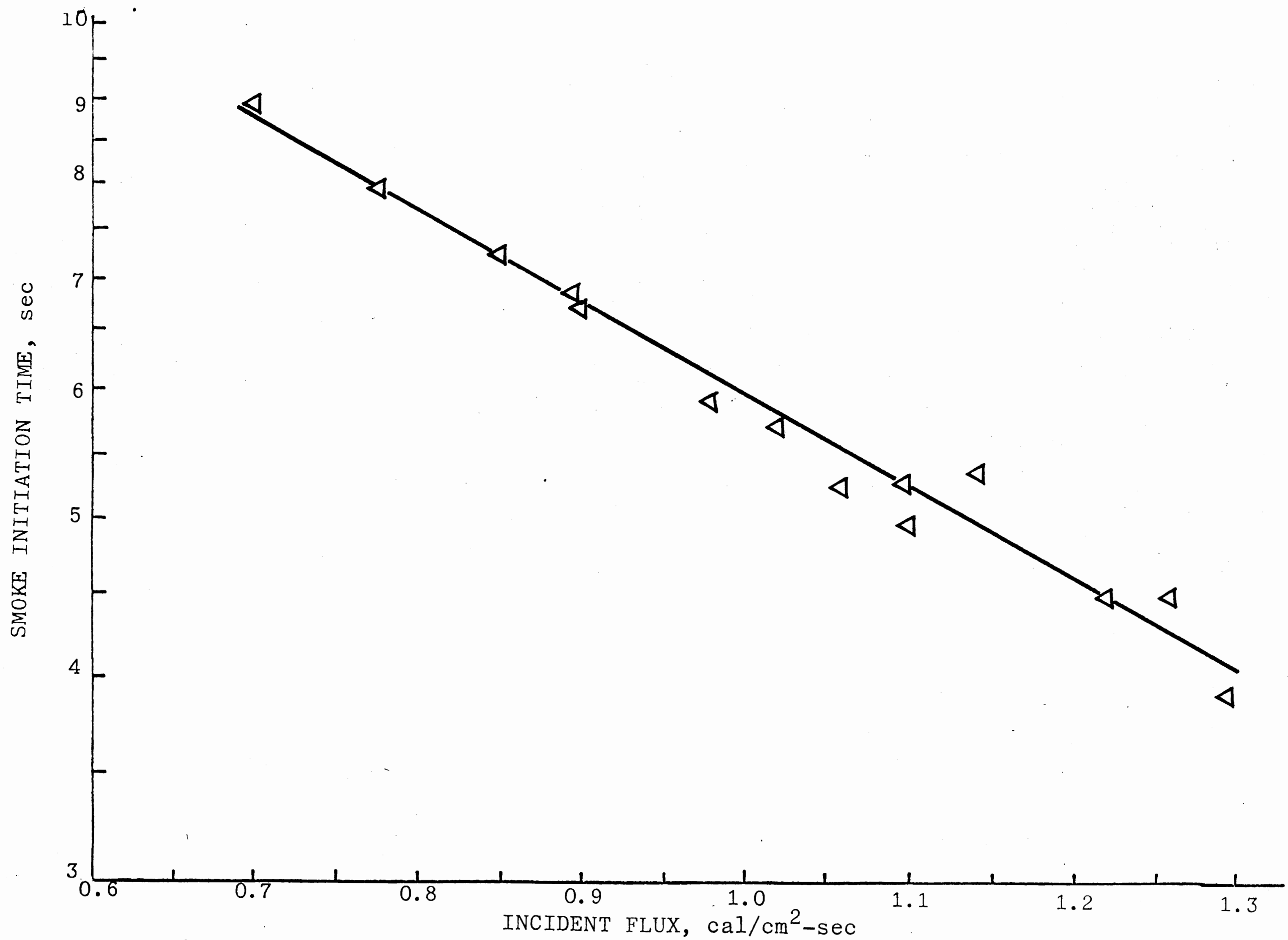


Figure 12. Smoke initiation time vs Incident flux: 100% cotton navy blue corduroy unwashed

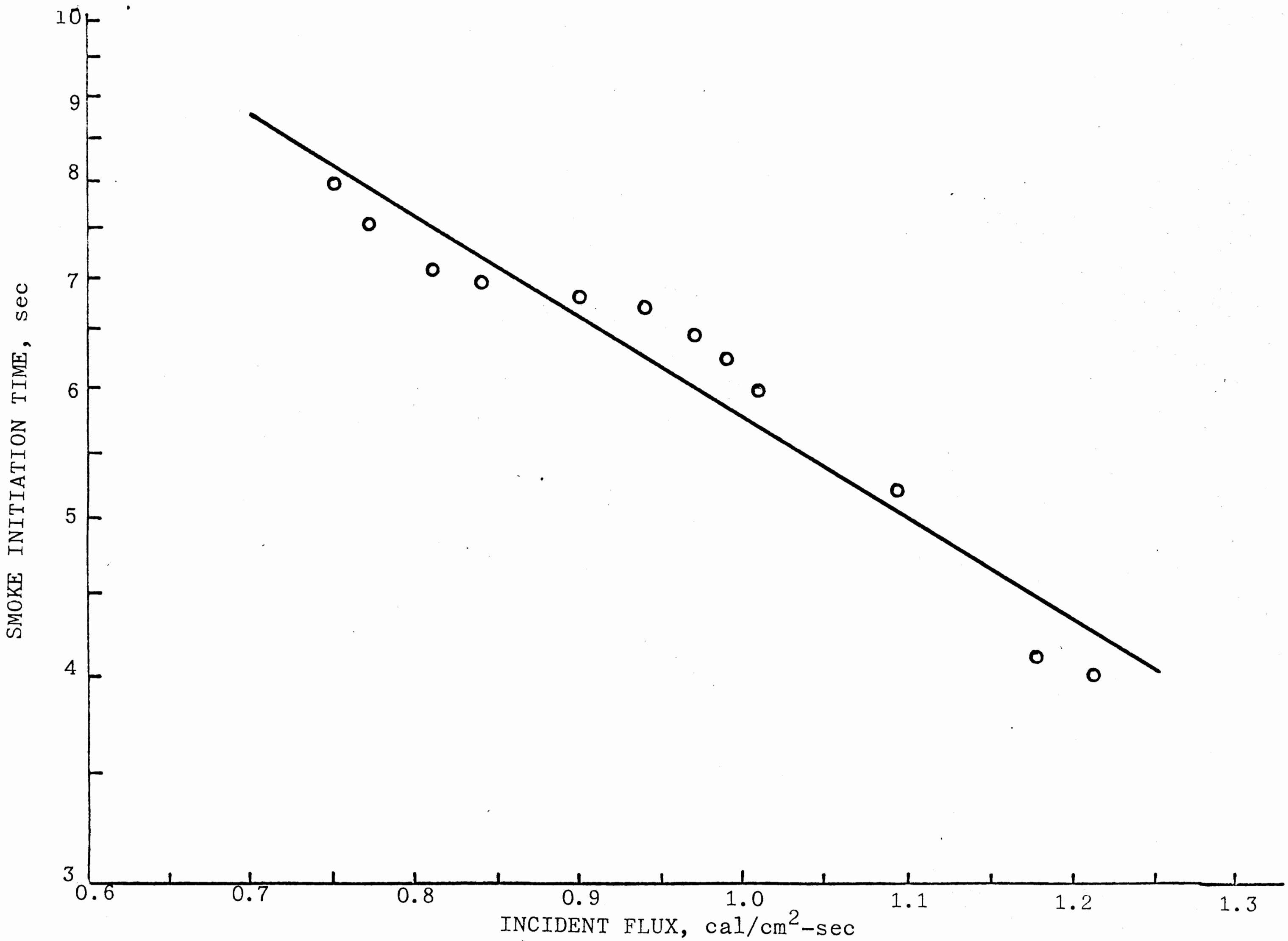


Figure 13. Smoke initiation time vs Incident flux: 50% cotton-50% polyester white unwashed

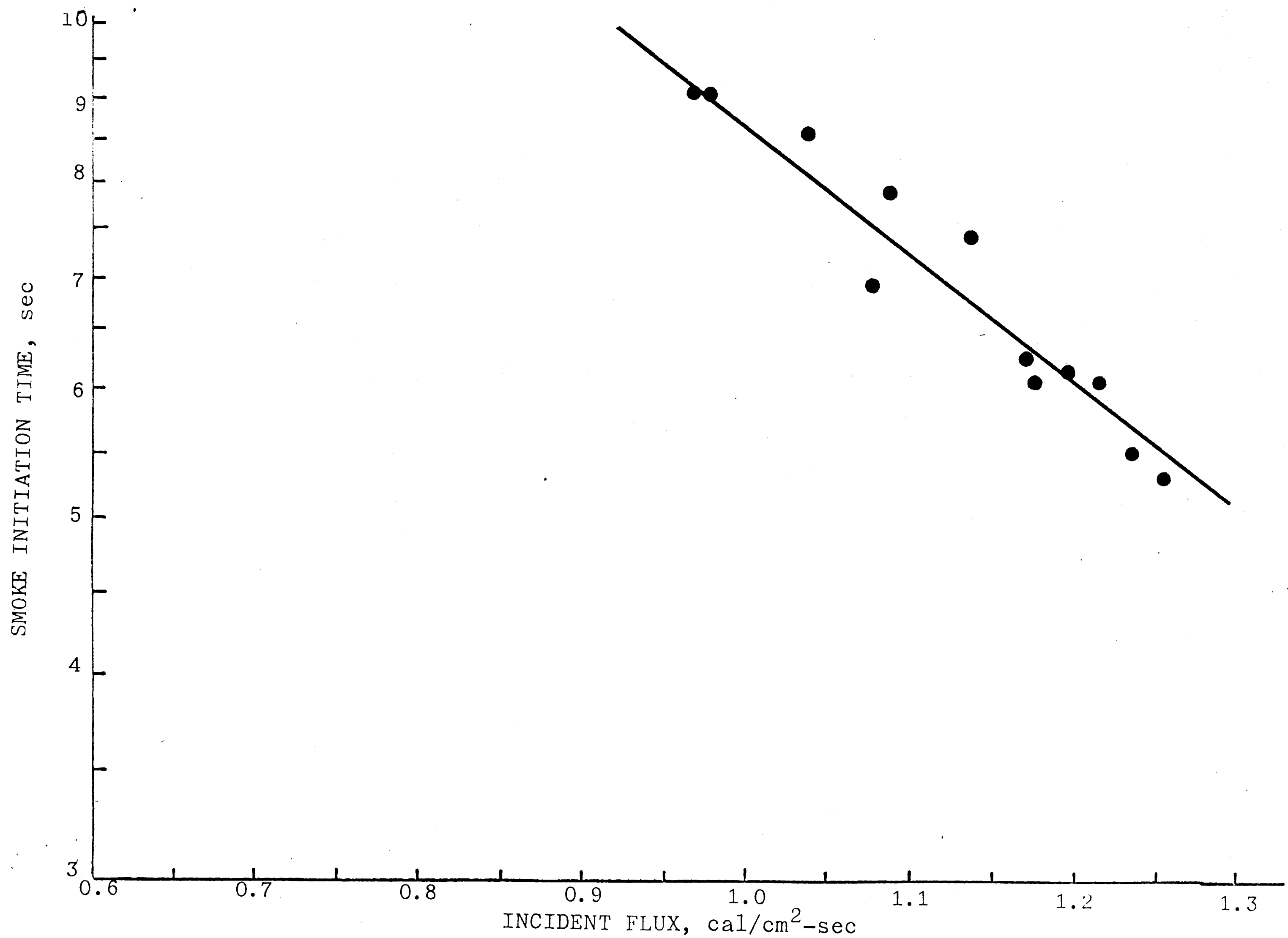


Figure 14. Smoke initiation time vs Incident flux: 50% cotton-50% polyester red duck unwashed

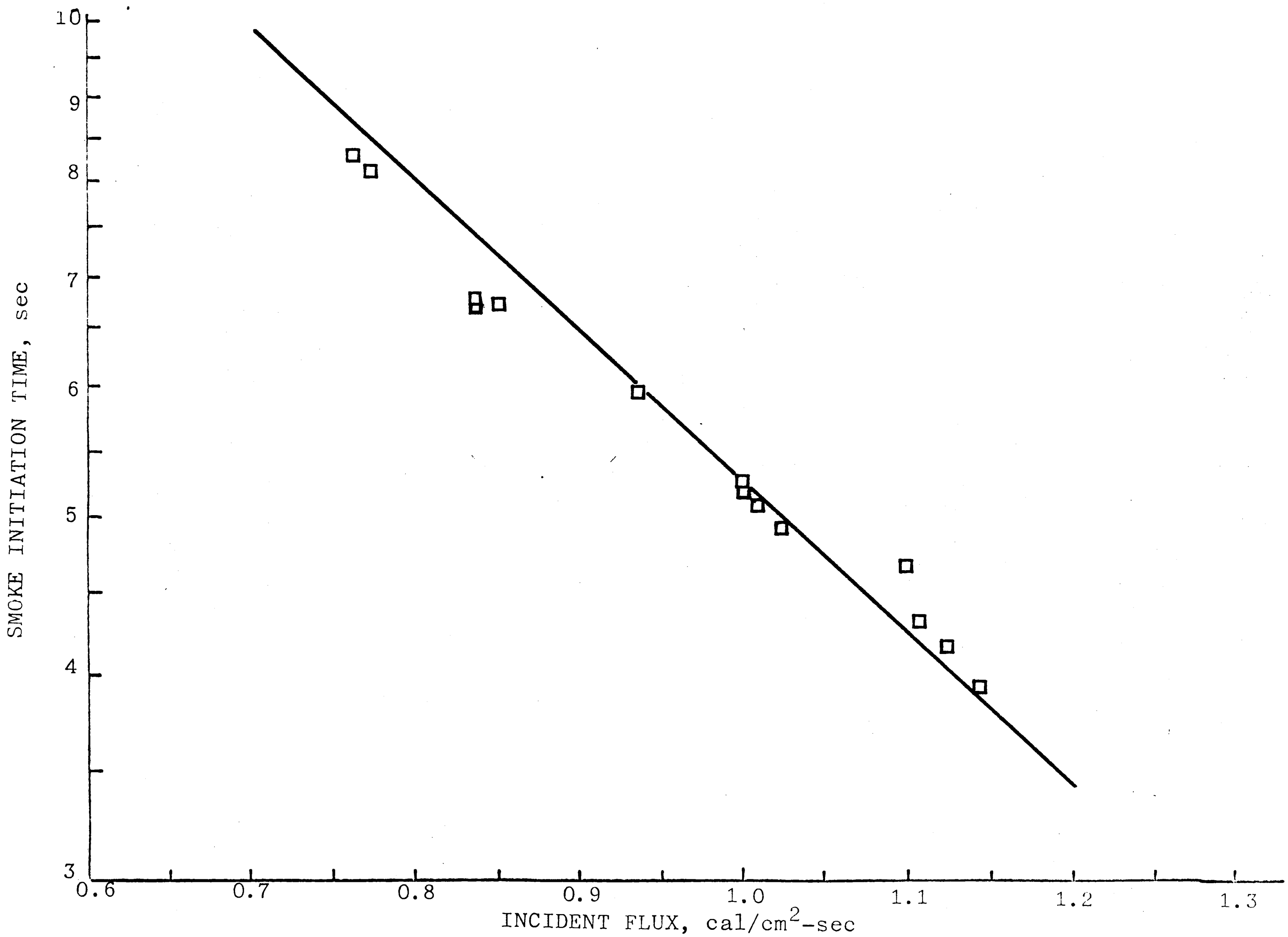


Figure 15. Smoke initiation time vs Incident flux: 50% cotton-50% polyester marine blue unwashed

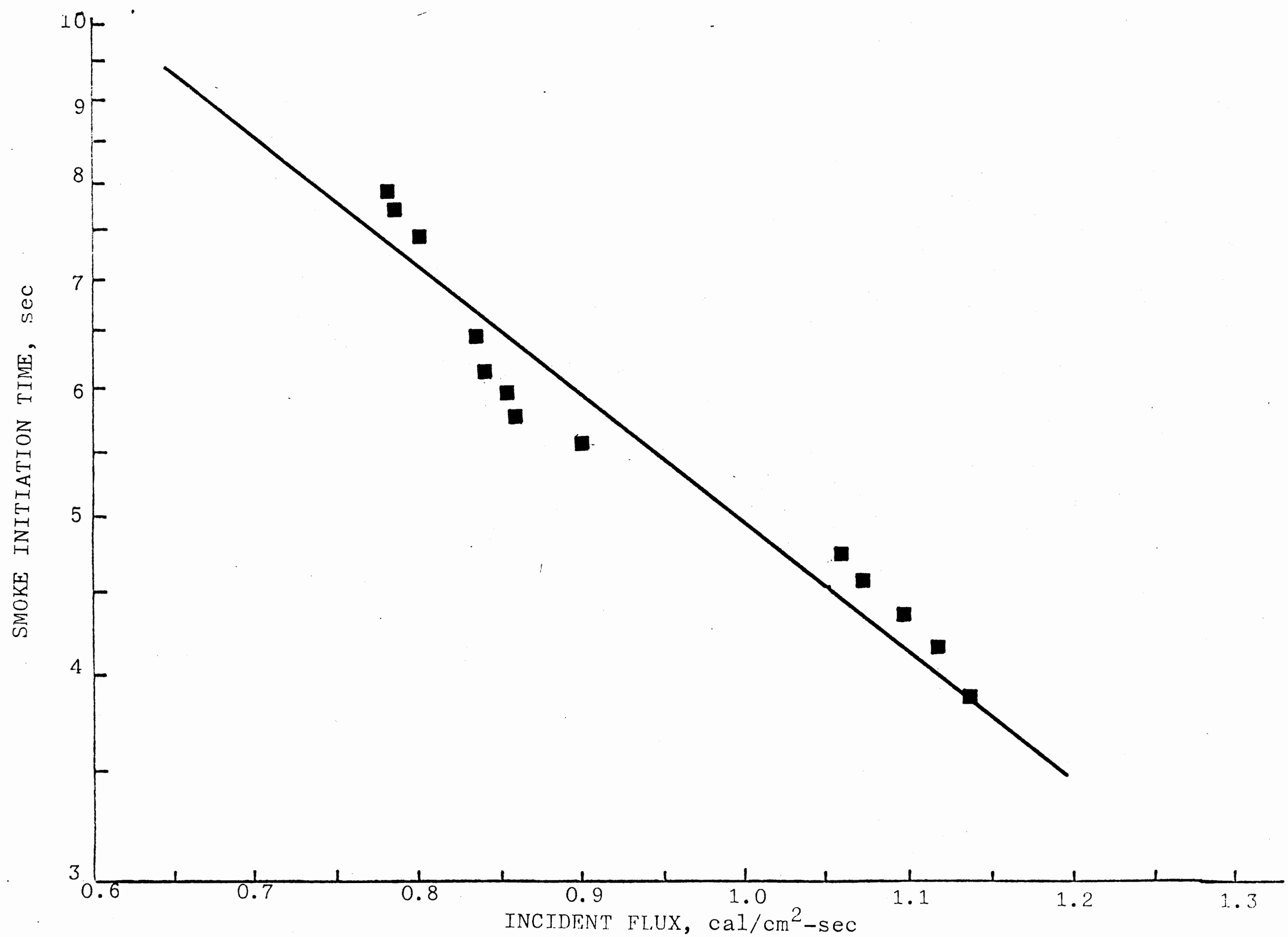


Figure 16. Smoke initiation time vs Incident flux: 50% cotton-50% polyester navy blue chino unwashed

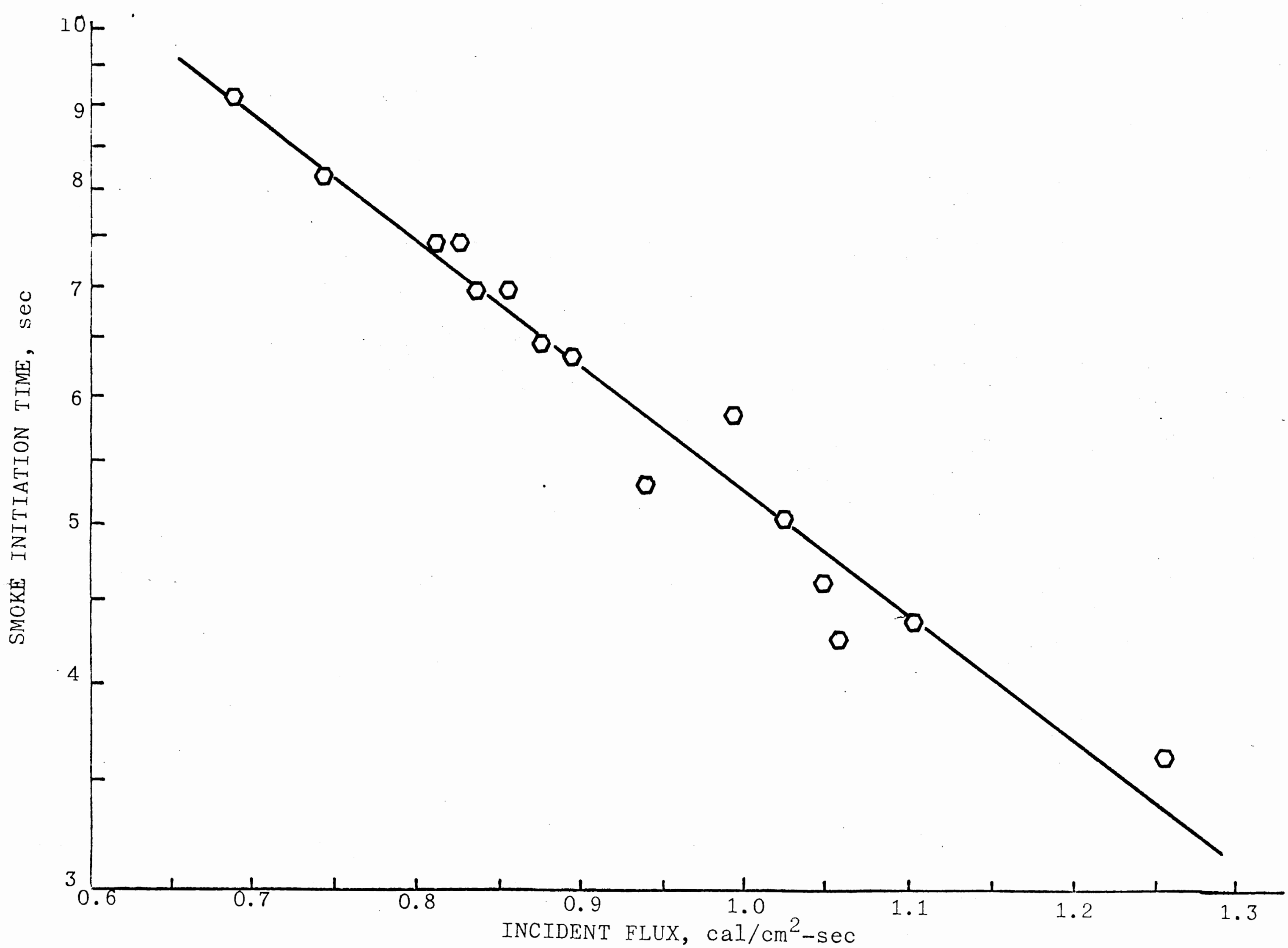


Figure 17. Smoke initiation time vs Incident flux: Military green cloth unwashed

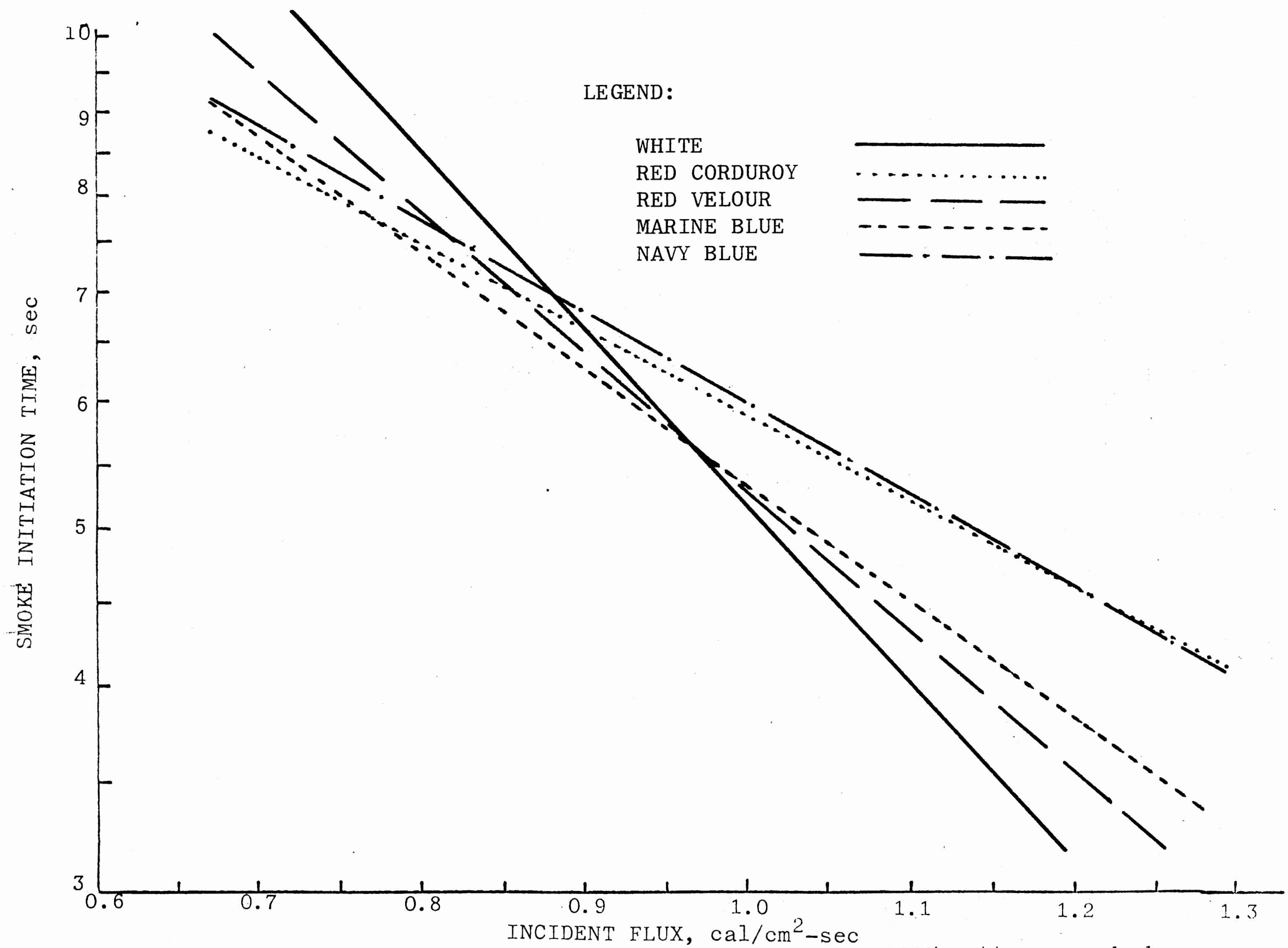


Figure 18. Smoke initiation time vs Incident flux: 100% cotton unwashed
All fabrics

Experiments were also conducted with multilayer clothing. Here, the flux was held constant and the thickness of the sample exposed was varied. The raw data are tabulated in Appendix D (Table IV). In this case equation of the form: T = a Exp(bW/A) was tested to see if fit the data.

Based on five runs made at an average flux of 1.07 cal/ cm^2-sec. on 100% cotton narrow wale red corduroy gave the following equation: T = 4.65 Exp(3.59W/A) which had an average error of 0.24%. The related curve has been plotted in Figure 20.

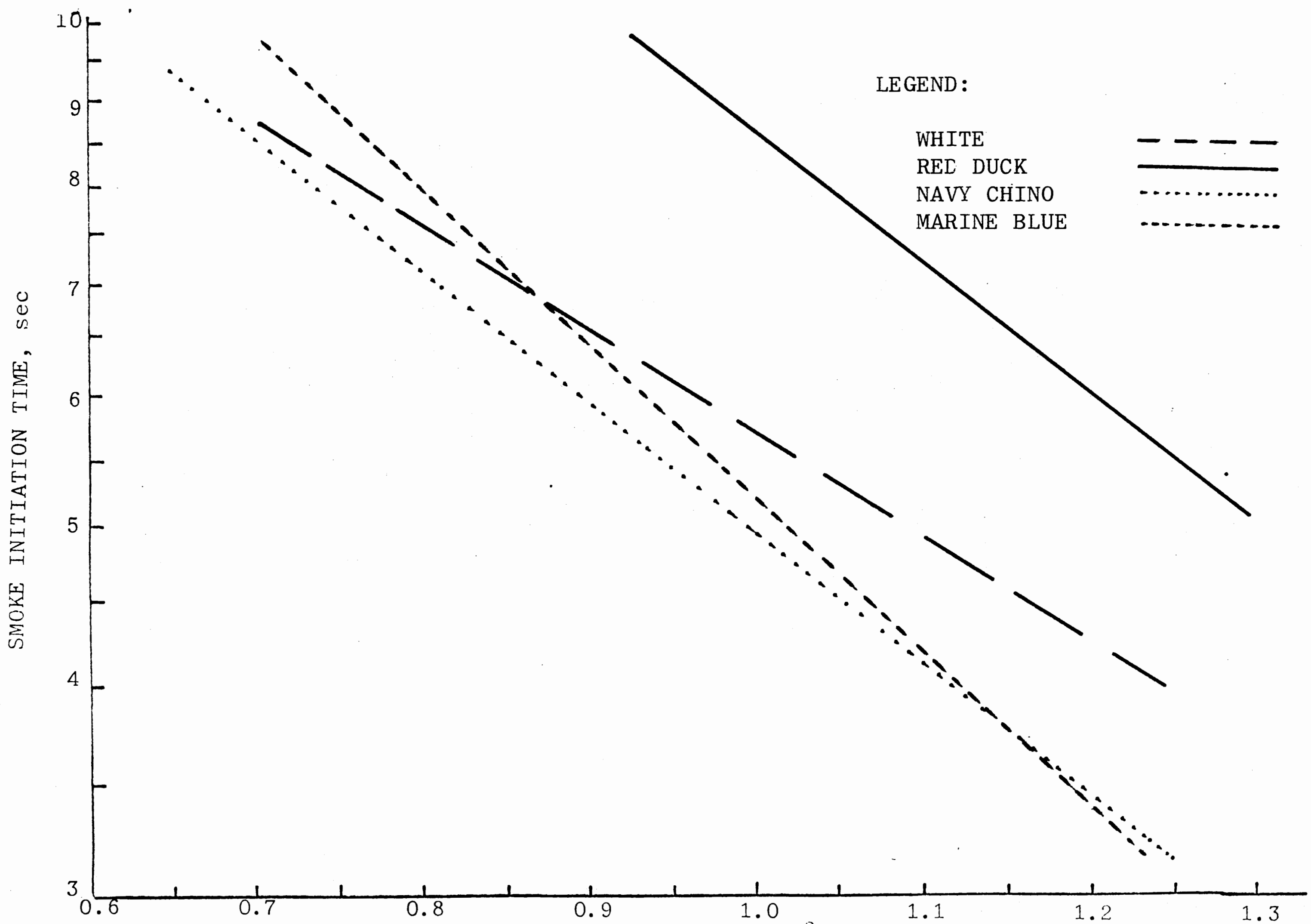


Figure 19. Smoke initiation time vs Incident flux: 50% cotton-50% polyester unwashed. All samples

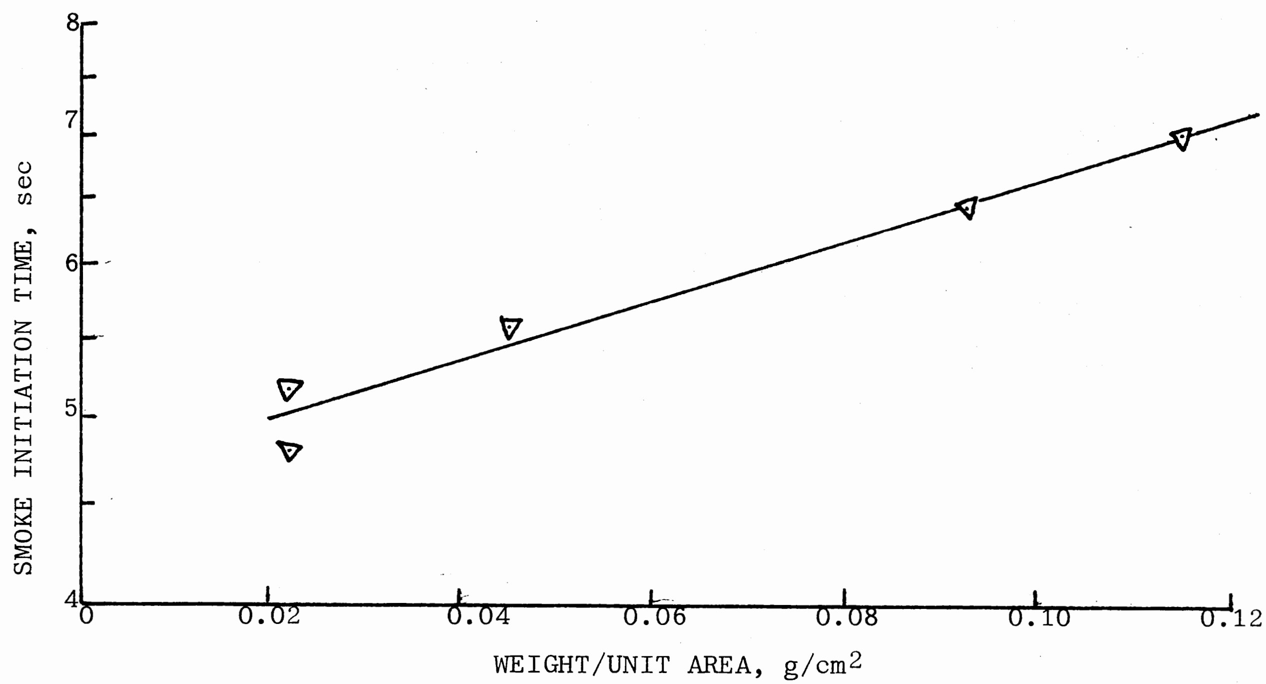


Figure 20. Smoke initiation time vs weight/unit area: 100% cotton red corduroy: Average flux of 1.07 cal/cm^2-sec

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS:

Examination of Figures 8 through 19, Table II and the Appendix D, yields the following for 100% cotton, military and a blend of 50% cotton-50% polyester fabrics:

1. There is a minimum flux, the threshold flux, below which the fabric does not smoke. This was observed to be around 0.6 cal/cm^2-sec, independent of the materials tested.
2. There is a certain flux above which the sample smokes, glows and/or bursts into flames and is reduced to ashes after shielding. This was observed to be around 1.15 cal/cm^2-sec.
3. Every fabric has an unique smoke initiation time for a given flux above the threshold flux.
4. An equation of the type: $T = a\ \mathrm{Exp}(bF)$, describes satisfactorily the time for smoke initiation in the range of fluxes between 0.6 and 1.4 cal/cm^2-sec.
5. There is no significant effect of surface texture within the range of flux studied.
6. 100% polyester fabrics melt down to a hard mass, independent of the level of irradiance above the threshold flux. They

smoke profusely and ignite only on direct contact with a pilot source.

7. Smoke initiation times can be correlated satisfactorily in multiple layers of the same fabric, by equations of the form,

   $T = a\ \mathrm{Exp}(bW/A)$.

8. The statistical scatter at the smoke initiation point may be due to: a) Not controlling all the effects of the primary and secondary variables listed in chapter I. b) Error in observing and recording the smoke initiation times, especially at higher fluxes. c) Deviation of the controller from the set point.

B. RECOMMENDATIONS:

1. To eliminate the statistical scatter at the smoke initiation point,

   a) All the primary and secondary variables listed in chapter I should be studied in detail.

   b) As far as possible, everything should be automated to eliminate human error. For instance, magnetic shutters or similar high speed devices should be used to control the exposure of the sample.

2. Various compositions of cotton and polyester, patterns and other fibers should be studied.

3. Correlations should be developed for smoke initiation time as a function of absorptivity and spectra of the materials.

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A P P E N D I X A

NOMENCLATURE

NOMENCLATURE

A	area exposed to radiation	cm^2
a	constant	dimensionless
b	constant	dimensionless
e	base of natural logarithm [2.71828]	dimensionless
F	incident flux	cal/cm^2-sec
T	smoke initiation time	sec
W	Weight of the sample	g

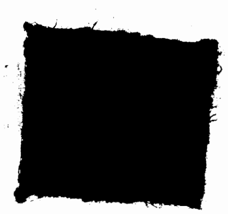
A P P E N D I X B

RATIONALE OF FABRIC CODING

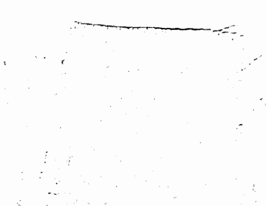
RATIONALE OF FABRIC CODING

In the present investigation, samples of 100% cotton, 100% polyester, 50% cotton-50% polyester and military unwashed fabrics of different colors were tested. Thus the type of fabric is the first part of the code: C - 100% cotton, P - 100% polyester, CP - 50% cotton-50% polyester and M - military. The second part of the code represents the color of the fabric: W - white, R - red, RV - red velour, BM - marine blue, BN - navy blue and B - black. Thus a 100% cotton white fabric was coded as CW. To differentiate prewashed from unwashed fabrics, the letter 'U' was added after the color code, which was followed by the sample number. Military green cloth was coded as MG. Thus the fourth sample of 100% cotton fabric was denoted by CWU4.

Attached below with labels are specimens of the materials studied, as received.



Military green cloth unwashed



100% polyester white unwashed

100% polyester black unwashed

100% cotton
white unwashed

100% cotton red
corduroy unwashed

100% cotton red
velour unwashed

100% cotton
marine blue
unwashed

100% cotton navy
blue unwashed

50% cotton-50%
polyester white
unwashed

50% cotton-50%
polyester red
unwashed

50% cotton-50%
polyester marine
blue unwashed

50% cotton-50%
polyester navy
blue unwashed

A P P E N D I X   C

CALIBRATION CURVE FOR CALORIMETER

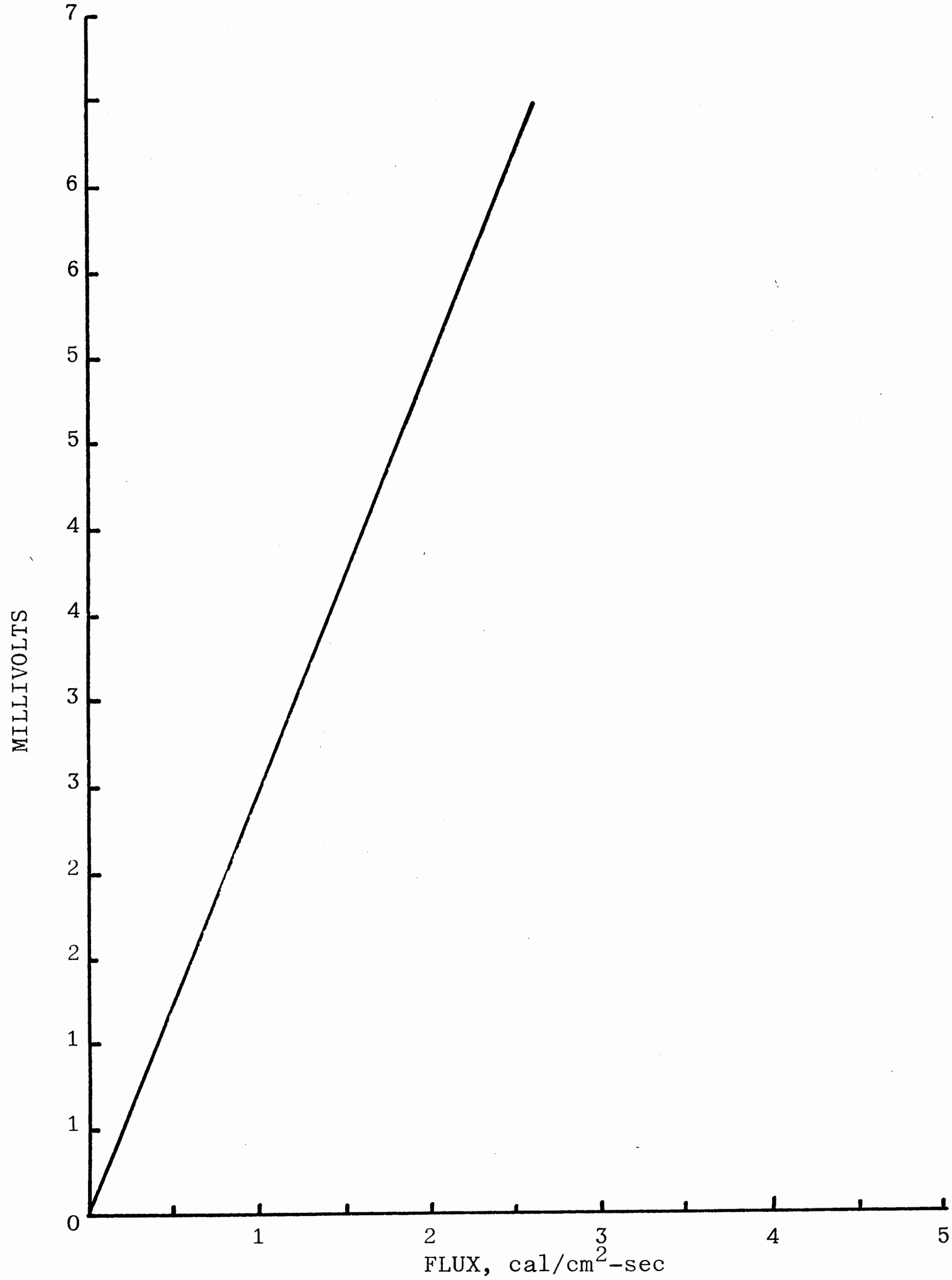


Figure 21. mv Output vs Incident energy - Calibration Curve

A P P E N D I X D

RAW DATA

TABLE III

RAW DATA FOR 100% COTTON WHITE NARROW WALE CORDUROY UNWASHED

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CWU1	0.0452	0.2472	0.0217	1.40	0.575	NO SMOKE
CWU2	0.0454	0.2531	0.0222	1.78	0.730	10.20
CWU3	0.0461	0.2514	0.0221	1.90	0.775	8.40
CWU4	0.0445	0.2434	0.0214	1.92	0.780	8.20
CWU5	0.0450	0.2521	0.0221	2.25	0.920	7.45
CWU6	0.0445	0.2515	0.0221	2.34	0.950	6.56
CWU7	0.0465	0.2479	0.0217	2.56	1.040	4.50
CWU8	0.0442	0.2471	0.0217	2.24	0.920	7.60
CWU9	0.0436	0.2557	0.0224	2.40	0.980	5.25
CWU10	0.0428	0.2379	0.0209	2.47	1.010	5.10
CWU11	0.0422	0.2393	0.0210	2.46	1.000	5.14

TABLE III (continued)

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CWU12	0.0412	0.2396	0.0210	2.62	1.075	4.15
CWU13	0.0425	0.2379	0.0209	2.61	1.070	4.20
CWU14	0.0444	0.2621	0.0230	2.64	1.080	4.10
CWU15	0.0450	0.2585	0.0227	2.60	1.060	4.04
CWU16	0.0433	0.2594	0.0228	1.78	0.730	10.02

TABLE IV

RAW DATA FOR 100% COTTON RED CORDUROY UNWASHED

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CRU1	0.0437	0.2770	0.0243	2.760	1.120	3.30
CRU6	0.0459	0.2550	0.0224	2.650	1.080	3.90
CRU7	0.0457	0.2673	0.0235	2.140	0.875	6.10
CRU9	0.0489	0.2650	0.0232	2.120	0.870	6.00
CRU10	0.0459	0.2522	0.0221	2.735	1.101	4.80
CRU15	0.0423	0.2529	0.0222	2.560	1.050	5.20
CRU17	0.0479	0.2732	0.0240	3.450	1.400	3.00
CRU18	0.0457	0.2591	0.0227	2.860	1.165	3.95
CRU19	0.0465	0.2627	0.0230	2.580	1.050	4.70
CRU20	0.0469	0.2702	0.0237	2.350	0.955	5.69
CRU21	0.0461	0.2622	0.0230	2.250	0.925	6.80

TABLE IV (continued)

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CRU22	0.0468	0.2675	0.0235	2.110	0.860	6.95
CRU23	0.0495	0.2715	0.0238	2.000	0.835	7.80
CRU24	0.0474	0.2739	0.0240	1.760	0.715	8.95
CRU25	0.0478	0.2591	0.0227	1.840	0.750	8.40
CRU26	0.0465	0.2636	0.0231	2.115	0.864	6.90
CRU27	0.0465	0.2578	0.0226	2.200	0.895	6.85
CRU28	0.0417	0.2576	0.0226	2.320	0.950	5.60
CRU29	0.0485	0.2634	0.0234	2.280	0.930	6.00
CRU30	0.0482	0.2650	0.0232	2.540	1.025	5.05
CRU31	0.0483	0.2632	0.0231	2.680	1.085	4.35
CRU11	0.0877	0.5136	0.0450	2.600	1.060	5.60
CRU13	0.2542	1.0680	0.0937	2.675	1.080	6.45
CRU14	0.2989	1.3170	0.1155	2.635	1.070	7.05

TABLE V

RAW DATA FOR 100% COTTON RED VELOUR UNWASHED

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CRVU1	0.0428	0.2440	0.0214	2.30	0.935	6.00
CRVU2	0.0457	0.2403	0.0211	2.70	1.100	4.10
CRVU3	0.0439	0.2435	0.0214	2.66	1.075	4.50
CRVU4	0.0451	0.2466	0.0216	1.82	0.790	8.00
CRVU5	0.0456	0.2500	0.0219	2.04	0.840	7.15
CRVU6	0.0448	0.2495	0.0219	2.46	1.000	5.25
CRVU7	0.0449	0.2394	0.0299	2.68	1.085	4.20
CRVU8	0.0442	0.2481	0.0218	2.66	1.075	4.50
CRUV9	0.0429	0.2371	0.0280	3.14	1.275	3.00
CRVU10	0.0434	0.2414	0.0212	3.00	1.225	3.50
CRVU11	0.0433	0.2447	0.0215	2.94	1.200	3.80

TABLE V (continued)

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CRVU12	0.0430	0.2468	0.0216	2.50	1.025	5.05
CRVU13	0.0440	0.2397	0.0211	2.27	0.920	6.50
CRVU14	0.0436	0.2396	0.0210	2.70	1.090	4.20
CRVU15	0.0434	0.2488	0.0218	2.82	1.150	3.85
CRVU16	0.0436	0.2438	0.0214	2.15	0.880	6.70

TABLE VI

RAW DATA FOR 100% COTTON NARROW WALE MARINE BLUE CORDUROY UNWASHED

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CBMU1	0.0445	0.2589	0.0227	1.830	0.750	8.25
CBMU2	0.0449	0.2771	0.0243	1.700	0.695	9.30
CBMU3	0.0444	0.2743	0.0241	1.695	0.690	9.40
CBMU4	0.0450	0.2739	0.0240	2.215	0.895	5.75
CBMU5	0.0436	0.2741	0.0240	2.160	0.875	6.90
CBMU6	0.0439	0.2670	0.0240	2.220	0.900	6.30
CBMU7	0.0437	0.2813	0.0247	2.225	0.905	6.15
CBMU8	0.0437	0.2704	0.0237	2.720	1.100	5.10
CBMU9	0.0434	0.2777	0.0244	2.840	1.160	3.80
CBMU10	0.0439	0.2765	0.0243	2.900	1.180	3.67
CBMU11	0.0434	0.2724	0.0239	3.200	1.300	3.50

TABLE VI (continued)

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CBMU12	0.0445	0.2846	0.0250	2.74	1.115	4.50
CBMU13	0.0439	0.2750	0.0241	2.30	0.940	5.30
CBMU14	0.0440	0.2669	0.0234	2.04	0.835	7.00
CBMU15	0.0446	0.2861	0.0251	2.28	0.935	5.80

TABLE VII

RAW DATA FOR 100% COTTON NARROW WALE NAVY BLUE CORDUROY UNWASHED

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CBNU1	0.0434	0.2634	0.0231	3.20	1.300	3.90
CBNU2	0.0434	0.2739	0.0240	3.12	1.265	4.50
CBNU3	0.0423	0.2606	0.0229	2.80	1.145	5.35
CBNU4	0.0504	0.2618	0.0230	2.50	1.020	5.70
CBNU5	0.0417	0.2812	0.0247	2.22	0.900	6.75
CBNU6	0.0418	0.2652	0.0233	2.20	0.895	6.90
CBNU7	0.0412	0.2496	0.0219	1.72	0.700	9.00
CBNU8	0.0413	0.2680	0.0235	1.90	0.775	8.00
CBNU9	0.0422	0.2564	0.0225	2.20	0.895	6.90
CBNU10	0.0411	0.2581	0.0226	2.40	0.980	5.90
CBNU11	0.0410	0.2594	0.0228	2.60	1.060	5.25

TABLE VII (continued)

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CBNU12	0.0419	0.2634	0.0231	3.20	1.300	3.90
CBNU13	0.0411	0.2514	0.0221	2.76	1.103	4.95
CBNU14	0.0408	0.2586	0.0227	3.00	1.225	4.50
CBNU15	0.0410	0.2685	0.0236	2.08	0.850	7.30

TABLE VIII

RAW DATA FOR MILITARY GREEN CLOTH UNWASHED

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
MGU1	0.0341	0.2232	0.0196	2.455	0.995	5.90
MGU2	0.0329	0.2180	0.0191	2.620	1.065	4.28
MGU3	0.0327	0.2132	0.0187	2.100	0.855	7.05
MGU4	0.0323	0.2155	0.0189	2.200	0.895	6.40
MGU5	0.0318	0.2215	0.0194	2.720	1.105	4.40
MGU6	0.0320	0.2185	0.0192	3.100	1.260	3.65
MGU7	0.0315	0.2189	0.0192	2.578	1.050	4.65
MGU8	0.0318	0.2156	0.0189	2.040	0.835	7.00
MGU9	0.0317	0.2113	0.0185	2.010	0.825	7.50
MGU10	0.0312	0.2138	0.0188	2.125	0.875	6.50
MGU11	0.0310	0.2310	0.0203	2.300	0.940	5.35

TABLE VIII (continued)

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
MGU12	0.0310	0.2129	0.0187	2.520	1.025	5.10
MGU13	0.0310	0.2223	0.0195	1.670	0.685	9.20
MGU14	0.0310	0.2140	0.0188	1.980	0.810	7.50
MGU15	0.0310	0.2140	0.0188	1.800	0.740	8.20
MGU16	0.0320	0.2253	0.0198	1.500	0.620	NO SMOKE

TABLE IX

RAW DATA FOR 50% COTTON-50% POLYESTER WHITE TEXTURE UNWASHED

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CPWU1	0.0363	0.2104	0.0185	1.980	0.810	7.10
CPWU2	0.0361	0.2081	0.0183	2.065	0.840	7.00
CPWU3	0.0379	0.2151	0.0189	2.200	0.900	6.85
CPWU4	0.0386	0.2136	0.0187	2.300	0.940	6.76
CPWU5	0.0377	0.2151	0.0189	2.385	0.970	6.50
CPWU6	0.0371	0.2101	0.0184	2.445	0.990	6.29
CPWU7	0.0381	0.2103	0.0185	2.480	1.010	6.00
CPWU8	0.0411	0.2115	0.0186	2.695	1.095	5.20
CPWU9	0.0378	0.2097	0.0184	2.900	1.180	4.10
CPWU10	0.0365	0.2076	0.0182	2.960	1.215	4.00
CPWU11	0.0358	0.2130	0.0187	1.500	0.620	NO SMOKE

TABLE IX (continued)

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CPWU14	0.0370	0.2118	0.0186	1.910	0.770	NO SMOKE
CPWU15	0.0337	0.2028	0.0178	1.820	0.750	8.05

TABLE X

RAW DATA FOR 50% COTTON–50% POLYESTER RED DUCK UNWASHED

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CPRU1	0.0312	0.2312	0.0203	2.800	1.140	7.50
CPRU2	0.0310	0.2301	0.0202	2.700	1.090	8.00
CPRU3	0.0309	0.2360	0.0207	2.560	1.040	8.70
CPRU4	0.0303	0.2252	0.0198	2.380	0.970	9.20
CPRU5	0.0308	0.2319	0.0203	2.030	0.830	11.20
CPRU6	0.0306	0.2344	0.0206	1.600	0.650	NO SMOKE
CPRU7	0.0307	0.2288	0.0201	3.040	1.240	5.50
CPRU8	0.0309	0.2358	0.0207	2.910	1.180	6.10
CPRU9	0.0308	0.2341	0.0205	2.890	1.175	6.30
CPRU10	0.0306	0.2337	0.0205	2.380	0.980	9.20
CPRU11	0.0306	0.2313	0.0203	2.200	0.900	10.50

TABLE X (continued)

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CPRU12	0.0309	0.2274	0.0199	1.580	0.645	NO SMOKE
CPRU13	0.0305	0.2211	0.0194	2.950	1.200	6.20
CPRU14	0.0312	0.2322	0.0204	2.640	1.080	7.00
CPRU15	0.0382	0.2095	0.0184	3.100	1.260	5.30
CPRU16	0.0307	0.2330	0.0243	2.960	1.220	6.10

TABLE XI

RAW DATA FOR 50% COTTON-50% POLYESTER MARINE TEXTURE UNWASHED

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CPBMU1	0.0527	0.2380	0.0209	2.460	1.000	5.20
CPBMU2	0.0512	0.2391	0.0210	2.700	1.100	4.70
CPBMU3	0.0526	0.2312	0.0208	2.760	1.125	4.20
CPBMU4	0.0470	0.2331	0.0204	2.740	1.109	4.35
CPBMU5	0.0510	0.2390	0.0210	2.800	1.145	3.95
CPBMU6	0.0474	0.2504	0.0220	1.880	0.770	8.20
CPBMU7	0.0475	0.2319	0.0203	2.080	0.850	6.80
CPBMU8	0.0469	0.2309	0.0203	2.450	0.999	5.30
CPBMU9	0.0516	0.2297	0.0202	2.515	1.025	4.95
CPBMU10	0.0511	0.2264	0.0199	2.475	1.010	5.10
CPBMU11	0.0456	0.2221	0.0195	2.295	0.935	6.00

TABLE XI (continued)

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CPBMU12	0.0479	0.2119	0.0186	2.060	0.8350	6.85
CPBMU13	0.0482	0.2151	0.0188	1.860	0.760	8.40
CPBMU14	0.0476	0.2198	0.0193	1.520	0.625	14.70
CPBMU15	0.0488	0.2145	0.0188	1.860	0.760	8.40
CPBMU16	0.0501	0.2201	0.0193	2.060	0.835	6.80

TABLE XII

RAW DATA FOR 50% COTTON-50% POLYESTER NAVY CHINO UNWASHED

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CPBN1	0.0411	0.2643	0.0232	1.60	0.650	11.38
CPBN2	0.0417	0.2928	0.0257	1.91	0.780	8.00
CPBN3	0.0414	0.2650	0.0232	1.92	0.785	7.80
CPBN4	0.0412	0.2905	0.0255	2.06	0.840	6.20
CPBN5	0.0410	0.2755	0.0242	1.95	0.800	7.50
CPBN6	0.0403	0.2595	0.0228	2.10	0.860	5.80
CPBN7	0.0406	0.2848	0.0249	2.05	0.835	6.50
CPBN8	0.0416	0.2709	0.0238	2.10	0.860	5.80
CPBN9	0.0409	0.2653	0.0233	2.08	0.855	6.00
CPBN10	0.0412	0.2697	0.0237	2.06	0.840	6.20
CPBN11	0.0456	0.2719	0.023	2.79	1.140	3.90

TABLE XII (continued)

SAMPLE #	AVERAGE THICKNESS cm	WEIGHT OF SAMPLE g	DENSITY g/sq cm	CALORIMETER RESPONSE mv	INCIDENT FLUX cal/cm^2-sec	SMOKE INITIATION TIME sec
CPBN12	0.0405	0.2654	0.0233	2.72	1.100	4.40
CPBN13	0.0411	0.2788	0.0245	2.74	1.120	4.20
CPBN14	0.0408	0.2859	0.0251	2.64	1.075	4.60
CPBN15	0.0400	0.2706	0.0237	2.62	1.060	4.80
CPBN16	0.0408	0.2687	0.0236	2.20	0.900	5.60

APPENDIX E

SEMI-LOG LEAST SQUARES CURVE FIT

COMPUTER PROGRAM FOR CORRELATING THE SMOKE INITIATION TIME AS A FUNCTION OF THE INCIDENT FLUX

```
C       PROGRAM FINDS A AND B FOR Y=A*EXP(B*X)
C       YA(I) IS DEPENDENT VARIABLE
C       XA(I) IS INDEPENDENT VARIABLE
C       A IS COEFFICIENT
C       B IS EXPONENT OF EXPONENTIAL FUNCTION
C       N IS NUMBER OF DATA POINTS.  MAXIMUM NUMBER IS 150
C       AP IS INTERCEPT OF LOG-LOG LINE
C       INP IS INPUT DEVICE NUMBER
C       IOUT IS OUTPUT DEVICE NUMBER
C       NSET = N  TERMINATES THE PROGRAM
C
        DIMENSION YA(150),XA(150),Y(150),X(150),YC(150)
        DIMENSION XX(150),XY(150),DIF(150),PDIF(150),ABDIF(150)
        INP=5
        IOUT=6
      1 READ(INP,100)N
        DO 2 I=1,N
        READ(INP,101)YA(I),XA(I)
      2 CONTINUE
        READ(INP,102) NSET
C
C       CONVERT INPUT TO LOGS
C
        DO 13 I=1,N
        Y(I)=ALOG(YA(I))
        X(I)=XA(I)
     13 CONTINUE
C
C       SET ALL SUMMATIONS EQUAL TO ZERO
C
        SUMX=0.0
        SUMY=0.0
        SUMXY=0.0
        SUMXX=0.0
        AN=N
C
C       CALCULATE AP AND B
C       B=N*SUMXY-SUMX*SUMY DIV BY N*SUMXX-SUMX*SUMX
C       AP=YAV-(B*XAV)
C
        DO 3 I=1,N
        XX(I)=X(I)*X(I)
        XY(I)=X(I)*Y(I)
        SUMX=SUMX+X(I)
        SUMY=SUMY+Y(I)
```

```
      SUMXX=SUMXX+XX(I)
      SUMXY=SUMXY+XY(I)
    3 CONTINUE
      XAV=SUMX/AN
      YAV=SUMY/AN
      BBB=(AN*SUMXY)-(SUMX*SUMY)
      BB=(AN*SUMXX)-(SUMX*SUMX)
      B=BBB/BB
      AP=YAV-(B*XAV)
      A=EXP(AP)
      SUMER=0.0
C
C     BACK CALCULATE Y VALUES USING A AND B
C     YC IS CALCULATED Y VALUE
C
      DO 4 I=1,N
      YC(I)=A*EXP(B*XA(I))
      DIF(I)=YA(I)-YC(I)
      PDIF(I)=(DIF(I)*100.0)/(YA(I))
      ABDIF(I)=ABS(PDIF(I))
      SUMER=SUMER+ABDIF(I)
    4 CONTINUE
C
C     AVDIF IS AVERAGE ABSOLUTE VALUE OF PERCENT DIFFERENCE
C
      AVDIF=SUMER/AN
      WRITE(IOUT,103)
      WRITE(IOUT,200)
      WRITE(IOUT,201)
      WRITE(IOUT,202)A
      WRITE(IOUT,203)B
      WRITE(IOUT,204)
      WRITE(IOUT,205)
      DO 5 I=1,N
      WRITE(IOUT,206) YA(I),YC(I),XA(I),DIF(I),PDIF(I)
    5 CONTINUE
      WRITE(IOUT,207)
      WRITE(IOUT,208) AVDIF
      WRITE(IOUT,209)
      IF(NSET-150)1,20,1
  100 FORMAT(I4)
  101 FORMAT(2F20.8)
  102 FORMAT(I4)
  103 FORMAT(/////////)
  200 FORMAT(5X,31HLOG-LOG LEAST SQUARES FIT)
  201 FORMAT(5X,12HY=A*EXP(B*X))
  202 FORMAT(5X,3HA= ,E13.6)
  203 FORMAT(5X,3HB= ,E13.6)
  204 FORMAT(//)
  205 FORMAT(10X,4HYOBS,9X,5HYCALC,10X,1HX,13X,4HDIFF,11X,8HPCT DIFF/)
  206 FORMAT(5X,E11.4,3X,E11.4,5X,E11.4,5X,E11.4/)
  207 FORMAT(//)
```

```
208 FORMAT(5X,E11.4,4X,E11.4,3X,E11.4,5X,E11.4,5X,E11.4/)
209 FORMAT(////////)
 20 STOP
    END
```

VITA

Rajagopalan Ravi

Candidate for the degree of

Master of Science

Thesis: AN INVESTIGATION OF FABRIC DESTRUCTION BY RADIANT HEAT FLUX

Major Field: Chemical Engineering

Biographical:

Personal Data: Born in Hyderabad, India, June 26, 1953 to Krishnaswamy Rajagopalan and Pattu Rajagopalan.

Education: Attended the Little Flower High School, Hyderabad, India; received the Degree of Bachelor of Technology in Chemical Engineering from Osmania University, Hyderabad, India in June, 1975; received Senior Diploma in German from Osmania University, Hyderabad, India in June, 1974; completed the requirements for the Degree of Master of Science in Chemical Engineering at Oklahoma State University, Stillwater, USA in December, 1976.

Professional Experience: Engineer Trainee, Indian Drugs and Pharmaceuticals Limited, Hyderabad, India, Summer, 1972; Trainee, Regional Research Laboratory, Hyderabad, India, Summer, 1973; Trainee, Bharat Heavy Electricals Ltd., Hyderabad, India, Summer, 1974; Trainee, Hyderabad Chemicals and Fertilizers, Hyderabad, India, Summer, 1975; Graduate Teaching Assistant, Oklahoma State University, Stillwater, Oklahoma, 1975-1976; Senior Representative, Consumer Services Inc., Houston, Texas, Summer 1976; Graduate Research Assistant, Oklahoma State University, Stillwater, Oklahoma, Fall, 1976.

Membership in Professional Societies: Affiliate Member of the American Institute of Chemical Engineers; Graduate Member of the Indian Institute of Chemical Engineers.