AD 683307

OCD Work Unit 2542A
NRDL-TR-68-139
22 August 1968

IGNITION OF RETARDANT TREATED CLOTH BY NUCLEAR WEAPON THERMAL PULSES

U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

SAN FRANCISCO · CALIFORNIA · 94135

34

THERMAL RADIATION BRANCH
R. S. Alger, Head

RADIATION PHYSICS DIVISION
C. S. Cook, Head

ADMINISTRATIVE INFORMATION

This report covers a portion of the work authorized by the Office of Civil Defense under Work Unit 2542A.

This document has been approved for public release and sale; its distribution is unlimited.

OCD REVIEW NOTICE

This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

Eugene P. Cooper
Technical Director

T. R. Fick, CAPT USN
Commanding Officer

SUMMARY OF REPORT

IGNITION OF RETARDANT TREATED CLOTH BY NUCLEAR WEAPON THERMAL PULSES

NRDL-TR-68-139 dated 22 August 1968

By L. L. Wiltshire and W. J. Parker

The Problem

In a nuclear explosion roughly one third of the energy is released as thermal radiation. The resulting exposure levels are high enough to ignite fabrics and other light weight materials inside of buildings well beyond the range of severe blast damage. These primary ignitions can result in destructive fires and, under some circumstances, could lead to the development of mass fires that could destroy whole sections of the city which would not be significantly damaged by the initial effects of the detonation. One way to reduce the number of these ignitions is to provide the household fabrics with fire retardant treatments. The effectiveness of these treatments in reducing the fire hazard due to nuclear detonations needs to be investigated.

The Findings

The fire retardant treatments recommended by the Department of Agriculture for application by the home owner significantly reduce the distance from a nuclear weapon at which flaming ignition will occur. However, flaming ignition still extends well beyond the 5 psi blast overpressure line for the treated fabrics. The treatments change the mode of ignition from sustained to transient, thereby greatly reducing the effectiveness of the fabrics in propagating fire to other combustible materials. Moreover, the fire retardants form an increased amount of char in the burned material. This char is strong enough to support its own weight in the case of a burned drapery which has been treated, and then remains in place to act as a thermal radiation shield for the duration of the thermal pulse.

AUTHORS: L. L. Wiltshire, W. J. Parker

ABSTRACT

The ignition responses of fire retardant treated black cotton cloth and black rayon cloth to the simulated thermal pulses from nuclear weapons were investigated. The temporal and spectral characteristics of the main thermal pulse from air bursts ranging from 300 KT to 100 MT were reproduced using a cored carbon arc along with a specially shaped rotating disk shutter. The treatments applied to the cloths were a combination of borax, boric acid, ammonium phosphate, diammonium phosphate, and ammonium sulfate which were recommended for home administered treatment of fabrics by the Department of Agriculture.

The data are presented as graphs of ignition distances versus weapon yield for fire retardant treated and untreated cloths. While the range of flaming ignition is significantly reduced by these treatments, flaming ignition would still occur well beyond the 5 psi blast overpressure range. The largest reduction in the area over which flaming ignitions would occur with the fire retardants tested amounts to about 50% over that of the untreated cloth.

The effect of the retardants on the glowing ignition of the cloth varied from no effect to a somewhat greater susceptibility to glowing in the case of cotton. However, for rayon, the recommended treatment eliminated glowing ignition altogether.

Both glowing and flaming ignition were transient in the case of the treated fabrics. Flaming and glowing died out rapidly after the conclusion of the thermal pulse.

Some large area treated and untreated black cotton fabrics simulating household draperies were exposed to a 4 x 4 ft. tungsten lamp bank. Under some circumstances, the mode of ignition of the large area treated fabrics was changed from transient glowing to transient flaming because of increased concentration of distilled gases near the upper part of the specimen.

The effectiveness of the transient flaming and glowing ignition of these fabrics in the spread of fire to other combustible materials coming in contact with them was tested and found to be very low. Fire retardants formed an increased amount of char in the burned material which allowed it to support its own weight and become a thermal radiation shield.

SUMMARY

The Problem

In a nuclear explosion roughly one third of the energy is released as thermal radiation. The resulting exposure levels are high enough to ignite fabrics and other light weight materials inside of buildings well beyond the range of severe blast damage. These primary ignitions can result in destructive fires and, under some circumstances, could lead to the development of mass fires that could destroy whole sections of the city which would not be significantly damaged by the initial effects of the detonation. One way to reduce the number of these ignitions is to provide the household fabrics with fire retardant treatments. The effectiveness of these treatments in reducing the fire hazard due to nuclear detonations needs to be investigated.

The Findings

The fire retardant treatments recommended by the Department of Agriculture for application by the home owner significantly reduce the distance from a nuclear weapon at which flaming ignition will occur. However, flaming ignition still extends well beyond the 5 psi blast overpressure line for the treated fabrics. The treatments change the mode of ignition from sustained to transient, thereby greatly reducing the effectiveness of the fabrics in propagating fire to other combustible materials. Moreover, the fire retardants form an increased amount of char in the burned material. This char is strong enough to support its own weight in the case of a burned drapery which has been treated, and then remains in place to act as a thermal radiation shield for the duration of the thermal pulse.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

The scope of work unit 2542A as given in OCD Task Order No. 66-200 (77), the work of which has continued under OCD Task Order Nos. 2540 (67) and 2530 (68), is as follows:

"(1) To determine the most effective fire retardant for fabrics in terms of ignition protection against high energy fluxes; (2) To determine the concentration of such a retardant required to prevent a material from being ignited by a thermal pulse from a given nuclear weapon burst; (3) To investigate the retardation mechanisms of various types of retarder treatment from the point of view of predicting even more effective but as yet untried candidates. The first phase of the work will measure the ignition energy of alpha cellulose as a function of retarder concentration for retarders selected from the list of fire retardant treatments recommended by the National Fire Protection Association. A more limited set of tests will be made on cotton and other household fabrics. The second phase of the work will examine different classes of treatments that might have potential value in thermal hardening. The third phase will involve the development of techniques necessary to study the retardation processes in some detail. This will include development of a highly sensitive means of determining the time history of the pyrolysis products."

In a nuclear explosion roughly one third of the energy is released as thermal radiation. The resulting exposure levels are high enough to ignite fabrics and other light weight materials inside of buildings well beyond the range of severe blast damage. These primary ignitions can result in destructive fires and, under some circumstances, could lead to the development of mass fires that could destroy whole sections of the city which would not be significantly damaged by the initial effects of the detonation. One way to reduce the number of these ignitions is to provide the household fabrics with fire retardant treatments. The effectiveness of these treatments in reducing the fire hazard due to nuclear detonations needs to be investigated.

During an earlier part of this program the ignition responses of blackened alpha-cellulose and cotton cloth, containing fire retardant additives, were compared to the ignition responses of these materials without additives.[1] This information was obtained by exposing the samples to various constant irradiance levels from a calibrated thermal radiation source. Similar ignition response measurements were made with untreated specimens which had been exposed to ionizing radiation. Alpha-cellulose samples containing a mixture of boric acid, borax, and ammonium di-hydrogen phosphate could not be ignited by irradiances up to 4.0 cal cm^{-2} sec^{-1}. Above this value, transient ignition only would occur. Cotton cloth containing a polymeric retardant with the designation THPC + MM was found to be ignition resistant below an irradiance of 7.0 cal cm^{-2} sec^{-1}. It was also found that gamma radiation results in ignition retardance of cellulose, while neutron doses up to 2×10^7R do not.

It was concluded that, as a rule, good flame retardants are good radiant ignition inhibitors. The extension of these results and the interpretation of the extended results in terms of their fire protection of interior household furnishings against the thermal radiation pulses from nuclear detonations is the subject of this report. In terms of the three phases of work mentioned above in the scope of work, the present report deals with work under the first and second phases.

The ignition responses of fire retardant treated black cotton and black rayon cloths to the simulated thermal pulses from nuclear weapons were investigated. The treatments applied to the cloth included (1) several treatments recommended by the Department of Agriculture for application by the home owner, (2) a durable fire retardant treatment which was administered by the Southern Regional Laboratory of the Department of Agriculture, (3) B.B.P., a solution of borax, boric acid, and ammonium di-hydrogen phosphate, a treatment found to be most effective in the previous work,[2] and (4) exposure to gamma radiation.

Several large area treated and untreated black cotton fabrics simulating household draperies were exposed to a 4 x 4 ft. tungsten lamp bank to examine (1) the effect of size on ignition response, (2) the mechanical integrity of the thermally irradiated cloth, and (3) the efficiency of the ignited material in propogating fires to other combustibles.

The range at which ignition will occur for untreated black cotton and black rayon fabrics is plotted against yield in Figures 1 and 2 along with the 2.3 psi line, the 3 psi line, and the 5 psi line. Some secondary fires caused by flying debris were observed at Hiroshima and Nagasaki at the 2.3 psi level.[3] Wood frame buildings would be completely destroyed by blast at 5 psi resulting in a large number of secondary fires. The goal of thermal hardening is to severely reduce the number of significant primary fires set by the nuclear weapon thermal pulse outside of the 5 psi blast line. Of course any significant decrease in the range of the primary fires would be of benefit.

II. EXPERIMENTAL PROCEDURE

The source of thermal radiation used for the simulated thermal pulse from a nuclear weapon was the Mitchell background projector[3] shown in Figure 3. This source consists of a high current carbon arc mechanism in conjunction with a relay condenser optical system with beam attenuators and shuttering devices for producing a square wave exposure and a simulated nuclear weapon pulse. The mechanism employs a 16 mm high current, cored carbon, fed through a cast-silver water-cooled head. Figure 4 shows a schematic of the optical system of the Mitchell source showing the location and special relationship of the lenses and shutters with the arc and the specimen plane. An automatic, air-driven, water-cooled shutter, called a "dowser", located between the arc and the first element of the optical system, protects the lenses and shutter blades from the arc radiation between exposures. When the dowser is opened the radiant energy from the arc is collected by a two-element quartz-lens, condenser unit, focused in the plane of the weapon-pulse shutter and refocused in the sample plane by a borosilicate, relay lens. An irradiance of 10.1 cal cm^{-2} sec^{-1} is obtained over a spot diameter of 4.6 cm. The location of the relay lens can be changed to produce an irradiance of 18.9 cal cm^{-2} sec^{-1} over a spot diameter of 2.3 cm. The variation in irradiance across the spot is less than ± 5%. Also the variation in irradiance with time due to fluxuations in the burning of the carbon amounts to less than ± 5%.

The simulated-weapon-pulse shutter, located in the exposure plane of the condenser lenses, consists of two synchronized, rotating, aluminum disks, cut eccentrically in order to attenuate the beam in such a manner as to provide a pulse shape which closely approximates the irradiance versus time characteristics of the thermal radiation in the second or main thermal pulse from a nuclear detonation. The relative irradiance versus time curve generated by the rotating disk shutter is shown in Figure 5. The total time of the exposure is equal to ten times the time of peak irradiance.

Pulse durations for weapons of different yields from 300 KT to 100 MT can be duplicated simply by changing the speed of rotation of the disks. The distance from a simulated nuclear detonation, which governs the intensity of the thermal radiation reaching the specimens, can be varied by insertion of any one of a series of specially-prepared, etched-glass attenuater plates between the disks and the specimen plane.

Martin and Holton[4] give the equation $t_{max} = 0.82\ W^{0.42}\ e^{-0.09h}$ seconds for the time to maximum intensity where the yield, W, is in megatons, and the altitude of burst, h, is in statute miles. From the Effects of Nuclear Weapons[5] the height of burst required to maximize the horizontal range of any particular peak overpressure can be determined as well as the ranges of any peak overpressure for any given height of burst.

Air bursts near the surface and bursts at altitudes which maximize the 15 psi blast overpressure range are both considered in this report. Table I gives the pertinent relationships between yield, height of burst, time to maximum irradiance, pulse duration, and the ranges of the 2.3 psi, 3 psi, and 5 psi blast overpressure ranges. Figure 6 shows a plot of the yield versus time to maximum irradiance for near sea level bursts and bursts at the altitude which maximizes the 15 psi range. This curve is plotted from the data in Table I and was used to determine the yields corresponding to the experimental pulse times which were controlled by the speed of the rotating disk shutter.

Dividing the total radiated power of the fireball by its surface area and assuming black body radiation, the surface temperature is given by $T_s = 6800W^{-0.03}$ °K.[6] For a 10 MT bomb the temperature would be 6350°K. The spectral distribution of energy from the cored carbon arc peaks around 4700Å which corresponds to a black body temperature of 6200°K. In spite of the fact that neither the arc nor the nuclear fireball radiate strictly as a black body their spectral distributions are similar enough for these ignition tests.

Figure 7 shows a generalized plot of radiant exposures divided by weapon yield versus range.[7] The data points are for nuclear air bursts in Nevada and in the Pacific. The straight line relationship displayed on the graph can be represented by the equation $Q = 710\ WD^{-2.16}$ where Q is the radiant exposure in cal cm^{-2}, W is the yield in megatons and D is the range in statute miles.

Integration of the irradiance versus time curve in Figure 5 shows that the radiant exposure in the sample plane is given by $Q = 0.154\ H_M t_M$ where H_M is the maximum irradiance and t_M is the time to maximum intensity. Using an attenuater of transmission T the maximum irradiance is given by $H_M = H_0 T$ where H_0 is the maximum irradiance with no attenuation. Equating the exposure received in the field due to a real nuclear detonation with that obtained in the laboratory we have $Q = 0.154\ H_M\ t_M = 710\ WD^{-2.16}$. We find that the simulated distance from a nuclear weapon is given by $D = \left(\frac{710\ W}{0.154\ H_0 T\ t_m}\right)^{0.463}$.

The maximum irradiance, H_0, was determined with an NRDL water-cooled radiometer[8] which had been calibrated against a standard tungsten iodine lamp.

The cloths used in the present study were black cotton duck, black rayon, and green cotton herringbone twill. They had weights of 10 oz, 7-1/2 oz, and 9 oz per square yard, respectively.

The fire retardant treatments listed in the U. S. Department of Agriculture leaflet No. 454 (available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402) and B.B.P., a treatment developed in the earlier part of this program, were used on the black cotton and rayon cloth. The compositions of these retardants are given in Table II along with the percent add on weight given to the fabric. A sample of black cotton also received a gamma ray dose of 7.5×10^7 R. The green cotton herringbone twill had been given a 24.4% add on weight from a durable treatment of THPC-Methylolmelamine by the Southern Regional Research Laboratory. Thermogravimetric analyses and differential thermal analyses have been run on this material by that laboratory.[9]

Cloth swatches (30 in. x 36 in.) were washed and dried in the NRDL laundry. The swatches were allowed to equilibrate to the moisture content of the air and were then weighed. The cloth swatches were immersed and agitated in the respective retardant solution, after which the excess solution was wrung out by hand. The wet samples were dried and allowed to equilibrate to the moisture content of the air. The swatches were then weighed and the retardant load calculated. A 10% load was considered to be optimum and some swatches had to be treated more than once to obtain this loading. The rayon did not gain much load in its second treatment. Samples of the treated cloth (3 in. x 5 in.) were placed in the sample holder and exposed to the simulated weapon thermal pulse. If the sample ignited, the type of ignition, either flaming or glowing and sustained or transient, was noted.

The effect of sample size was studied using a large area source[10] (4 ft. x 4 ft.) consisting of quartz line tungsten lamps with a total power of 192 kilowatts. A sliding asbestos curtain was employed as a shutter for all the tests except those where the sample was six inches from the lamp bank. In the latter case, the source was turned on and off for shuttering. To obtain irradiance values of 1, 2, and 3 cal cm^{-2} sec^{-1} the distances of the cloth samples from the large area were 30 in., 15 in., and 6 in., respectively. Only washed black cotton cloth untreated and treated with fire retardant type A was used in these large area tests.

III. RESULTS AND DISCUSSION

The ignition characteristics of the black cotton control cloth exposed to the simulated weapon thermal pulse are shown in Figure 8. The ordinate is the peak irradiance on the cloth and the abscissa is the total pulse time (10 times the time to peak irradiance). The experimental points indicate whether the exposure resulted in flaming ignition, glowing ignition, or no ignition at all. The curves represent the boundaries between these three ignition regimes. All ignitions were sustained in the case of the control samples. For all the fire retardant treated specimens, the ignition, if it occurred, was always transient.

The results from a 11% load of type A flame retardant on black cotton cloth are shown in Figure 8. The dashed curves in this and the following figures represent the upper and lower limits of the glowing ignition regime for the control cloth. The effect of the retardant is to increase the threshold irradiance for flaming ignition, but to decrease the threshold irradiance for glowing ignition. This behavior is typical of the other flame retardant treated cotton samples as evidenced by Figure 8, and which show the effects of a 9.3% load of type B, a 10% load of type D, a 10% load of B.B.P., and a 24% load of THPC + MM.

The ignition response of the black rayon control cloth to the simulated weapon thermal pulse is shown in Figure 8. When a 7-1/2% load of type C flame retardant was used on black rayon, there was a very large increase in threshold irradiance for flaming ignition as seen in Figure 8 and glowing ignition was eliminated altogether. The flaming ignition was transient.

When black cotton cloth was exposed to 7.5×10^7 rad of gamma radiation from a Co^{60} source, no change of ignition response to the simulated weapon thermal pulse was noted. This was different than the result on gamma irradiated black alpha cellulose where a small decrease in response was noted.

The effectiveness of the various retardant treatments in reducing the range of flaming ignition is shown in Figure 1, where the minimum ranges in miles for glowing and flaming ignition are drawn as a function of weapon yield for burst altitudes at which the range of the 15 psi blast overpressure is maximized. The hatched bands show the decrease in range of flaming ignition and the increase in range of glowing ignition when the retardants are added to the cloth.

The 2.3 psi, 3 psi, and 5 psi blast overpressure ranges are also shown in the graphs. The ranges of glowing and flaming ignition for near surface bursts are shown in Figure 2. Since black cloth was used throughout the tests, the ignition threshold ranges represent maximum values. The exception to this was the green cotton cloth treated with the durable retardant, THPC+methylolmelamine, by the Southern Regional Laboratory. The ranges for light colored fabrics would be appreciably smaller.

These graphs show that the retardants as normally applied will not restrict the range of flaming ignition to the range of severe blast damage and will actually increase the range of susceptibility to glowing ignition in the case of the home treated cotton fabrics. However, the mode of ignition is changed in all cases by the treatment, from sustained to transient ignition.

The sample area which could be tested with the simulated weapon thermal pulse was restricted to a circle 4.6 cm in diameter. The effect of sample size on the ignition characteristics was investigated next. Large black cotton samples with and without type A flame retardant were exposed to the thermal radiation from the 4 ft. x 4 ft. tungsten lamp bank source. The significant effect of size on the retardant treated sample was to change the mode of ignition from transient glowing to transient flaming as the vertical dimension of specimen was increased from 4 in. to 26 in. for an irradiance of 3 cal cm^{-2} sec^{-1}. The time for flaming ignition in the long sample was the same as for glowing ignition in the smaller specimen. Evidently the gases which are distilled out of the lower portions of the cloth enrich the mixture near the top as they flow upward, and this mixture is ignited by the onset of glowing. This flame does not last long nor does it couple much energy back to the surface. The charred samples which had undergone transient flaming ignition under these circumstances were not distinguishable from those that charred but did not flame because of their shorter length.

The effectiveness of the transient flaming and glowing of these fabrics in the spread of fire to other combustible materials coming in contact with them was considered next. A 30 in. by 36 in. sample of untreated cotton cloth which was exposed to 3 cal cm^{-2} sec^{-1} from the large area source experienced sustained flaming ignition at 3 seconds. Then it was immediately dropped onto a newspaper on the floor, and the paper was rapidly consumed by flaming. A similar sized sample of cotton cloth with a 14% load of type A flame retardant was exposed to the same irradiance. It underwent transient flaming ignition at 8 seconds, then rapidly changed from the flaming to the glowing mode of combustion. The glowing cloth was then dropped onto a newspaper on the floor. Although glowing continued for a few seconds because of heat trapped by the folds of the cloth, it soon died out and the newspaper was barely scorched. A similar treated sample was hung as pleated drapes in front of the lamp bank. With an irradiance of 3 cal cm^{-2} sec^{-1} it suffered transient flaming ignition at 9 seconds then rapidly changed to transient glowing combustion. The glowing cloth was dropped onto a cotton covered innerspring cushion from a club chair. The glowing persisted for several seconds but did not even scorch the cushion fabric.

Whereas the untreated cloth burned to a light weight ash, the treated cloth formed a brittle char after combustion was finished. This char was capable of supporting an appreciable amount of weight. The next question was whether retardant treated drapes might not remain in place throughout their burning phase and thus provide effective thermal radiation shielding of the other internal household furnishings. By attaching weights to the cloth samples and exposing the cloth to the 21 second simulated weapon thermal pulse at 10 cal cm^{-2} sec^{-1}, it was found that types A and B.B.P. treated cotton cloths would support 30 lbs per yard width of the cloth, the type B treated cotton cloth would support 15 lbs, the durable retardant, THPC+MM, treated cotton cloth would support 10 lbs, and the type D treated cotton cloth would support 5 lbs. The rayon cloth treated with type C retardant would support 3 lbs per yard width. The untreated cotton and rayon control cloths would support less than 0.2 lbs per yard width. In all cases the cloth samples underwent flaming ignition. Since glowing combustion in the treated samples depends on the presence of the external thermal radiation, the degree of combustion of the char, and thus the strength of the residual char after combustion, depends on the duration of the thermal pulse. The 21 second total duration pulse is longer than that of a 100 MT detonation at the optimum altitude for maximizing the 15 psi line but is somewhat shorter than the thermal pulse from a 10 MT weapon near surface burst detonated near sea level.

Since the weights of the cloths were about 10 oz per yard, a six foot drapery treated with any of the retardants reported on here would be able to support its own weight after being ignited by the thermal pulse and thus act as an effective thermal radiation shield. The fact that the fire retardant treated materials tend to stay in place during combustion further reduces their potential for fire initiation.

This ability to block the thermal radiation is demonstrated in Figure 9 which shows the output of a radiometer located one inch behind the sample exposure plane. Curve A shows the radiation output with no sample in the holder. Curves B and C show the output with two different untreated samples in place. Curve D which is indistinguishable from the base line shows the output with a type A treated cotton sample in place. The treated sample underwent transient flaming ignition forming the char which blocked thermal radiation.

Finally, the fire propagation to other combustible materials during the thermal pulse was considered by placing test strips of newspaper at different distances behind the irradiated specimen. At 3/4 inches back of the treated sample, the newspaper was ignited by flame contact. Beyond this distance, the newspaper was not affected. The transmitted thermal radiation through the flaming untreated materials would ignite the newspaper over considerably greater distances.

The greatest ignition protection for both flaming and glowing ignition was demonstrated by the type D retardant. However, treatment with type D slightly reduces the strength of the material, and its char strength is considerably less than that of a material treated with type A. In view of its adequate ignition protection and its relatively small effect on the other material property, type A is the best retardant to use for cotton. Type C is recommended in the Department of Agriculture Pamphlet, referred to above, for use on rayon and resin-treated cotton even though it tends to weaken the material when stored over long periods of time.

IV. CONCLUSIONS

The presently recommended flame retardants significantly reduce the range of primary flaming ignitions caused by the weapon thermal pulse. For a 100 MT weapon the area of a city subjected to primary flaming ignitions in fabrics can be reduced as much as 50% by treating them with flame retardants. The range of flaming ignition still, however, extends well beyond the 5 psi overpressure range within which the severe blast damage occurs.

One of the chief virtues of the treatments is that they change the mode of ignition from sustained to transient. A brief investigation of the treated materials which have undergone transient ignition indicates that after the completion of the thermal pulse, they leave a residue which is strong enough to support its own weight. Cotton and rayon draperies which have been given the recommended treatments will remain in place throughout the thermal pulse and thus effectively shield the interior of the room from the thermal radiation. The treated materials can spread fire by flame contact to other combustible materials within about three fourths of an inch during the period of transient flaming, which is less than that of the thermal pulse. If the flame has not died out earlier, it ceases abruptly at the conclusion of the thermal pulse. Glowing then persists for a few seconds but is ineffective in propagating fire to other combustible materials even in contact.

The type A retardant is recommended for use on cotton, and the type C is recommended for use on rayon.

REFERENCES

1. N. J. Alvares and T. H. Anderson, "Ignition Hardening of Cellulosic Materials," USNRDL-TR-67-125, 10 August 1967.

2. J. McAuliffe and K. Moll, "Secondary Ignitions in Nuclear Attack," Stanford Research Institute, Final Report, OCD Work Unit, 2534A, July 1965.

3. S. B. Martin and N. J. Alvares, "Ignition Thresholds for Large-Yield Nuclear Weapons," USNRDL-TR-1007, 11 April 1966.

4. S. B. Martin and S. Holton, "Preliminary Computer Program for Estimating Primary Ignition Ranges for Nuclear Weapons," USNRDL-TR-866, 3 June 1965.

5. S. Glasstone, "The Effects of Nuclear Weapons," U. S. Government Printing Office P. 139, 1962 Revised Edition.

6. R. H. Renner, S. B. Martin, and R. E. Jones, "Parameters Governing Urban Vulnerability to Fire from Nuclear Bursts (Phase I)," USNRDL-TR-1040, 30 June 1966.

7. Private communication from Ruth W. Shnider, U. S. Naval Radiological Defense Laboratory, San Francisco, California.

8. R. J. Jenkins, "Calorimeters and Radiometers for the Measurement of Large Thermal Irradiances," USNRDL-TR-839, 6 April 1965.

9. R. M. Perkins, G. L. Drake, and W. A. Reeves, Journal of Applied Polymer Science, Volume 10, PP 1041-1066 (1966).

10. N. J. Alvares, L. L. Wiltshire, "Ignition and Fire Spread in a Thermal Radiation Field," USNRDL-TR-68-56, 7 May 1968.

TABLE I

PULSE TIMES AND OVERPRESSURE RANGES FOR VARIOUS YIELDS

Weapon Yield (MT)	Height of Burst (ft)	Time to Max[2] (sec)	Pulse Duration (sec)	2.3 psi Range[3] (mi)	3 psi Range[3] (mi)	5 psi Range[3] (mi)
1	0	0.82	8.2	4.5	3.7	2.9
1	6,500[1]	0.73	7.3	6.2	5.3	4.2
5	0	1.6	16.	7.7	6.3	4.9
5	11,000[1]	1.3	13.	11.	9.	7.
10	0	2.2	22.	9.8	7.9	6.3
10	14,000[1]	1.7	17.	13.	11.	8.9
25	0	3.2	32.	13.	11.	8.5
25	19,000[1]	2.3	23.	17.	14.	11.
100	0	5.7	57.	21.	17.	14.
100	30,000[1]	3.4	34.	29.	24.	19.

[1]Height required to maximize the 15 psi blast overpressure range.

[2]Based on equation $t_{max} = 0.82\ W^{0.42}\ e^{-0.09h}$ where W is the yield in megatons and h is the height of burst in statute miles.

[3]From reference 5 (pages 135 and 139).

TABLE II

FORMULAS FOR RETARDANT TREATMENTS

Chemicals	A	B	C	D	B.B.P.
Borax	7 oz	6 oz	-	-	3 oz
Boric Acid	3 oz	-	-	-	1.5 oz
Diammonium Phosphate	-	6 oz	12 oz	-	-
Ammonium Sulfate	-	-	-	13 oz	-
Ammonium (mono) Phosphate	-	-	-	-	5 oz
Household Ammonia	-	-	-	Trace	-
Wetting Agent	Trace	Trace	Trace	Trace	Trace
Water	2 qt	2 qt	2 qt	2 qt	2 qt
Percent Add On	11	9.3	7.5	13.2	10

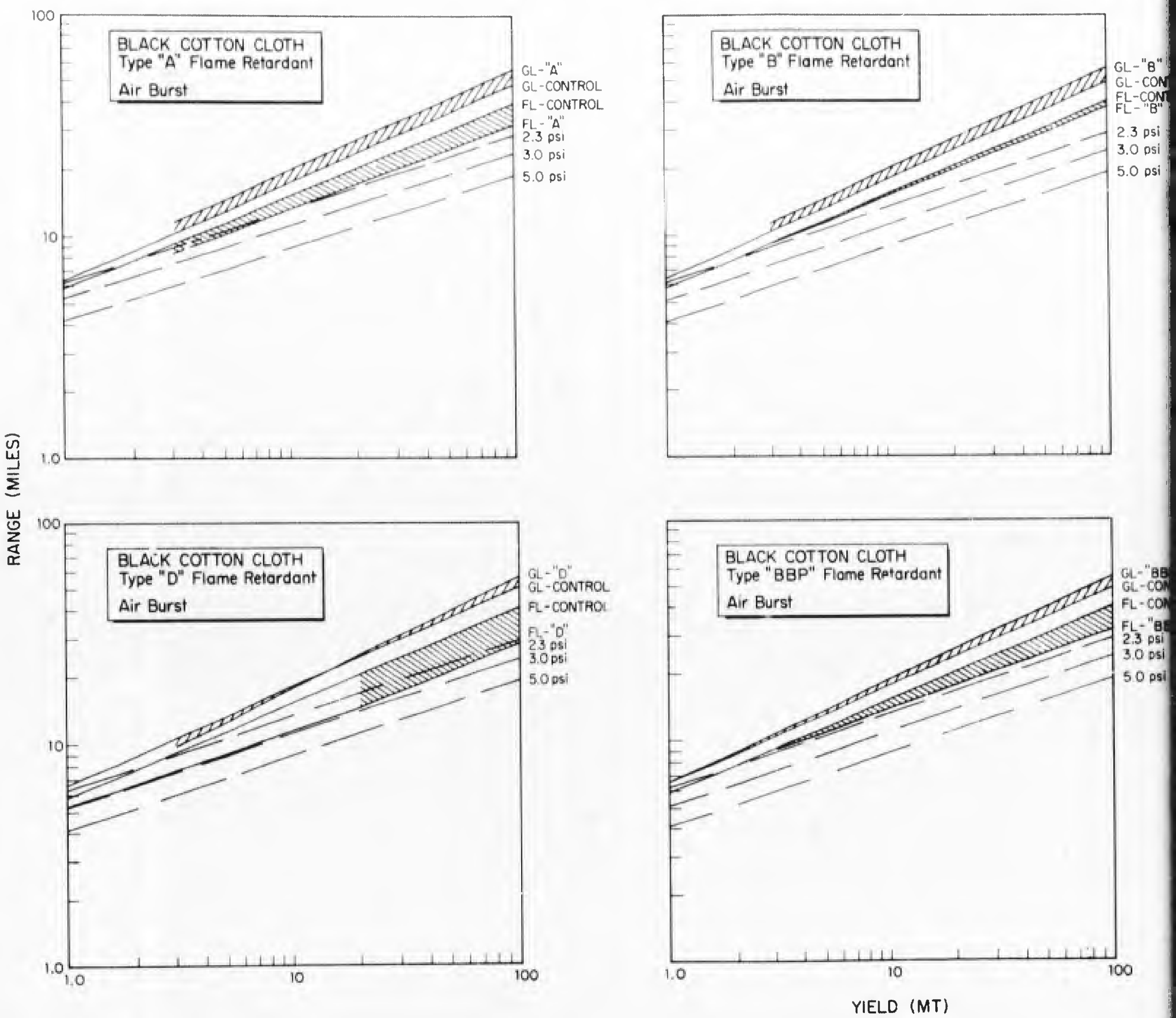
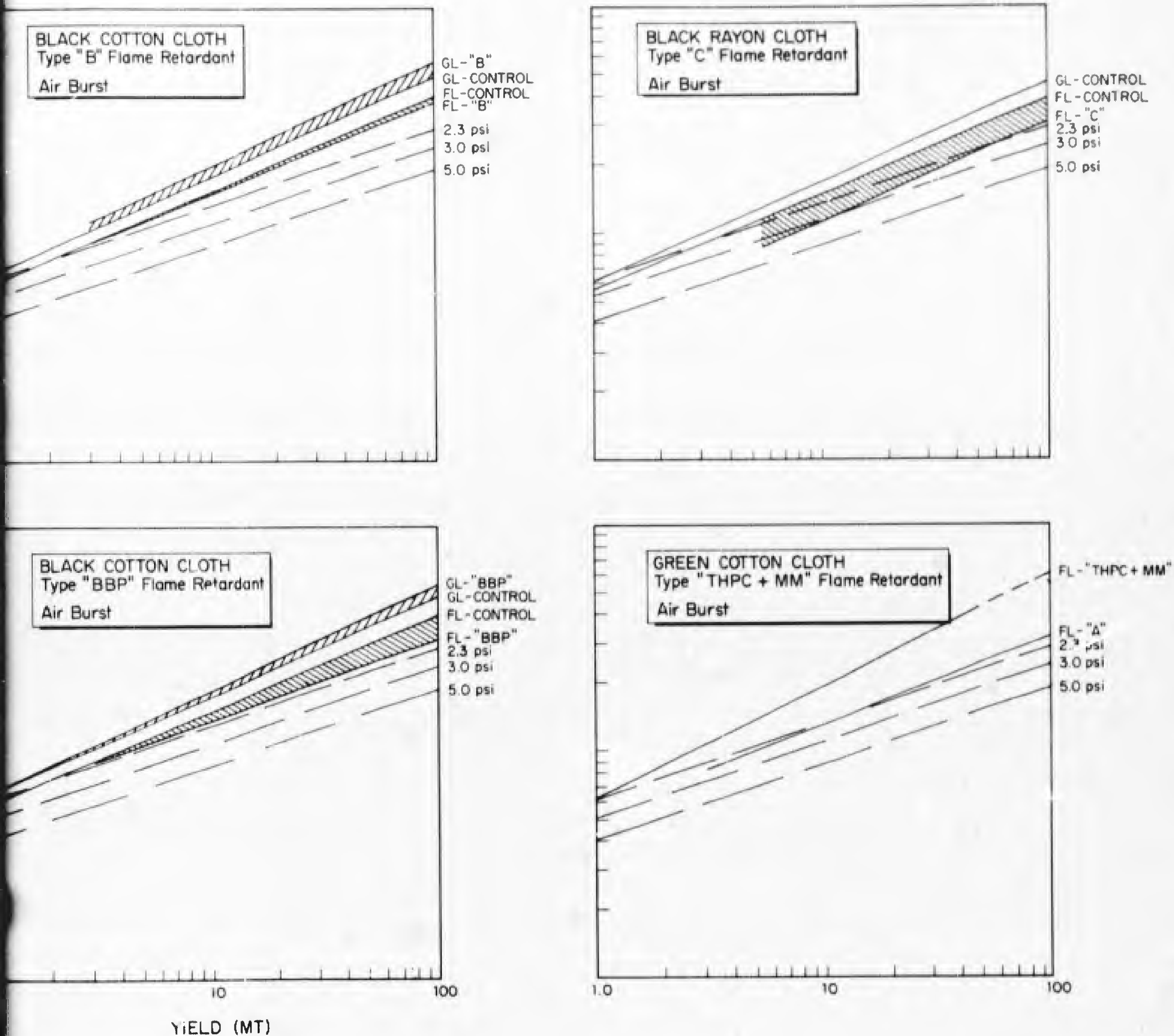


Fig. 1 Ignition Ranges of Retardant Treated Cloth for Height of Burst to Maximize

A



d Cloth for Height of Burst to Maximize the 15-psi Range

B

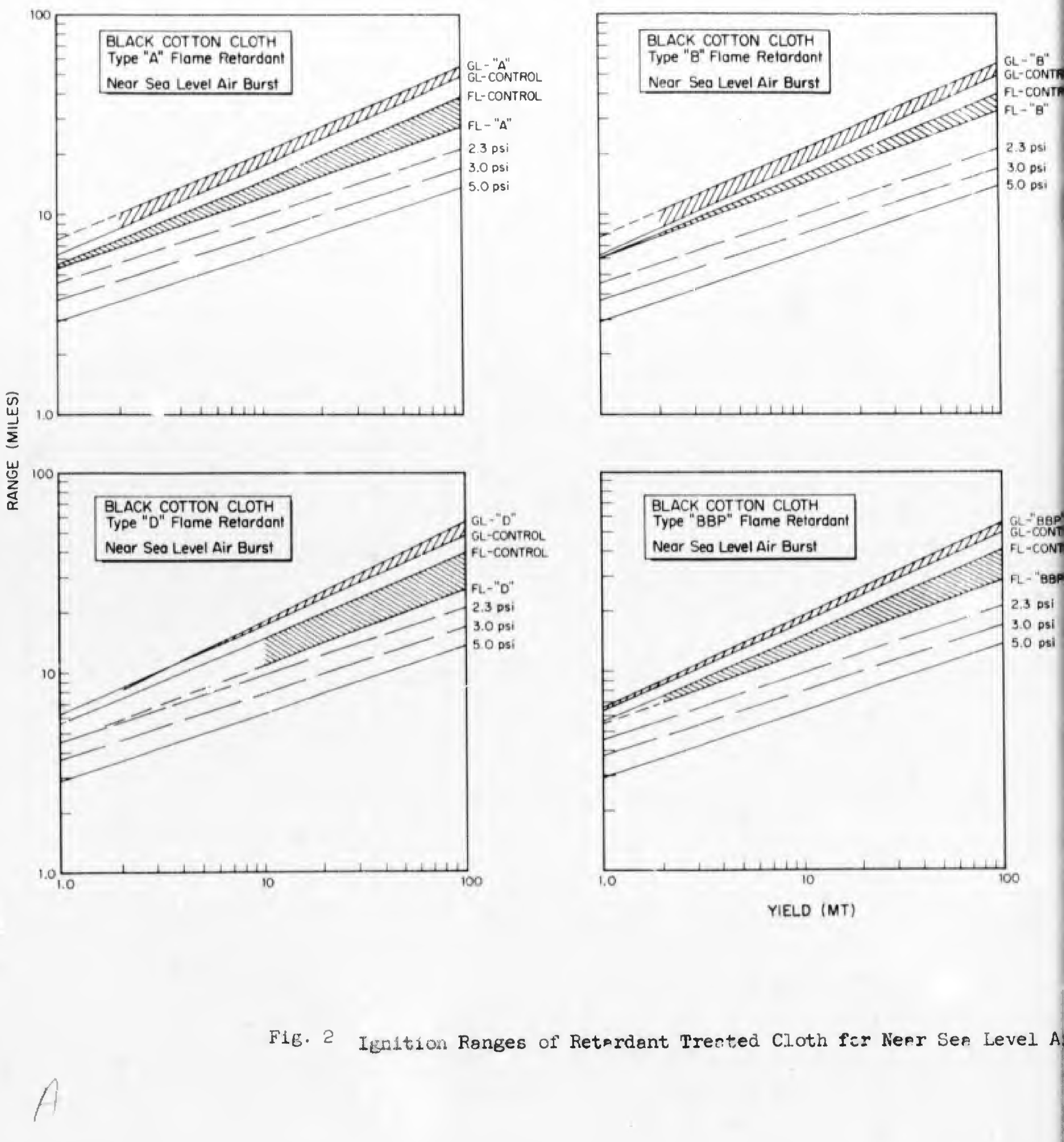
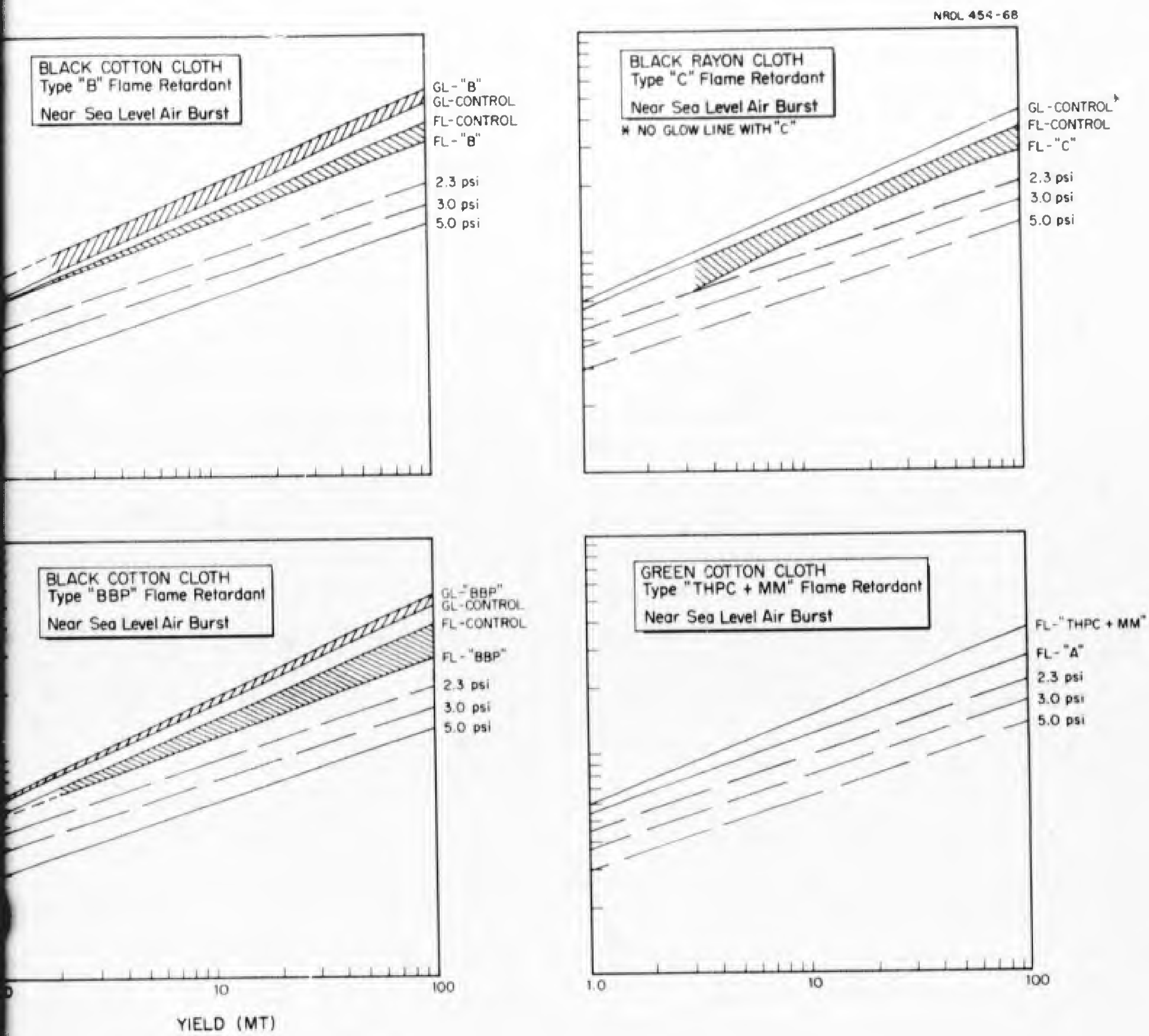


Fig. 2 Ignition Ranges of Retardant Treated Cloth for Near Sea Level A

A



rdant Treated Cloth for Near Sea Level Air Bursts

B

BLANK PAGE

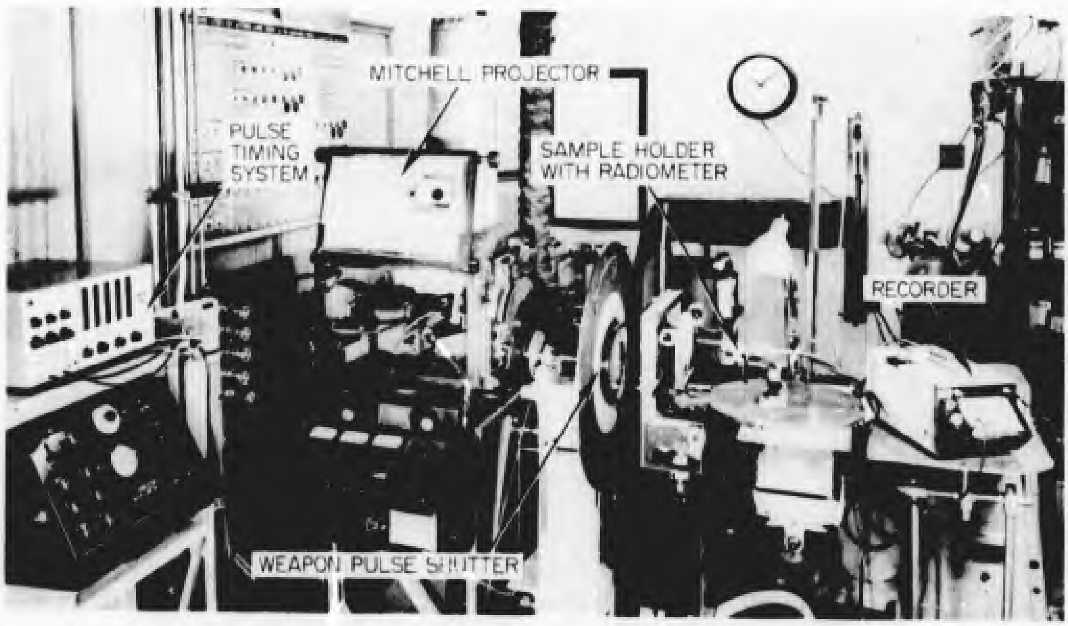


Fig. 3 Photograph of Experimental Arrangement

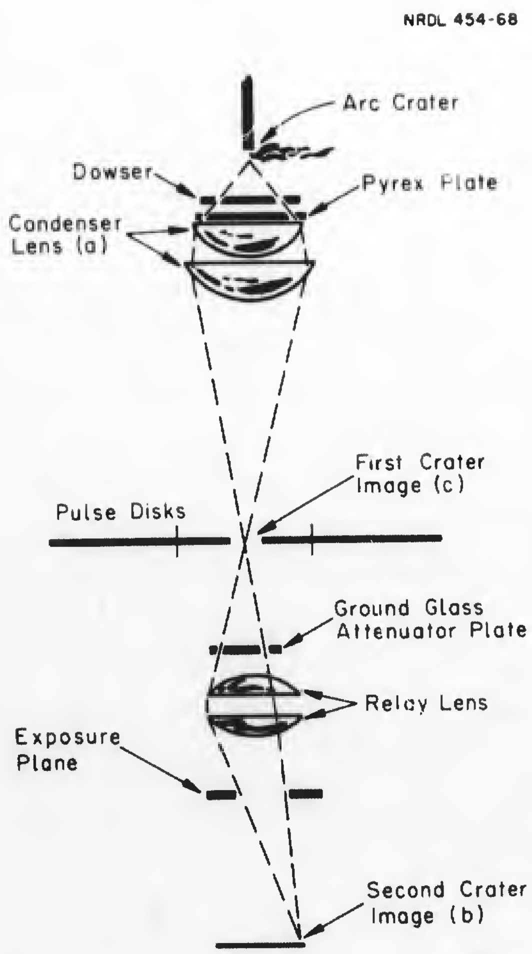


Fig. 4 Radiation Source Optical System

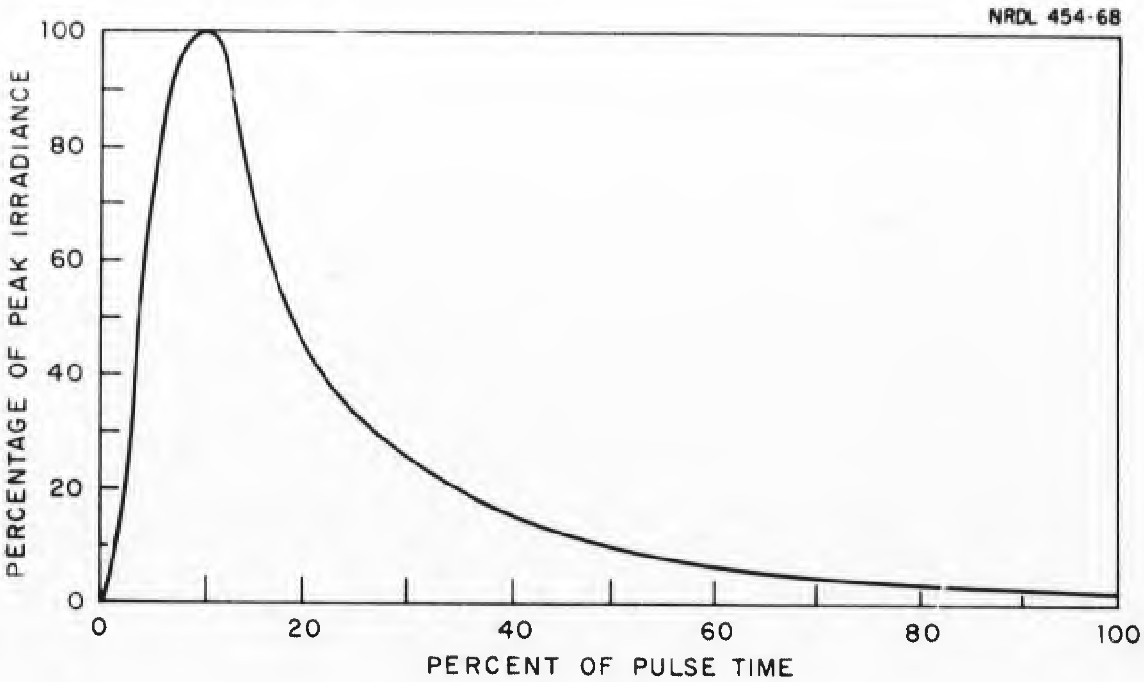


Fig. 5 Irradiance versus Time Curve Generated by Rotating Disk Shutter

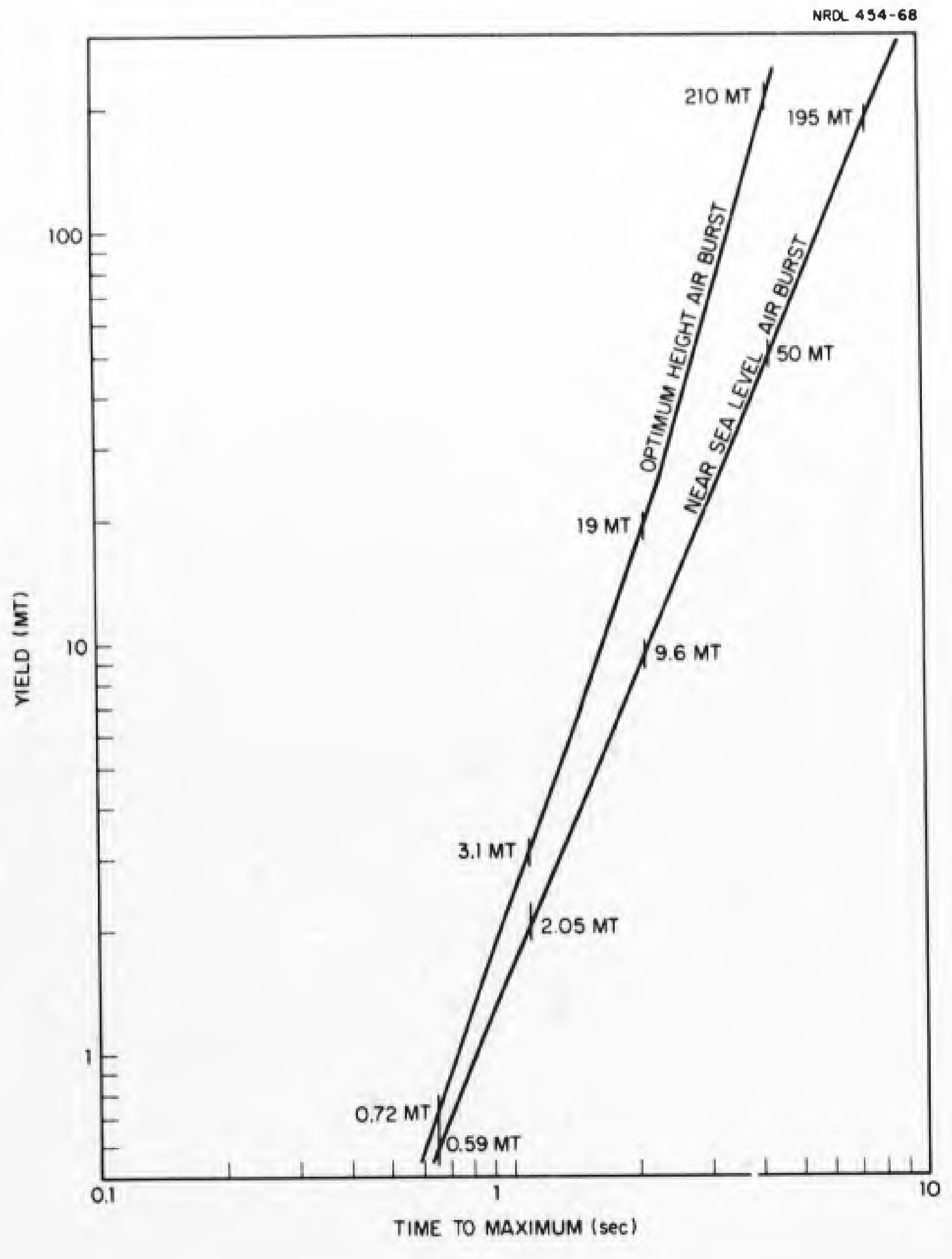


Fig. 6 Weapon Yield versus Time to Maximum Irradiance

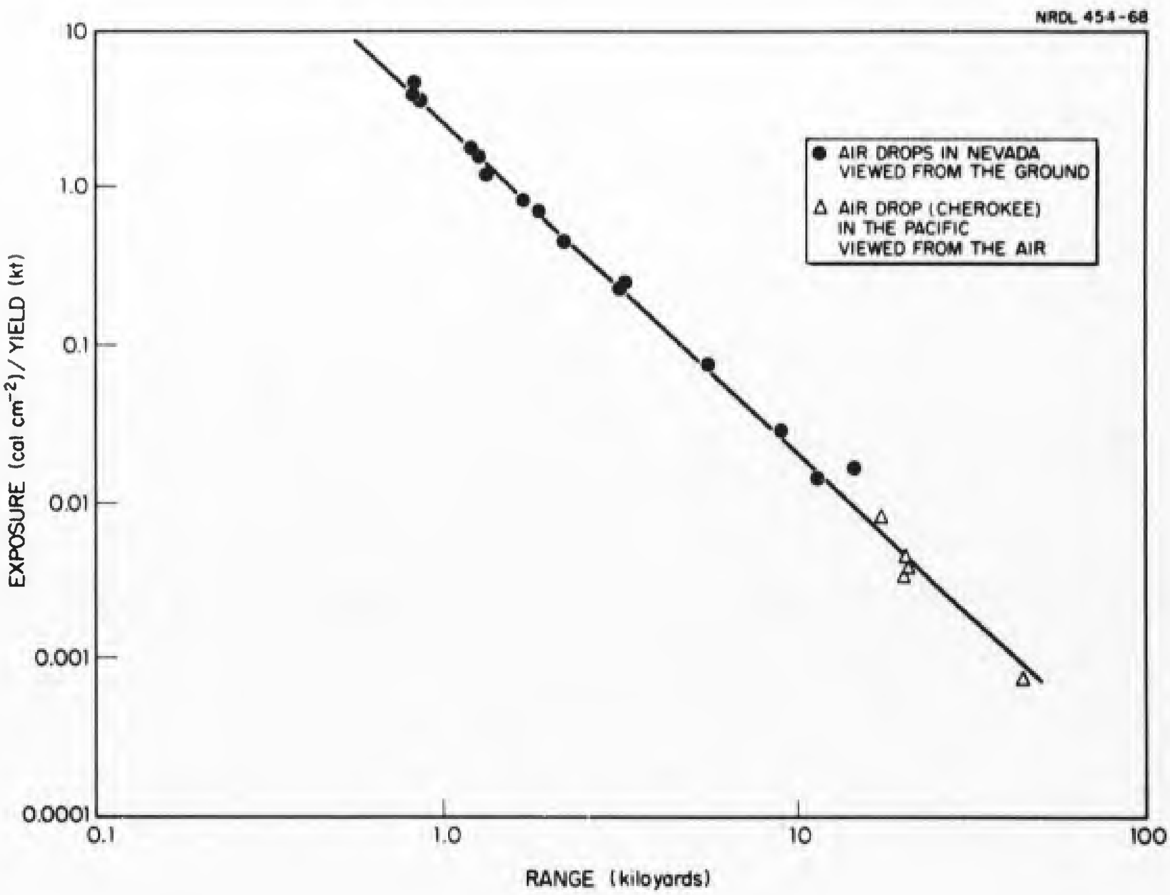


Fig. 7 Generalized Plot of Exposure versus Distance

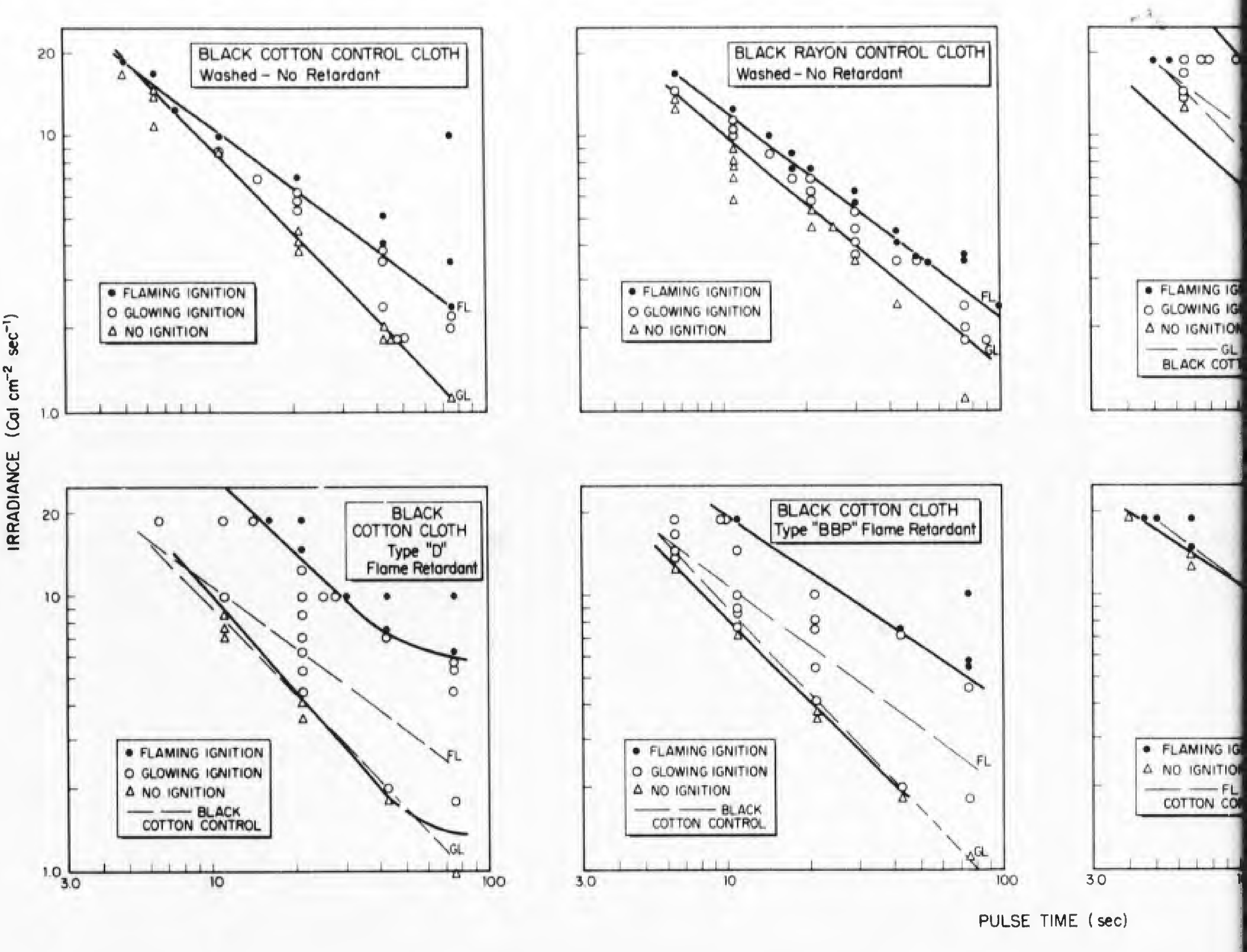
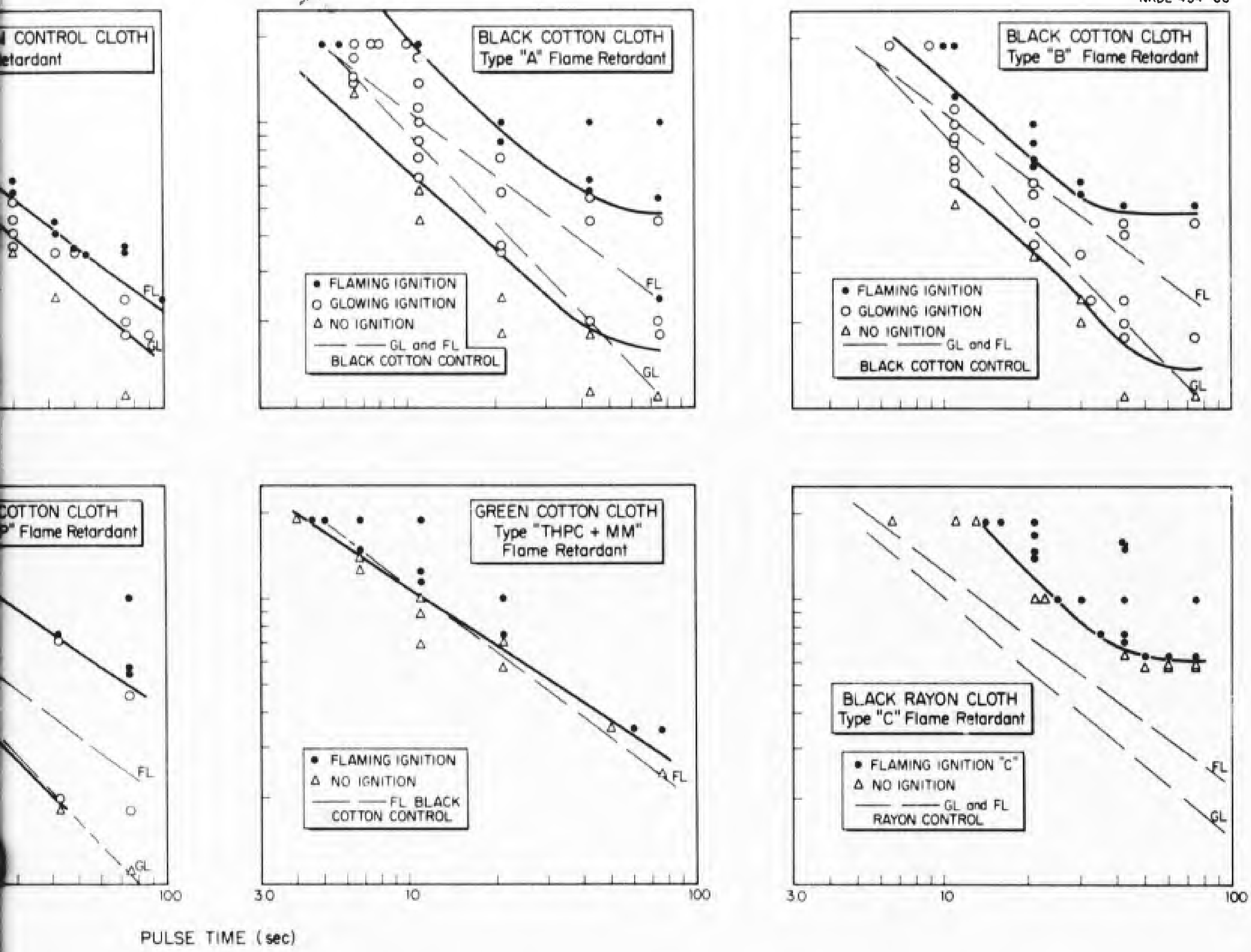


Fig. 8 Ignition Characteristics of Treated and Untreated Black Cotto

A



reated and Untreated Black Cotton and Black Rayon Cloths

B

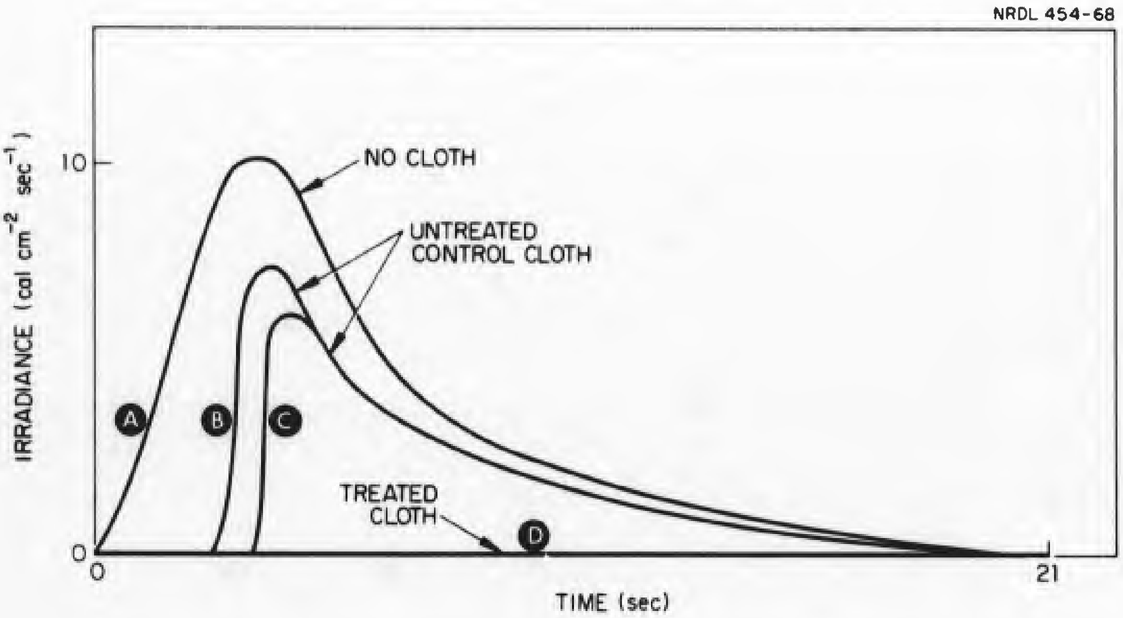


Fig. 9 Effect of Treated and Untreated Cloth in Shielding from the Thermal Pulse

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Naval Radiological Defense Laboratory San Francisco, California 94135	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

IGNITION OF RETARDANT TREATED CLOTH BY NUCLEAR WEAPON THERMAL PULSES

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

Lyman L. Wiltshire
William J. Parker

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
(Distribution) 10 February 1969	35	10

8a. CONTRACT OR GRANT NO. b. PROJECT NO. OCD, Work Unit 2542A c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NRDL-TR-68-139 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Office of Civil Defense Washington, D. C. 20310

13. ABSTRACT

The ignition responses of fire retardant treated black cotton cloth and black rayon cloth to the simulated thermal pulses from nuclear weapons were investigated. The temporal and spectral characteristics of the main thermal pulse from air bursts ranging from 300 KT to 100 MT were reproduced using a cored carbon arc along with a specially shaped rotating disk shutter. The treatments applied to the cloths were a combination of borax, boric acid, ammonium phosphate, diammonium phosphate, and ammonium sulfate which were recommended for home administered treatment of fabrics by the Department of Agriculture.

The data are presented as graphs of ignition distances versus weapon yield for fire retardant treated and untreated cloths. While the range of flaming ignition is significantly reduced by these treatments, flaming ignition would still occur well beyond the 5 psi blast overpressure range. The largest reduction in the area over which flaming ignitions would occur with the fire retardants tested amounts to about 50% over that of the untreated cloth.

The effect of the retardants on the glowing ignition of the cloth varied from no effect to a somewhat greater susceptibility to glowing in the case of cotton. However, for rayon, the recommended treatment eliminated glowing ignition altogether.

Both glowing and flaming ignition were transient in the case of the treated fabrics. Flaming and glowing died out rapidly after the conclusion of the thermal pulse.

Some large area treated and untreated black cotton fabrics simulating household draperies were exposed to a 4 x 4 ft. tungsten lamp bank. Under some circumstances (Abstract continued on another page.)

UNCLASSIFIED
Security Classification

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

2a. REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

IGNITION OF RETARDANT TREATED CLOTH BY NUCLEAR WEAPON THERMAL PULSES

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*

Lyman L. Wiltshire
William J. Parker

6. REPORT DATE

7a. TOTAL NO. OF PAGES

7b. NO. OF REFS

8a. CONTRACT OR GRANT NO.

b. PROJECT NO.

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

NRDL-TR-68-139

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

(Abstract continued from another page)

the mode of ignition of the large area treated fabrics was changed from transient glowing to transient flaming because of increased concentration of distilled gases near the upper part of the specimen.

The effectiveness of the transient flaming and glowing ignition of these fabrics in the spread of fire to other combustible materials coming in contact with them was tested and found to be very low. Fire retardants formed an increased amount of char in the burned material which allowed it to support its own weight and become a thermal radiation shield.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Ignition						
Flame retardants						
Nuclear weapons						
Thermal pulse						
Fire						

DD FORM 1 NOV 65 1473 (BACK)
(PAGE 2)