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THE SUB-FABRIC FLASH BURN: QUANTITATIVE EFFECT ON PROTECTIVITY
OF FABRIC REFLECTANCE, FABRIC WEIGHT AND EXPOSURE TIME

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THE SUB-FABRIC FLASH BURN: QUANTITATIVE EFFECT ON PROTECTIVITY
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ABSTRACT

Cotton sateens impregnated with carboxymethyl-cellulose and varying quantities of carbon black were used in a systematic study of burn production as a function of reflectance and of fabric weight in relation to exposure time. A modified carbon arc provided the source of thermal energy; anesthetized white pigs were used as indicators. Reflectances and weights of the fabrics were determined in this laboratory. Exposure-response tables and probit analyses are presented to show the empiric dependence of protectivity upon these three parameters. Within limits, the protective index of these fabrics in contact with skin may be expressed by

$$\frac{2+EE_{50} \text{ under fabric}}{2+EE_{50} \text{ bare skin}} = P. I. = \frac{.42 + .056 d t^{-.41}}{1 - R}$$

Where d = surface density (oz/yd²)

t = exposure time

R = reflectance

Separation of fabric by 0.5 cm from skin increases the protective index from two to four times this value.

NOTE: This study was carried out through the facilities of the University of Rochester Atomic Energy Project, under contract with the U. S. Atomic Energy Commission, and a portion of its expenses defrayed under grant from the Quartermaster Corps, U. S. Army.

INTRODUCTION

Since the bombing of Hiroshima, it has been noted that light colored fabrics give more skin protection from atomic thermal energy sources than dark ones, and thicker fabrics more protection than thin ones (1, 2, 3). The influence of exposure time upon the burn sustained from a given quantity of radiant energy has been amply shown for bare skin (4, 5) and for fabric-covered skin (6, 7, 8). The present report covers a number of experiments designed to quantitate, within limits, the effects of the three parameters - reflectance, fabric weight, and exposure time - on the protection afforded to "white" skin by cotton fabrics. Wherever possible, explicit mathematical expression will be given to such empirical relationships.

Equipment

A modified 24" Army carbon arc searchlight with ellipsoidal mirror, shutter and diaphragms as previously described (9) was used as the energy source. The relative spectral energy distribution of the source as received at the 1.7 cm circular exposure port has recently been described by Krolak and Davis (10). The maximum energy delivered is approximately $34 \text{ cal/cm}^2/\text{sec}$, (which is some 15% lower than estimates given in earlier papers (up to and including UR-355)).

Chester and Yorkshire white pigs of 10 to 18 kg were anesthetized with Dial-Urethane 70 mg/kg intraperitoneally, closely clipped and gently washed, prior to exposure. Room temperature was maintained at 76-80° F. to minimize cooling of the skin (11).

The fabrics used were especially prepared by the U. S. Army Quartermaster by impregnating cotton sateens with carboxymethyl-cellulose and varying quantities of finely divided carbon black, to give two series of fabrics; one of nearly equal weights, but graded in reflectance from "white" through greys to "black", the other of nearly equal reflectances but varying in weight. These physical characteristics are enumerated in Table 1. The spectral reflectances of these fabrics have been determined by Krolak and Davis (12) and the total reflectance under irradiation from our arc source computed from these data for inclusion in the table. Mean weights are given as determined in our laboratory.

Table 1

Designation	Wt. (oz/yd ²)	Total Reflectance	Sample No. in UR-380
White	8.26	0.746	9
Light Grey	7.85	0.593	8
Med. Grey	8.21	0.274	7
Dark Grey	8.25	0.060	6
Black	9.05	0.035	5
6 oz. per yd.	6.12	0.073	10
8.5" " "	7.51	0.073	11
12 " " "	12.12	0.070	12

All fabrics were conditioned for at least 48 hours in a force-ventilated box kept at a relative humidity of 60%, and were removed only at the time of the actual exposure.

Methods

Seven basic exposure times using a trapezoidal pulse wave were chosen ranging from 0.25 to 20 sec. There were eight fabrics, and it was desired to study the effects both with fabric in contact and separated from skin. A

minimum of four irradiances and twelve replications are needed to obtain statistically sound results. To pursue such a plan fully, with complete randomization, would require 149 animals in addition to at least 20 more for pilot studies. As carried out, the study was broken down into segments, studying two or three fabrics at two to seven different exposure times in each segment. There were 30 to 40 potential exposure areas on each side of a pig; the individual exposures required were randomly assigned to the available positions on each animal and the exposures then made in a regular sequential manner.

Previously prepared squares of fabric were clipped to the back of the water-cooled exposure port and the animal was pressed firmly against it during the exposure. Separation of 5 mm between fabric and skin was obtained by a machined and polished aluminum ring supported by a spring clip (3), between fabric and skin. A mirror supported below and in front of the exposure port facilitated the observation and timing of post-exposure flame and/or glow, when these occurred.

Burns were assessed at 18 - 24 hours after exposure and classified according to the previously described scale from 0 to 5+. No microscopic studies were made, and the severity of burn was deliberately centered about the 2+ mild level, at which a minimal spotty white burn occurred.

RESULTS

1. Fabric in Contact with Skin

The number and degree of burns observed in response to each exposure studied are presented in tabular form in Appendices A, B, and C. Table 2 gives the result of probit analysis of Appendix A, which compares bleached white sateens with and without CMC impregnation. This ancillary study was made necessary by the fact that in the original series of fabrics, the

95% CONFIDENCE LIMITS OF $2+EE_{50}$ 'S (PIGS' SKIN) UNDER 9 OZ. WHITE COTTON SATEENS, WITH (DOTTED LINE), AND WITHOUT (SOLID LINE), CMC IMPREGNATION.

FIG. 1

Table 2

Separation	Exposure Time (sec)	9 oz. White Sateen, Plain		9 oz. White Sateen, CMC	
		2+ EE ₅₀ (cal/cm ²)	95% C. I. (cal/cm ²)	2+ EE ₅₀ (cal/cm ²)	95% C. I. (cal/cm ²)
0	0.5	11.8	10.9-12.8	12.0	11.0-13.0
	1.0	11.0	10.3-11.7	11.3	10.7-11.9
	2.0	11.7	11.1-12.35	11.7	11.05-12.35
	5.0	13.3	12.5-14.2	13.4	12.7-14.15
	10.0	14.5	13.6-15.4	14.4	13.65-15.2
5 mm	1.0	33.1	31.7-34.6	32.7	30.4-35.1
	2.0	27.0	25.8-28.2	28.0	26.8-29.3
	5.0	28.6	27.7-29.5	30.3	29.0-31.7
	10.0	37.8	36.5-40.3	38.0	36.3-39.9

white alone had not been so treated. Fig. 1 shows the latter data graphically, and reveals that the two fabrics when simultaneously compared in this fashion possessed virtually the same degree of protectivity, and that therefore the original data on non-impregnated white may be accepted for comparison with others of the series.

This latter comparison is made in Table 3, summarizing the raw data of Appendix B. In Fig. 2a the same information is presented graphically. It is seen that the caloric requirement for a mean effective exposure at the 2+ minimal burn level (the 2+ EE₅₀) is uniformly higher for the lighter than for the darker fabrics, and that all these values are dependent in some way upon exposure time. The simplest approach to the quantitation of the observed facts would be to assume that energy which fails to enter the system does the animal no harm. Stated differently, we may suppose that the actual dose received by the system (Q_a) is the incident energy (Q_i) multiplied by the fraction absorbed ($1 - R$), where R is the reflectance of the fabric:

$$Q_a = (1 - R) Q_i \quad (1)$$

In Fig. 2b the ordinate is the dose, Q_a , so defined, and it will be seen that the individual curves for the various fabrics are now almost identical. That is, our assumption appears to be correct, and equation (1) holds, independent of exposure time.

The data on fabrics at constant reflectance and varied weights (Appendix C) are summarized in Table 4. As one would naturally suppose, the data indicate that increasing the fabric weight increases the energy required to attain the 2+ EE₅₀ level. When these values are plotted, as in Fig. 3, it appears that, at any given exposure time, the EE₅₀ increases linearly with fabric weight. It is convenient at this point to employ a concept of protectivity introduced in an earlier publication (7). The protective index

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2+ EE₅₀ BENEATH SINGLE LAYERS 9 OZ. SATEEN
(CONTACT) AS A FUNCTION OF EXPOSURE TIME

FIG. 2a

FIG. 2b

Table 3

Exposure Time (sec)	Exposure (cal/cm ²)	White	Light Grey	Medium Grey	Dark Grey	Black
0.25	2+ EE ₅₀ 95% C. I.	- -	6.05 5.6-6.55	3.71 3.42-4.02	3.35 3.15-3.52	3.32 3.11-3.54
0.5	2+ EE ₅₀ 95% C. I.	12.0 11.45-12.55	7.05 6.7-7.45	5.2 5.1-5.35	3.3 3.1-3.49	3.15 2.94-3.37
1.0	2+ EE ₅₀ 95% C. I.	12.4 11.7-13.1	5.95 5.5-6.45	4.18 3.91-4.68	3.34 3.1-3.58	3.5 3.29-3.72
2.0	2+ EE ₅₀ 95% C. I.	12.6 12.0-13.2	6.8 6.35-7.3	4.6 4.24-5.0	3.64 3.4-3.84	3.17 2.97-3.38
5.0	2+ EE ₅₀ 95% C. I.	15.5 14.7-16.35	7.85 7.45-8.3	5.72 5.4-6.05	4.7 4.4-5.02	3.86 3.67-4.06
10.0	2+ EE ₅₀ 95% C. I.	16.3 15.4-17.3	9.3 8.7-9.9	6.15 5.8-6.55	5.1 4.83-5.39	4.3 4.04-4.58
20.0	2+ EE ₅₀ 95% C. I.	18.8 18.0-19.6	11.1 10.3-11.9	7.0 6.55-7.45	5.96 5.64-6.31	5.0 4.7-5.32

Table 4

Exposure Time (sec)	6 oz.		7.5 oz.		12 oz.	
	2+ EE ₅₀ (cal/cm ²)	95% C. I. (cal/cm ²)	2+ EE ₅₀ (cal/cm ²)	95% C. I. (cal/cm ²)	2+ EE ₅₀ (cal/cm ²)	95% C. I. (cal/cm ²)
0.25	2.98	2.79-3.18	3.86	3.6 -4.15	5.65	5.2 -6.14
0.5	2.97	2.71-3.26	3.47	3.25-3.70	4.4	4.09-4.73
1.0	3.2	2.95-3.47	3.52	3.26-3.80	4.5	4.1 -4.92

has been defined as the ratio between $2+EE_{50}$ under fabric and the $2+EE_{50}$ of bare skin at any given exposure time, t . This may be written

$$\frac{Q_{if}}{Q_{io}} = \text{P. I.} \quad (2)$$

We may now state the hypothesis that protection varies linearly with fabric weight, d , but with coincident dependence upon some function of exposure time. That is, that

$$\text{P. I.} = \phi_1(d, t) = (k + k'd \quad f_2(t)) \quad (3)$$

where k and k' are constants and $f_2(t)$ is some as yet undetermined function of exposure time. This hypothesis may be tested as follows. In UR-316 it was shown that the necessary energy incident upon bare skin to produce the $2+EE_{50}$, (Q_{io}), could be given by

$$Q_{io} = A \quad t^\alpha \quad (4)$$

where*

$$A = 3.78$$

$$\alpha = .224$$

Our hypothesis may be written

$$\text{P. I.} = \frac{f_1(t, d)}{1 - R} = \frac{k + k'd \quad f_2(t)}{1 - R} \quad (5)$$

In terms of the necessary energies, this can be expressed by combining (5) with (2) and (4)

$$Q_{if} = \frac{A (k + k'd \quad f_2(t))}{1 - R} t^\alpha \quad (6)$$

Rearranging and transposing, we have

$$\frac{Q_{if} (1-R)}{t^{.224}} = k A + 3.78 k'd \quad f_2(t) \quad (7)$$

*After appropriate correction for the redetermination of arc output: see p. 3.

FIG. 3

FIG. 4

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FIG. 5

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In Fig. 4, the left-hand quantity as experimentally obtained is plotted against d , the fabric weight. The linearity of these curves now supports the assumption (2) above. The actual lines drawn through these points are influenced by two additional pieces of information, which will be brought out below under "discussion". Accepting these three lines, we obtain a value for $k A$ of 1.6. A is known, and therefore

$$k = .42 \quad (8)$$

In the formula given, the slopes of these lines are equal to

$$A k' \left[f_2(t) \right]$$

and are thus dependent upon exposure time. We may advantageously plot these slopes against t on logarithmic paper, as in Fig. 5, where it becomes evident that a very good fit is obtained for the assumption that

$$f_2(t) = t^\beta \quad (9)$$

In this case, the intercept where $t = 1$ gives $A k'$, and our hypothesis is fit by the values

$$\begin{aligned} k' &= .056 \\ \beta &= -.41 \end{aligned} \quad (10)$$

Thus it is seen that we have arrived at an approximate statement of the effect upon protectivity of the three parameters: reflectance, R , surface density (or weight), d , and exposure time, t , as follows

$$P. I. = \frac{k + k' d t^\beta}{1 - R} \quad (11)$$

This may alternatively be stated in terms of energy requirements

$$Q_{if} = \frac{(A k + A k' d t^\beta) t^\alpha}{1 - R} \quad (12)$$

and in both statements, all constants are now known.

Table 5

Exposure Time (sec)		Exposure (cal/cm ²)				
		White	Light Grey	Medium Grey	Dark Grey	Black
0.5	2+ EE ₅₀ 95% C. I.		14.7 13.9-15.6	11.7 11.0-12.6	13. 12.0-14.1	11.7 10.8-12.7
1.0	2+ EE ₅₀ 95% C. I.	30.5 28.6-32.6	19. 17.2-20.9	16.1 14.7-17.6	13.9 13.2-14.6	15. 13.8-16.2
2.0	2+ EE ₅₀ 95% C. I.	28. 26.8-29.2	12.7 11.9-13.55	10.0 9.3-10.75	8.9 8.35-9.5	8.3 7.8-8.8
5.0	2+ EE ₅₀ 95% C. I.	29.5 27.7-31.4	17.2 16.4-18.0	12.2 11.6-12.8	11.2 10.4-12.1	10.9 10.4-11.4
10.0	2+ EE ₅₀ 95% C. I.	35. 33.6-36.4	18.3 17.2-19.5	13.0 11.9-14.2	11.4 10.9-11.9	11.6 10.0-12.2
20.0	2+ EE ₅₀ 95% C. I.	40.5 38.7-42.4	20.1 19.0-21.3	16.1 15.2-17.0	13.0 12.1-13.9	13.8 13.2-14.5

2. Fabric Separated from Skin

When separated from skin by 5 mm, fabric invariably scorches, chars, glows or flames at the level of the $2+ EE_{50}$ of pigs. When sustained (post-exposure) flame or glow appeared, a record was kept of the type and duration of exothermic reaction. The exposure-response data of Appendix D are summarized in Table 5, which shows the $2+ EE_{50}$'s and their 95% confidence limits. These data are presented graphically in Fig. 6. Let us now define a separation factor.

$$S. F. = \frac{2+ EE_{50} \text{ with fabric 5 mm from skin}}{2+ EE_{50} \text{ with fabric in contact with skin}}$$

In Fig. 7 the separation factors are plotted. It is apparent that 5 mm separation of 9 oz. sateen from skin approximately doubles the protection afforded in most instances. In the case of darker fabrics at shorter exposure times, this factor exceeds a value of 4.

DISCUSSION

To test the validity of equation (12) above, the physical constants of 20 different fabric systems studied in this laboratory, in contact with pigs' skin, are enumerated in Table 6. Since these were investigated at a number of different exposure times, there are a total of 71 variations of the three parameters which can be examined. Where 2-layer systems are computed, the reflectance of the outer layer is given, and the weight is calculated as the sum of the two.

The failure of wool and of fabrics treated with polymerized fire-resistant compounds to conform with the behavior of cellulosic fibres is not surprising. The physical and chemical characteristics of such compounds differ radically from those of the cottons, and their behavior may be expected to be different.

MEAN EFFECTIVE EXPOSURE FOR 2+ BURNS IN PIGS BENEATH

9 OZ. SATEENS 0.5 CM. SEPARATED FROM SKIN.

FIG. 6

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SEPARATION FACTOR FOR 9 OZ. SATEENS

FIG. 7

Table 6

Designation	R	d (oz/yd ²)	t (sec)	2+ EE ₅₀	
				Predicted (cal/cm ²)	Observed (cal/cm ²)
H-W (2 layers, tropical)	.183	8.32	.5	4.11	6.2
HW-FR (same, fire-resistant)	.283	9.52	.5	5.08	6.3
HW 50/50 (wool underwear)	.183	15.75	1.0	6.01	21.0
HW-FR 50/50 (same, fire resistant)	.283	16.95	1.0	7.20	15.0
OG (olive green 9 oz. sateen)	.202	9.4	.25	4.67	4.9
	.202	9.4	.5	4.53	5.1
	.202	9.4	1.0	4.48	5.5
OF-FR (same, fire resistant)	.275	10.5	0.5	5.35	4.45
OG x 2 (2 layers of OG)	.202	18.8	.3	7.84	--
			.5	7.34	13.6
			.8	7.07	8.5
			1.0	6.95	8.4
			1.5	6.87	7.65
			2.0	6.70	7.6
			5.0	6.57	7.8
			10.0	6.58	8.3
			20.0	6.79	8.8
			25.0	6.85	7.65
Black	.035	9.05	.25	3.76	3.32
			.5	3.66	3.15
			1.0	3.63	3.5
			2.0	3.67	3.17
			5.0	3.85	3.86
			10.0	4.06	4.3
			20.0	4.39	5.0
Dark Grey	.060	8.25	.25	3.63	3.35
			.5	3.55	3.3
			1.0	3.55	3.34
			2.0	3.61	3.64
			5.0	3.81	4.7
			10.0	4.05	5.1
			20.0	4.40	5.69

Table 6 (Continued)

Designation	R	d (oz/yd ²)	t (sec)	2+ EE 50	
				Predicted (cal/cm ²)	Observed (cal/cm ²)
Medium Grey	.276	8.21	.25	4.70	3.71
			.5	4.60	5.2
			1.0	4.59	4.18
			2.0	4.67	4.6
			5.0	4.95	5.72
			10.0	5.25	6.15
			20.0	5.71	7.0
Light Grey	.593	7.85	.85	8.12	6.05
			.5	7.97	7.05
			1.0	7.98	5.95
			2.0	8.15	6.8
			5.0	8.66	7.85
			10.0	9.22	9.3
			20.0	10.1	11.1
White	.746	8.26	.5	13.2	12.0
			1.0	13.1	12.4
			2.0	13.4	12.6
			5.0	14.1	15.5
			10.0	15.0	16.3
			20.0	16.3	18.8
6 oz. Grey Sateen	.073	6.12	.25	3.06	2.98
			.5	3.05	2.97
			1.0	3.11	3.2
8.5 oz. Grey Sateen	.073	7.51	.25	3.46	3.86
			.5	3.41	3.47
			1.0	3.43	3.53
12 oz. Grey Sateen	.070	12.12	.25	4.80	5.65
			.5	4.58	4.40
			1.0	4.46	4.5
CF ₁ (Unbleached Oxford)	.658	7.96	.5	9.56	6.85
			5.0	10.35	6.5
CF ₂ " "	.666	7.54	.5	9.49	7.65
			5.0	10.40	6.9
CF ₃ " "	.685	7.58	.5	10.10	6.70
			5.0	11.05	6.95
CF ₄ " "	.664	7.11	.5	9.13	7.15
			5.0	10.14	6.65
CF ₅ " "	.649	7.08	.5	8.71	6.75
			5.0	9.70	6.65

Certain other failures of the "formula prediction" call for more detailed comment. As has been shown by this laboratory (8), the active chemical participation of fabric during and after exposure tends to complicate thermal transfer mechanisms. Scorching, charring and flare (a brief ignition of decomposition products during exposure; not sustained) are all endothermic, in the sense that incident radiant energy has been absorbed, dissipated, and hence lost to the system. This process tends to enhance protectivity. Returning to Fig. 4, it will be noted that the line drawn for 0.25 sec. exposures does not pass through the experimental points for the heavier fabrics. It was marked at the time that the fabric samples at these exposures were heavily scorched; it was concluded that the $2+EE_{50}$ had thereby been increased, and that in order to derive a general statement, this enhancement should be disallowed, and the lines drawn below these points. A natural corollary of this treatment of results is that the formulated estimate of protectivity will be lower than observed for short exposures of heavier fabrics. This is in fact observed in Table 5; a quantitative allowance for this phenomenon has not yet been worked out.

It was stated above that a second observation influenced the placement of lines in Fig. 4. An experiment soon to be reported (14) arose from the implications of the apparent convergence of the points in Fig. 4 at the zero intercept of the weight axis. This would seem to intimate that for very thin films in contact with skin - where "fabric" weight approached zero - all exposure times would have a common protective index. This hypothesis was tested by running a parallel series of exposures with the skin bare and with skin blackened by India ink, which was nearly 100% absorptive (15). Referring back to equation (6), this means that

$$Q_{if} = A k t^{\alpha}, \text{ and, since (3)}$$

$$Q_{io} = A t^{\alpha}$$

it is possible to investigate the ratio

$$\frac{Q_{if}}{Q_{io}} = k \quad (13)$$

This ratio was experimentally determined to be 0.42, which yields a value for $A k$ of 1.6. In the plot of Fig. 4, this value was therefore used for the $d = 0$ intercept of all three straight lines. The agreement of this independently derived data lends a certain strength to the assumption of equation (2) itself.

A quite consistent failure of this formulation to account for the lighter fabrics will also be noted. It seemed possible that the transmission of radiant energy directly through fabric to the skin might account for the discrepancy, and further experiments are to be reported (16) in which the transmission parameter is measured and applied to these same data.

As to the data on fabrics separated from skin, it must be reiterated that chemical degradation of the fabrics dominates the picture completely. For a large proportion of situations studied, it is necessary to ignite the fabric before significant burns are produced. The requirements for ignition of cellulose laminae under thermal irradiance are known to be a matter of extreme complexity. It has been the experience in this study, for example, that a minimal exposure, which will cause only 5 or 10% of samples exposed to ignite, produces a very long period of flame and/or glow; whereas more intense exposures, which produce 100% ignition, give progressively shorter periods of exothermic reaction. This relationship obtained in every instance studied in this series. On the other hand, the more translucent fabrics (which are also lighter in shade) may transmit damaging

amounts of energy prior to their ignition. All fabrics scorch or char to some degree at the $2+ EE_{50}$ level when separated from skin. Thus the physical and optical qualities of the protective barrier are changing rapidly during the period of exposure, complicating the picture still further.

On the whole, then, it is felt that unknown parameters concerned with fabric chemistry dominate the problem where separation is concerned, and that attempts accurately to define protectivity solely in terms of the three parameters under consideration are inadequate in the present state of knowledge. The statement that 5 mm separation increases the protectivity by approximately two times, and up to four times for dark fabrics at short exposures, seems to be sufficiently detailed.

A few precautions as to extension of these results should be added. The present experiments have been carried out on pigs, over relatively small exposure areas, and are primarily concerned with the $2+$ level of damage. It should not be supposed that they may be directly and accurately extended to other animal skins (i. e., human), to wide area results, nor to greater or lesser degrees of damage than $2+$.

Nevertheless, it may be hoped that other systems, when fully investigated, will follow the essential generalities expressed in equations (11) and (12). It is even possible that fabric protectivity under energy pulses other than trapezoidal will behave in analogous fashion. Most desirable of all is the possibility that the empiric statement derived from these experiments may be given theoretical significance. To date, such attempts in our hands have failed, except in the case of reflectance, where the relationship appears to be fairly clear.

SUMMARY AND CONCLUSIONS

1. That fabric reflectance operates upon protectivity inversely as its remainder from unity: that is, that the absorbed rather than the incident dose of thermal radiation, determines injury.
2. That, with certain exceptions, fabric weight (surface density in oz/yd²) has a linear effect upon protectivity.
3. That exposure time enters the degree of protectivity, in regard to fabric weight, as a negative fractional power.
4. That in the case of cotton fabrics in contact with the skin of white pigs, the incident energy required to produce a 2+ EE₅₀ burn may be approximately described by the formula:

$$Q_{if} = \frac{A t^{\alpha} (k + k' d t^{\beta})}{1 - R}$$

conventions and constants being described in the text.

5. That separation of fabric from the skin by 5 mm introduces unknown parameters concerned with fabric chemistry, currently incapable of simple algebraic expression.
6. That such separation of fabric enhances protection by two to four times, empirically.
7. That the introduction of fibres or compounds other than cellulosic tends to invalidate the relationships above described.
8. That thickness of fabric and brevity of exposure tend to enhance protectivity of fabrics so predicted in contact with bare skin, and that fabrics of high reflectance afford less than the expected protection.

BIBLIOGRAPHY

1. Effects of Atomic Weapons, para. 6.55, Rev. Sept. 1950, U. S. Gov't Printing Office, (1950).
2. Morton, J. H., Kingsley, H. D., and Pearse, H. E., Studies on Flash Burns: The Protective Effects of Certain Fabrics, Surg., Gyn. and Obs., vol. 94, 497-501, (1952).
3. Mixter, George, Jr. and Krolak, L. J., Critical Energy of Fabric as Indicated by Its Persistence Time Under Thermal Radiation, Univ. of Roch. Atomic Energy Project Report, UR-260, (1953).
4. Perkins, J. B., Kingsley, H. D., and Pearse, H. E., A Study of Radiant Energy Burns: The Effect of Exposure Time and Intensity, Univ. of Roch. Atomic Energy Project Report, UR-217, (1952).
5. Mixter, George, Jr., The Empirical Relation Between Time and Intensity of Applied Thermal Energy in Production of 2+ Burns in Pigs, Univ. of Roch. Atomic Energy Project Report, UR-316, (1954).
6. Mixter, George, Jr., and Davis, T. P., An Evaluation of Black Polyethylene As A Skin Simulant Under Fabrics Exposed to Thermal Energy, Univ. of Roch. Atomic Energy Project Report, UR-353, (1954).
7. Mixter, George, Jr., Studies on Flash Burns: Further Report on the Protective Qualities of Fabrics as Expressed by a Protective Index, Univ. of Roch. Atomic Energy Project Report, UR-354, (1954).
8. Mixter, George, Jr., and Pearse, H. E., Studies on Flash Burns: The Influence of Exposure Times and Irradiance on the Thermal Protective Qualities of Two Fabric Assemblies, Univ. of Roch. Atomic Energy Project Report, UR-355, (1954).
9. Davis, T. P., Krolak, L. J., Blakney, R. M., and Pearse, H. E., Modification of the Carbon Arc Searchlight for Producing Experimental Flashburns, J.O.S.A., 44: 766-769, (1954).

BIBLIOGRAPHY (Continued)

10. Krolak, L. J., and Davis, T. P., A Universal Spectrophotometer for the Measurement of the Relative Spectral Distribution of the Carbon Arc Source, Univ. of Roch. Atomic Energy Project Report, UR-367, (1954).
11. Berkley, K. M., Pearse, H. E., and Davis, T. P., Study on Flash Burns: The Influence of Skin Temperatures on the Production of Cutaneous Burns in Swine, Univ. of Roch. Atomic Energy Project Report, UR-338, (1954).
12. Krolak, L. J., and Davis, T. P., The Measurement of Diffuse Reflectance of the Relative Spectral Distribution of the Carbon Arc Source, Univ. of Roch. Atomic Energy Project Report, UR-380, (1955).
13. Mixter, George, Jr., A Comparison Between Bare and Blackened Porcine Skin in Response to Pulses of High Intensity Radiant Thermal Energy, Univ. of Roch. Atomic Energy Project Report, UR-385, (1955).
14. Lipkin, M., and Hardy, J. D., Measurement of Some Thermal Properties of Human Tissues, Report No. 001 090.04.01 (NADC-MA-5405), April 1954.
15. Mixter, George, Jr., and Krolak, L. J., The Effect of Fabric Transmittance Upon the Protectivity of Material Against Thermal Radiant Energy, Univ. of Roch. Atomic Energy Project Report, UR-388, (to be published).

APPENDIX A

COMPARISON OF 9 OZ. SATEENS IN CONTACT WITH SKIN: PLAIN VS. CMC

Time (sec)	Fabric	Exposure (cal/cm ²)	BURN					
			0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
0.5	Plain	19.0		7	7	3		
		23.1		5	6	4	2	
		28.0				11	5	1
		34.0			1	6	6	4
	CMC	19.0		13	2	2		
		23.1		4	5	7	1	
		28.0			3	11	3	
		34.0			1	5	3	8
1.0	Plain	9.65		7	6	1	1	
		10.65		2	5	6	2	
		11.7			4	8	1	
		12.9			3	6	5	1
		14.2				2	2	4
		22.0					1	1
	CMC	9.65		7	7	1		
		10.65		4	5	5	1	
		11.7		2	2	8	1	
		12.9			4	6	5	
		14.2					4	4
		22.0					1	1
2.0	Plain	8.0	1	0	1			
		9.9	12	5				
		10.8	1	5	1			
		11.9		2	1	7	5	
		13.1			2	8	6	1
		14.4				3	3	2
		15.8						2
	CMC	8.0	2					
		9.9	9	8				
		10.8	3	4				
		11.9		1	4	10		
		13.1			2	10	5	
		14.4				2	4	2
		15.8				1	0	1

APPENDIX A (Continued)

Time (sec)	Fabric	Exposure (cal/cm ²)	BURN					
			0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
5.0	Plain	9.5	2					
		10.5		4	3			
		11.5	2	1	6	4		
		12.5		1	4	3		
		13.0		1	10	5	1	
		14.5			4	8	2	1
		16.0			1	3	1	1
	CMC	9.5	2					
		10.5	2	2	3			
		11.5		3	7	3		
		12.5		1	5	2		
		13.0		1	9	7		
		14.5			2	12	1	
		16.0			1	3	1	1
10.0	Plain	12.0	3	1				
		13.3		1	7	5		
		14.5			7	10		
		16.0			6	5	6	
		17.4				3	9	1
		19.0					3	1
	CMC	12.0	1	3				
		13.3	2	1	5	5		
		14.5			6	10	1	
		16.0			4	10	3	
		17.4		1	1	5	6	
		19.0				2	1	1

APPENDIX A (Continued)

COMPARISON OF 9 OZ. SATEENS SEPARATED 5 MM FROM SKIN: PLAIN VS. CMC

Time (sec)	Fabric	Exposure (cal/cm ²)	BURN					
			0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
1.0	Plain	25.4		12	5			
		28.0	1	9	6	1		
		30.8	2	6	7	2		
		34.0		2	5	3	3	4
	CMC	25.4		9	6	2		
		28.0		6	10	1		
		30.8		1	10	4	2	
		34.0		2	6	8	0	1
2.0	Plain	23.4	6	8	2	0	0	1
		25.8	1	4	6	0	2	4
		28.4			1	0	8	8
		31.4					8	9
	CMC	23.4		8	6	3		
		25.8		4	11	2		
		28.4	1	2	8	4	0	2
		31.4		1	1	3	5	7
5.0	Plain	24.7	15	2				
		27.0	6	1				
		29.7		1	1	0	5	10
		32.7			1	2	5	9
		36.0					4	6
	CMC	24.7	13	2	1	1		
		27.0	5	2				
		29.7	1	2	7	7		
		32.7			3	0	5	9
		36.0					1	9
10.0	Plain	26.0	3	2	1			
		29.0	1	3	4			
		32.0		1	5	4		
		36.0	1	3	7	4	1	1
		40.0			6	3	0	2
		45.0		1	0	2	1	5
		49.5						7
	CMC	26.0	2	1	3			
		29.0	1	3	4			
		32.0	1	4	4	1		
		36.0	1	4	5	6	1	
		40.0		3	1	7		
		45.0			2	5	2	
		49.5				1	2	4

APPENDIX B

EXPOSURE VS. RESPONSE, WHITE, CONTACT, PIG'S SKIN

Time (sec)	Exposure (cal/cm ²)	RESPONSE					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
.25	5.41	2					
	6.0	2					
	6.6	4	3				
	7.3	6	4				
	8.1	7	8				
.50	6.6	2					
	7.3	2					
	8.2	2					
	9.0	2					
	10.0	1	5	2			
	10.9	1	5	4	3		
	12.0		1	4	8	1	
	13.3			1	7	4	2
	14.6		1	1	2	6	4
	16.1					1	2
1.0	6.3	1	1				
	6.9	2					
	7.6	2					
	8.35	2					
	9.2	3	1				
	10.15		6				
	11.2		6	8	1		
	12.3		1	6	7		
	13.5		1	1	5	7	
	14.9				4	1	1
2.0	7.65	2					
	8.3	4					
	9.4	4	2				
	10.3	2	2	4			
	11.35		3	8	3		
	12.5		1	5	8	3	
	13.75			3	9	1	
	15.1				3		
	16.7				2		
5.0	8.7	1	1				
	9.7	2					
	10.75	2					
	11.85	1	0	1			
	13.0	1	4	3			
	14.3			11	2		
	15.7			7	6	3	
	17.35			1	6	4	1
	19.1				2	4	2
	20.8					2	

APPENDIX B (Continued)

Time (sec)	Exposure (cal/cm ²)	RESPONSE					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
10.0	13.25	2	0	4			
	14.6	1	1	5	1	0	1
	16.0			7	5	2	
	17.65			3	5	5	
	19.4			2	3	7	2
	21.4				1	1	4
20.0	14.6	3	1	2			
	16.0	1	2	5			
	17.6		2	9	3		
	19.8			5	3	5	1
	21.8				1	5	2

APPENDIX B

EXPOSURE VS. RESPONSE, LIGHT GREY, CONTACT, PIG'S SKIN

Time (sec)	Exposure (cal/cm ²)	RESPONSE						
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev	3+
.25	4.65		5	3				
	5.15		2	5	1			
	5.7		1	5	1	1		
	6.2		2	1	2	1	1	1
	6.9		1	0	1	1	4	1
.5	5.15		1					
	6.0			1				
	6.45	2	3	3	2			
	6.9		2	3	4	2		
	7.3		2	3	3	1		
	7.75			2	5	2	2	
	8.2						1	
	8.6						1	
1.0	5.15		4	4				
	5.7		3	1	3	1		
	6.3		1	1	5	1		
	6.9			2	4	2		
	7.55				1	4	2	1
2.0	5.5	4	5	2	1			
	6.0	2	6	3	2			
	6.6		2	3	4	3		
	7.4		2	2	3	1	4	
	8.2	1	1	0	2	7	1	
	9.0					1	1	
5.0	5.6	1	1					
	6.25	6	6	0	1			
	6.9	1	7	4	1			
	7.75		4	3	3	2		
	8.6		1	1	2	6	2	
	9.5			1	3	4	4	
10.0	7.1	1	5					
	7.85		4	2				
	8.8			5	3	2		
	9.7		1	2	6	4	1	
	10.7				7	5	2	
	11.8		1	0	4	0	3	
	13.0				1	1	4	
	14.3						3	2
20.0	8.75	1	7	1				
	9.6		4	8	2			
	10.6		2	7	5			
	11.7		1	6	2	4	1	
	12.9			2	2	6	4	
	14.2				1	4	4	

APPENDIX B

EXPOSURE VS. RESPONSE, MEDIUM GREY, CONTACT, PIG'S SKIN

Time (sec)	Exposure (cal/cm ²)	RESPONSE						
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev	3+
.25	3.52		3	3	2			
	3.86			3	3	2		
	4.2				2	4	2	
	4.65				4	3	1	
	5.15			1	1	2	3	1
.5	3.98	4	6	13	1			
	4.4		6	8	6	3	1	
	4.8	1	1	2	7	5	9	
	5.1		1	7	7	5	4	
	5.35		3	3	13	14	14	1
	5.6			6	8	3	7	
	5.85		1	4	9	9	21	4
	6.15			4	4	6	8	2
	6.45				5	3	11	5
	6.8				2	4	8	10
1.0	3.54	1	2	5				
	3.86		2	2	3	1		
	4.25			4	1	2	1	
	4.7	1	1	0	1	3	2	
	5.15				3	0	4	1
2.0	3.78	2	5	2	1			
	4.1		3	4	5			
	4.55	1	4	2	3	2		
	5.0				8	3	2	
	5.5				3	3	5	1
	6.0			1	0	0	1	3
5.0	4.3		2					
	4.72	3	3	3	1			
	5.15	2	4	4	2			
	5.6		3	4	3	2		
	6.25	1	0	3	3	3	1	
	6.9			1	4	4	2	1
	7.55				1	0	0	1
10.0	4.8	2	5	2				
	5.3	2	8	3	1			
	5.85		4	4	6			
	6.45	1	2	2	6	2	1	
	7.1		1	1	7	3	2	
	7.85				3	2	2	2
20.0	5.4	3	3	2	1			
	5.95	1	8	5				
	6.45	1	4	9				
	7.2			7	7			
	8.0			2	10	2		
	8.8				1	5	3	

APPENDIX B

EXPOSURE VS. RESPONSE, DARK GREY, CONTACT, PIG'S SKIN

Time (sec)	Exposure (cal/cm ²)	RESPONSE						
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev	3+
.25	2.58		6	2				
	2.88		5	4	5			
	3.18		7	1	3	3		
	3.52			6	6	2		
	3.86			1	6	3	2	2
	4.25				1	3	2	
.50	2.15		1					
	2.58	3	8	1				
	2.84	3	5	1				
	3.05	1	3	6	1			
	3.35	1	1	2	5			
	3.52			1	3	3	1	
	3.86				4	3	1	
	4.3				1	2	4	1
1.0	2.84		3	8	1			
	3.18		2	2	9	1		
	3.52		1	4	6	3		
	3.86		1	3	4	4	2	
	4.25			1	2	4	5	2
2.0	2.50	1	0	1				
	2.75	6	4					
	3.1	2	7	1	2			
	3.44		5	3	2	2		
	3.78	1	3	1	7			
	4.12		1	1	5	5		
	4.65				1	1	1	
5.0	3.14		2					
	3.48			2				
	3.86	1	3	1	4			
	4.3		2	8	2			
	4.72	1	3	4	4			
	5.15	1	1	3	4	3		
	5.6			2	1	3	4	
10.0	6.25					1	2	
	3.3	1	3					
	3.6		4					
	4.0	2	1	1				
	4.4	2	6	1	1			
	4.8		5	4	5			
	5.3		1	1	10	1	1	
	5.85			1	4	2	3	
	6.45			1	1	1	7	
20.0	7.1						2	2
	3.25	4						
	3.6	4						
	4.0	1	3					
	4.4	4	3	1				
	4.9	3	5	5				
	5.4	1	3	7	3			
	5.95			3	6	1		
	6.5		1	3	5	1		
	7.2			1	1	3	1	

APPENDIX B

EXPOSURE VS. RESPONSE, BLACK, CONTACT, PIG'S SKIN

Time (sec)	Exposure (cal/cm ²)	RESPONSE						
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev	3+
.25	2.58		5	1				
	2.84	2	5	3	2	1		
	3.1	1	3	3	6	1		
	3.4		4	2	7	1		
	3.69		1	4	4	3	1	
	4.08			1	3	2	3	
.50	2.58	1	7	1	2			
	2.84		5	6	2			
	3.14		3	2	8			
	3.44		1	4	5	3		
	3.78		1	0	6	5	1	
1.0	2.86	1	1	2				
	3.16		3	4	4			
	3.47		2	2	7	2		
	3.83		2	0	4	4	3	
	4.15		1	3	4	4	1	
	4.6						6	
2.0	2.65	1	3	6	1			
	2.92		2	7	4			
	3.2		1	5	7	1		
	3.53			1	11	2		
	3.88		1	0	6	1		
	4.28			1	2	2	1	
	4.73				1	1	1	1
5.0	3.0		4	7				
	3.3	1	2	9	1			
	3.65	2	2	4	5	1		
	4.0			3	6	5		
	4.4			2	3	2	3	
	4.95					2	2	
	5.45					1	4	1
10.0	3.1			5				
	3.4		3	6				
	3.75	2	1	9	1			
	4.07	1	1	5	5	1		
	4.5		1	3	8	1		
	4.96			2	2	4	2	
	5.45				1	1	4	
20.0	4.2			8				
	4.64	2	0	6	5			
	5.1			5	4	4		
	5.6			2	1	7	2	
	6.2			1	2	7	3	

APPENDIX C

EFFECT OF FABRIC WEIGHT

Time (sec)	Fabric Weight (oz/yd ²)	Exposure (cal/cm ²)	BURN					
			0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
.25	6	2.3		7	1	1		
		2.55	3	6	1	1		
		2.8		6	3	2	1	
		3.06	1	5	3	2	2	
		3.35				9	3	
		3.65			1	3	1	4
.5		2.10	3	4				
		2.31	5	4	3			
		2.55	1	5	1	5		
		2.80		5	2	2	2	2
		3.10			3	3	1	
		3.40		1	1	3	1	1
1.0		3.74			1	2	2	1
		2.3	1	0	2			
		2.64		9	2	1	1	
		2.9	2	3	2	4	1	1
		3.2		1	4	2	1	4
		3.45		2	1	6	1	2
.25	7.5	3.8			1	1	2	2
		3.2	1	4	1			
		3.6	1	4	2	1		
		3.95		4	6	3	1	
		4.3		1	4	5	1	1
		4.75		1	3	3	1	4
.5		5.25			5	2	3	3
		5.8			1	4	4	3
		6.3		1	1	1	4	3
		7.0				4	1	3
		2.72	1	3				
		3.0	3	3	1			
1.0		3.3		8	3			
		3.65		5	3	4	1	
		4.0	1	3	3	3	2	1
		4.4		1	3	3	5	1
		4.85				7	2	2
		5.3			1	4	2	1
1.0		3.1	2	4	1			
		3.4	1	2	3	0	1	
		3.75	2	2	2	2		
		4.07	1	1	2	7	1	1
		4.5			2	6	1	3
		4.95			3	2	3	3
		5.45				3	1	4

APPENDIX C (Continued)

EFFECT OF FABRIC WEIGHT

Time (sec)	Fabric Weight (oz/yd ²)	Exposure (cal/cm ²)	BURN					
			0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
.25	12	4.3	2	3	1			
		4.74		5	3			
		5.25		6	3	2		
		5.8		3	7	3	1	
		6.3		2	4	8		
		7.0	1	1	4	6	2	
		7.75		1	4	4	2	
		8.5			3	5	2	
		9.4				4	1	1
.5		4.0		5	4			
		4.4		4	7	3		
		4.85		2	6	3	3	
		5.3		2	2	6	4	
		5.9		1	1	3	3	1
		6.5			1	2	2	
1.0		3.4	1	3	2			
		3.75	3	3	3			
		4.07	1	5	5	3		
		4.5		3	4	3	2	1
		4.95	1	2	2	4	3	1
		5.45		1	4	4	2	1
		6.0		2	2	0	3	7
		6.6				1	2	3
		7.3					1	3

APPENDIX D

EXPOSURE VS. RESPONSE, WHITE, SEPARATED, PIG'S SKIN

Time (sec)	Exposure (cal/cm ²)	RESPONSE					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
1.0	26.6		4	2			
	29.2		3	2	3	1	1
	32.0		1	3	1	3	1
2.0	22.4	1					
	24.6	1	4				
	27.0		6	0	0	1	
	29.8			1	0	2	5
	32.6						2
5.0	23.5	1					
	25.8	4	2				
	28.4	2	2	2	0	0	4
	31.4			3	0	2	2
	34.4				1	3	1
10.0	32.0		2	2	1		
	35.0		1	7	2		
	38.7			1	3	1	3
	42.0					1	5
20.0	32.4		1	2			
	35.6			6	1		
	39.2			6	3		
	43.3			3	7		
	48.0					2	1
	49.5						1

APPENDIX D (Continued)

EXPOSURE VS. RESPONSE, LIGHT GREY, SEPARATED, PIG'S SKIN

Time (sec)	Exposure (cal/cm ²)	RESPONSE					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
.5	12.0	6					
	13.3	3	1	0	0	0	2
	14.6	1	1	3	1		
	16.1			2	1	3	2
1.0	14.8	3	0	0	0	0	1
	16.3		2	2	0	1	1
	18.0			3	0	2	1
	20.35		1	2	0	1	1
	21.8				4	0	2
	24.0					2	
	25.6				1	1	
	29.2						1
2.0	11.3	6					
	12.5	3	0	0	0	0	3
	13.7	1	0	0	0	0	5
	15.1						4
	16.65					1	
	18.4						4
	20.3					2	1
	22.3					1	1
	24.6						2
5.0	14.7	2	4				
	16.3			6			
	17.9			2	2	1	1
	19.7				1	0	5
10.0	16.3	2	3	1			1
	17.9	1	1	2	1	0	4
	19.7				1	1	
	21.6						6
20.0	17.6	4	1	1			
	19.4		1	5			
	21.4			1	0	0	5
	23.5						6

APPENDIX D (Continued)

EXPOSURE VS. RESPONSE, MEDIUM GREY, SEPARATED, PIG S SKIN

Time (sec)	Exposure (cal/cm ²)	RESPONSE					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
.5	8.2	1					
	9.0	2					
	10.2	5	0	0	0	0	1
	10.9	5	0	0	0	2	1
	12.0	2	1	1	1	1	1
	13.3			1	2	0	1
	14.6		2	1	1		
1.0	12.3	1	3				
	13.5		5	1			
	14.9		1	3	0	0	2
	16.3			4	2		
	18.0			1	4	1	
	20.4					1	1
	21.8				2		
2.0	8.5	1	1				
	9.3	3	1				
	10.3	2	0	0	0	0	4
	11.3						5
	12.5					1	3
	13.7					1	3
	15.1					3	
	16.7					1	2
	18.4						2
	20.3						2
5.0	10.9		3	2	1		
	12.0			5	1		
	13.3			1	2	1	2
	14.8						6
10.0	12.0		4	2			
	13.3		1	1	2	0	2
	14.8						6
	16.4						6
20.0	14.55		4	2			
	16.1	1	1	1	3		
	17.2						6
	19.0						6

APPENDIX D (Continued)

EXPOSURE VS. RESPONSE, DARK GREY, SEPARATED, PIG'S SKIN

Time (sec)	Exposure (cal/cm ²)	RESPONSE					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
.5	10.2	3	1				
	10.9	5	2	0	0	1	
	12.0	2	3	0	0	2	1
	13.3	1	0	2	1	4	
	14.6			1	2		
1.0	12.3		4	2			
	13.5		2	2	0	2	
	14.9	1	0	0	0	3	2
	16.3					4	2
2.0	7.65	4	2				
	8.5	2	2	2			4
	9.3	2	0	0	1	0	5
	10.3				1	0	2
	11.3					1	1
	12.5					1	
	13.7						
5.0	9.7		1	5			
	10.9			4	2		
	12.0			1	2	1	2
	13.3						6
10.0	10.9		1	4	1		3
	12.0				3	0	6
	13.3						6
	14.8						
20.0	11.7	2	3	0	1		
	12.9		1	5			
	14.2				1	0	5
	15.7				1	0	5

APPENDIX D (Continued)

EXPOSURE VS. RESPONSE, BLACK, SEPARATED, PIG'S SKIN

Time (sec)	Exposure (cal/cm ²)	RESPONSE					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
.5	9.0	5					
	10.0	4	1	0	2	1	1
	10.9	2	2	0	1	3	1
	12.0	1	4	0	1	2	
	13.3		3	0	2	1	
1.0	12.3		2	3	1		
	13.5		5	2	0	1	
	14.8		4	2	2	3	
	16.3			3	3	2	1
2.0	7.65	8					
	8.3	4	1	0	1	2	2
	9.2				1	3	5
	10.01						1
	11.1						1
	12.2					1	
5.0	9.7			5			
	10.7		1	4	3		
	11.8			1	3	3	1
	13.2				1	0	1
10.0	9.9	1	2				
	10.9		2	4	2		
	12.0			2	5	3	
	13.3			1	2	2	1
	14.6					1	
	16.0						1
20.0	12.0	1	1	1			
	13.2	1	0	4	2		
	14.6			2	5		
	16.0				1	2	