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FUEL FIRE TESTS OF SELECTED ASSEMBLIES

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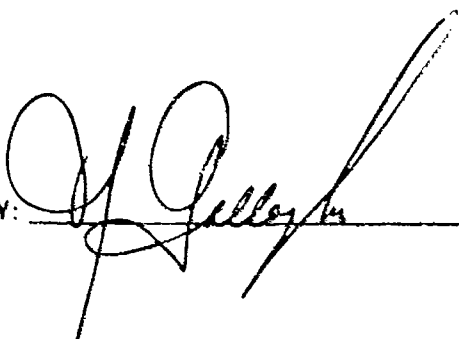
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A varying assortment of clothing assemblies was tested in the Fuel Fire Test Facility at the Naval Air Development Center. Included was a Nomex-Kevlar Cloque Coverall which had relatively good protection from fuel flames.		

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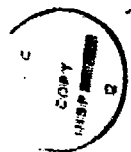
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INTRODUCTION

In its continuing effort to provide maximum protection from fire to its personnel, the Naval Sea Systems Command has initiated a program in which the fire protective qualities of clothing in development for wear by Naval shipboard personnel is tested. Part of this program consists of a cooperative effort of the Naval Clothing and Textile Research Facility (NCTRF) and the NAVAIR-DEVCEN wherein battle dress clothing is subjected to tests simulating open fuel fires. In the tests to be described, seven garment configurations were evaluated. They included four type garments using 95/5 Nomex-Kevlar fabrics, two different designs in the 100% flame-retardant treated (F.R.T.) cotton, and one garment made from a PFR Rayon/Nomex fabric.

METHOD AND MATERIAL

The facility in which the tests were run has been described previously (1). Briefly it is a rectangular 20 x 30 ft. enclosure about one foot deep filled with water to about 8 inches, to almost cover a grid which divides the surface into 20 equal cells. Each of the cells is provided with a submerged nozzle which is connected to a fuel distribution system. At the proper time fuel, in this case, JP-4, is pumped to the 20 cells through the nozzle and allowed to float to the top of the water and distribute itself. At the proper time the fuel is ignited by four propane air spark igniters.

The manikin wearing the clothing assembly was carried through the flames on a steel crane that rotated through the flames at a pre-set velocity, depending on the length of the exposure. In the present series, it was either two or three seconds. Still photographs were made of the dressed manikin before and after the exposure and two movie cameras took views of the enveloping fire as the manikin passed through.

Surface temperatures on the manikin were determined at twenty sites corresponding to twenty used previously. The relationship between the previous sites and the present ones are shown in table I. The regions are now designated as upper torso, front and back; lower torso, front and back; the arms and the right and left legs, front and back. The present scheme is easily expandable to cover a larger number of sensors.

Temperatures were obtained from sensitive papers measuring approximately 5/16 x 1 7/8 inches, stamped with a temperature activation value. They were constructed so that at the designated temperature the appearance changes from gray to black. A set of seven papers, mounted on a leather patch was placed at each of the twenty manikin sites just described. The temperature values were 220°, 230°, 240°, 250°, 260°, 270° and 280°F.

The tapes were evaluated by a procedure in which they were subjected to a known heat flux for 1-4 seconds and the results plotted on Stoll's graph in reference 2. By this procedure the following were obtained.

<u>Exposure</u>	<u>Burn Injury</u>	<u>Paper Tapes, Temp (°F)</u>
1.0 sec	— Before pain	220
2.0 sec	1st degree — After pain	230 — 240
3.0 sec	2nd degree — Before blister	250 — 260
4.0 sec	3rd degree — After blister	270 — 280

Table I. Sensor Sites

<u>Current</u>		<u>Past</u>
1.	UT2F Upper Torso 2 Front,	T1
2.	UT2B Upper Torso 2 Back,	T2
3.	UT3F Upper Torso 3 Front,	T3
4.	UT3B Upper Torso 3 Back,	T4
5.	UT6F Upper Torso 6 Front,	T5
6.	UT6B Upper Torso 6 Back,	T6
7.	LT1F Lower Torso 1 Front,	T13
8.	LT1B Lower Torso 1 Back,	T14
9.	LT2F Lower Torso 2 Front,	T15
10.	LT2B Lower Torso 2 Back,	T16
11.	RA1F Right Arm 1 Front,	A10
12.	LA1F Left Arm 1 Front,	A11
13.	RL1F Right Leg 1 Front,	L6
14.	RL1B Right Leg 1 Back,	L7
15.	RL3F Right Leg 3 Front,	L8
16.	RL3B Right Leg 3 Back,	L9
17.	LL1F Left Leg 1 Front,	L27
18.	LL1B Left Leg 1 Back,	L18
19.	LL3F Left Leg 3 Front,	L19
20.	LL3B Left Leg 3 Back,	L20

Still photographs were made of each assembly before the exposure and after. Two movie cameras viewed the passage of the manikin through the flames. One of these operated at 24 frames/second and the other at 100 frames/second.

RESULTS

The data are shown in table II and table III. The abbreviations along the left margin refer to the sensor sites explained in table I. The seven columns are for the seven temperatures tested in each site. Zeros indicate that the sensors at a site for a particular temperature were not triggered during the exposure. (The temperature was not reached).

Table IV shows the assemblies with the number of runs per assembly and the average percentage of body burned.

MOVIE FILM SUMMARY

The movie footage serves mainly in the observation of the fire and its development. In this series one camera was placed so as to ostensibly observe the entrance and exit of the manikin over the pit but in actuality as the fire reaches full development the manikin is obscured. The other camera was on one side of the pit so that it observed the manikin as it emerged from the pit. One can observe whether any material was burning at this point. In the present series, the only flaming was observed with the 80/20 Rayon/Nomex Twill Coverall, 6.5oz. These flames self-extinguished and were out in one or two seconds, well before the crane was stopped. There was some smoking without flames associated with several of the assemblies.

STILL PHOTOGRAPHY SUMMARY

- NKCC 95/5 Nomex/Kevlar Cloque Coverall, 5.5oz. Of the several Cloque assemblies run, it was clear that it had an extra measure of resistance to flames compared to the other materials in this series. The range of effects was somewhat wide varying from those assemblies that came through unscathed to those that were discolored. A process can be observed that varies with increasing intensity of the exposure. It appears to start with the loss of folds and wrinkles due to shrinkage; next the shrinkage ripples before giving way to changes in the composition of the material indicated by the appearance of a brownish discoloration. This is an every absorbing process that serves as a barrier between the wearer and the radiation. (See Appendix A Figures 7 & 8)
- NKEC Nomex/Kevlar Enhanced Coverall, 4.5oz. These assemblies while tending to remain intact in the pit and thus protect the wearer, tend to shrink especially at the legs exposing the wearer. The underwear was occasionally stained. (See Appendix A Figures 9 & 10)
- CLC 100% Flame Retardant Treated (F.R.T.) Cotton Coverall, 6.5oz. All three of the assemblies tested showed scorching and areas of charring on the left side which would indicate a possible wind or convection current effecting the fire. The underwear was occasionally discolored. (See Appendix A Figures 11 & 12)
- NKC 95/5 Nomex/Kevlar Coverall, 4.5oz. Overall considerable shrinkage as indicated by a loss of folds and wrinkles that existed before the exposure. Legs and arms are smooth and tight. The torso is less so. Anklets of strips of Velcro were effective in preventing creeping up the legs. No discoloration or other evidence of burning. (See Appendix A Figures 1 & 2)

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- CCD 100% F.R.T. Cotton Chambray Shirt, 6.5oz. Denim Trousers, 12oz. shirt shows slight discoloration on the rear torso and the left sleeve. Trousers little if any evidence of the exposure, perhaps a very slight, almost non-discernible brownish discoloration. (See Appendix A Figures 3 & 4)
- RNT 80/20 Rayon/Nomex Twill Coverall, 6.5oz. Some shrinkage and brownish discoloration on front legs; front torso little affected. Rear torso and legs body scorched as indicated by brownish discoloration. Left leg is burned through. (See Appendix A Figures 5 & 6)
- RNT Emerged in flames until stop (1-2 seconds), one run.
- FSC Nomex/Kevlar Flight Suit Coverall, 4.5oz. Discoloration with shrinkage with creeping up arms and legs. Underwear discolored. (See Appendix A Figures 13 & 14)

[illegible]

Table II. Accumulated Run Data (Cont.)

The two identification numbers appears above each matrix. On the left margin are the 20 manikin locations described in the text and shown in figure 1. The seven columns represent seven temperature sensors for each location. Zeros indicate that the temperature was not reached at that location.

	AMEC 1294041	2 SEC	AMEC 1294042	2 SEC	AMEC 1294043	2 SEC
U12F	0	0	0	0	0	0
U12G	0	0	0	0	0	0
U12H	0	0	0	0	0	0
U12I	0	0	0	0	0	0
U12J	0	0	0	0	0	0
U12K	0	0	0	0	0	0
U12L	0	0	0	0	0	0
U12M	0	0	0	0	0	0
U12N	0	0	0	0	0	0
U12O	0	0	0	0	0	0
U12P	0	0	0	0	0	0
U12Q	0	0	0	0	0	0
U12R	0	0	0	0	0	0
U12S	0	0	0	0	0	0
U12T	0	0	0	0	0	0
U12U	0	0	0	0	0	0
U12V	0	0	0	0	0	0
U12W	0	0	0	0	0	0
U12X	0	0	0	0	0	0
U12Y	0	0	0	0	0	0
U12Z	0	0	0	0	0	0
U13A	0	0	0	0	0	0
U13B	0	0	0	0	0	0
U13C	0	0	0	0	0	0
U13D	0	0	0	0	0	0
U13E	0	0	0	0	0	0
U13F	0	0	0	0	0	0
U13G	0	0	0	0	0	0
U13H	0	0	0	0	0	0
U13I	0	0	0	0	0	0
U13J	0	0	0	0	0	0
U13K	0	0	0	0	0	0
U13L	0	0	0	0	0	0
U13M	0	0	0	0	0	0
U13N	0	0	0	0	0	0
U13O	0	0	0	0	0	0
U13P	0	0	0	0	0	0
U13Q	0	0	0	0	0	0
U13R	0	0	0	0	0	0
U13S	0	0	0	0	0	0
U13T	0	0	0	0	0	0
U13U	0	0	0	0	0	0
U13V	0	0	0	0	0	0
U13W	0	0	0	0	0	0
U13X	0	0	0	0	0	0
U13Y	0	0	0	0	0	0
U13Z	0	0	0	0	0	0
U14A	0	0	0	0	0	0
U14B	0	0	0	0	0	0
U14C	0	0	0	0	0	0
U14D	0	0	0	0	0	0
U14E	0	0	0	0	0	0
U14F	0	0	0	0	0	0
U14G	0	0	0	0	0	0
U14H	0	0	0	0	0	0
U14I	0	0	0	0	0	0
U14J	0	0	0	0	0	0
U14K	0	0	0	0	0	0
U14L	0	0	0	0	0	0
U14M	0	0	0	0	0	0
U14N	0	0	0	0	0	0
U14O	0	0	0	0	0	0
U14P	0	0	0	0	0	0
U14Q	0	0	0	0	0	0
U14R	0	0	0	0	0	0
U14S	0	0	0	0	0	0
U14T	0	0	0	0	0	0
U14U	0	0	0	0	0	0
U14V	0	0	0	0	0	0
U14W	0	0	0	0	0	0
U14X	0	0	0	0	0	0
U14Y	0	0	0	0	0	0
U14Z	0	0	0	0	0	0
U15A	0	0	0	0	0	0

UT22	CLC1294044	2 SEC	CLC1294045	2 SEC	CLC1294046	2 SEC
UT22	0	0	0	0	0	0
UT20	0	0	0	0	0	0
UT21	0	0	0	0	0	0
UT23	0	0	0	0	0	0
UT24	0	0	0	0	0	0
UT25	0	0	0	0	0	0
UT26	0	0	0	0	0	0
UT27	0	0	0	0	0	0
UT28	0	0	0	0	0	0
UT29	0	0	0	0	0	0
UT30	0	0	0	0	0	0
UT31	0	0	0	0	0	0
UT32	0	0	0	0	0	0
UT33	0	0	0	0	0	0
UT34	0	0	0	0	0	0
UT35	0	0	0	0	0	0
UT36	0	0	0	0	0	0
UT37	0	0	0	0	0	0
UT38	0	0	0	0	0	0
UT39	0	0	0	0	0	0
UT40	0	0	0	0	0	0
UT41	0	0	0	0	0	0
UT42	0	0	0	0	0	0
UT43	0	0	0	0	0	0
UT44	0	0	0	0	0	0
UT45	0	0	0	0	0	0
UT46	0	0	0	0	0	0
UT47	0	0	0	0	0	0
UT48	0	0	0	0	0	0
UT49	0	0	0	0	0	0
UT50	0	0	0	0	0	0
UT51	0	0	0	0	0	0
UT52	0	0	0	0	0	0
UT53	0	0	0	0	0	0
UT54	0	0	0	0	0	0
UT55	0	0	0	0	0	0
UT56	0	0	0	0	0	0
UT57	0	0	0	0	0	0
UT58	0	0	0	0	0	0
UT59	0	0	0	0	0	0
UT60	0	0	0	0	0	0
UT61	0	0	0	0	0	0
UT62	0	0	0	0	0	0
UT63	0	0	0	0	0	0
UT64	0	0	0	0	0	0
UT65	0	0	0	0	0	0
UT66	0	0	0	0	0	0
UT67	0	0	0	0	0	0
UT68	0	0	0	0	0	0
UT69	0	0	0	0	0	0
UT70	0	0	0	0	0	0
UT71	0	0	0	0	0	0
UT72	0	0	0	0	0	0
UT73	0	0	0	0	0	0
UT74	0	0	0	0	0	0
UT75	0	0	0	0	0	0
UT76	0	0	0	0	0	0
UT77	0	0	0	0	0	0
UT78	0	0	0	0	0	0
UT79	0	0	0	0	0	0
UT80	0	0	0	0	0	0
UT81	0	0	0	0	0	0
UT82	0	0	0	0	0	0
UT83	0	0	0	0	0	0
UT84	0	0	0	0	0	0
UT85	0	0	0	0	0	0
UT86	0	0	0	0	0	0
UT87	0	0	0	0	0	0
UT88	0	0	0	0	0	0
UT89	0	0	0	0	0	0
UT90	0	0	0	0	0	0
UT91	0	0	0	0	0	0
UT92	0	0	0	0	0	0
UT93	0	0	0	0	0	0
UT94	0	0	0	0	0	0
UT95	0	0	0	0	0	0
UT96	0	0	0	0	0	0
UT97	0	0	0	0	0	0
UT98	0	0	0	0	0	0
UT99	0	0	0	0	0	0
UT100	0	0	0	0	0	0

Table III. Accumulated Run Data (Cont.)

The even identification number appears above each matrix. On the left margin are the 20 manikin locations described in the text and shown in table 1. The seven columns represent seven temperature sensors for each location. Zeros indicate that the temperature was not reached at that location.

[illegible][illegible]

Table III. Accumulated Run Data (Cont.)

The run identification number appears above each matrix. On the left margin are the 20 manikin locations described in the text and shown in table 1. The seven columns represent seven temperature sensors for each location. Zeros indicate that the temperature was not reached at that location.

	FSC1295053			3 SEC			NKCC1295054			7 SEC			NKCC1296055			2 SEC		
	U	O	U	U	O	U	U	O	U	U	O	U	O	U	U	O	U	
UT2F	220	230	240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
UT2B	220	230	240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
UT3F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
UT3B	220	230	240	250	260	270	280	0	0	0	0	0	0	0	0	0	0	
UT6F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
UT6B	220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
LT1F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
LT1B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
LT2F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
LT2B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
RA1F	220	230	240	250	260	270	280	220	230	240	250	260	270	280	220	230	240	
LA1F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	220	230	240	
RL1F	0	0	0	0	0	0	0	220	230	240	250	260	270	280	220	230	240	
RL1B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	220	230	240	
RL3F	220	230	240	250	260	270	280	220	230	240	250	260	270	280	220	230	240	
RL3B	0	0	0	0	0	0	0	220	0	0	0	0	0	0	220	0	0	
LL1F	220	230	240	250	260	270	280	220	230	240	250	260	270	280	220	230	240	
LL1B	220	230	240	250	260	270	280	0	0	0	0	0	0	0	220	230	240	
LL3F	0	0	0	0	0	0	0	220	230	240	250	260	270	280	220	230	240	
LL3B	220	0	0	0	0	0	0	220	230	240	250	260	270	280	220	230	240	

[illegible]

**Table IV. Assemblies With The Percent Body Burned
2-Second Exposure**

<u>Description</u>	<u>Symbol</u>	<u>No. Runs</u>	<u>Ave. Total Heat Exposure (Cal/cm²)</u>	<u>Percent Body Burned³</u>
100% F.R.T. 6.5oz/yd ² Cotton Chambray Shirt; 12oz/yd ² Denim Trousers	CCD	2	4.5	0
80/20 PFR Rayon-Nomex 6.5oz/yd ² Twill Coverall	RNT	2	8.3 ²	23
95/5 Nomex-Kevlar Cloque 5.5oz/yd ² Coverall	NKCC	3	5.6	25
100% F.R.T. Cotton 6.5oz/yd ² Coverall	CLC	3	5.2	25
95/5 Nomex-Kevlar 4.5oz/yd ² Enhanced Coverall	NKEC	3	4.8	29
95/5 Nomex-Kevlar 4.5oz/yd ² Coverall	NKC	2	6.0	33

3 Second Exposure

95/5 Nomex-Kevlar Cloque 5.5oz/yd ² Coverall	NKCC	3	5.3	15
95/5 Nomex-Kevlar Enhanced 4.5oz/yd ² Coverall	NKEC	2	6.8	33
95/5 Nomex-Kevlar Flight Suit Coverall, 4.5oz/yd ²	FSC	2	7.7	22

¹ F.R.T = Flame Retardant Treated

² A Single Value Percent body burn 46 percent at heat exposure of 8.3 Cal/cm²

³ At 250°F (121°C)

DISCUSSION

In evaluating the result of an environmental change it is always desirable to look back on a change that was measured well and was well behaved in that it could be called typical. In this respect, the wedge calorimeters were used in the present tests to give some objective measure of the intensity of individual fires. The results from these measurements are shown in table IV.

Tables II and III containing the results from direct observations show that most of the burning takes place on the lower limbs. The torso escapes burning for two reasons: 1) it is covered with a T shirt and 2) variability in the fire will lessen the heat flux seen by the torso in most cases. Shrinking which leaves the legs uncovered does not occur on the torso.

The movie footage is an important contribution to the results being a permanent record of what can be observed visually. The side camera views the manikin as it emerges from the flames and thus reveals whether the assembly is flaming at that time. In the present series, only one of the Rayon-Nomex Twill Coverall assemblies was flaming but the flames were out before the crane came to its resting position. The view from the other camera is obscured by a well developed fire as far as the manikin is concerned so that consideration will have to be given to moving it to the side position with a longer focal length lens so that emerging condition of the manikin can be better viewed.

The two-piece F.R.T. cotton chambray shirt and denim trouser ensemble performed best in this series. There was no measured body burn in the two trial runs made. Of the other ensembles the Nomex-Kevlar Cloque Coveralls was best. The changes taking place, shrinking, rippling in the fire is less detrimental in that the physical change does not expose the wearer. The change was called shrinkage but it was not the creeping kind that exposes ankles. It contracts on itself, finally smoothing and rippling.

The data obtained in this study is considered preliminary because fire exposures from one run to the next were quite variable and the number of runs conducted on each clothing assembly were insufficient to establish the statistical significance of the data for each assembly.

REFERENCES

1. Stoll, A.M., L.R. Monroe, M.A. Chianta, J.R. Piergallini and D.E. Zaccania. A Facility and Method for Evaluation of Thermal Protection. NADC-75286-40, 1 Dec 1975.
2. Stoll, A.M. and M.A. Chianta. Method and Rating System for Evaluation of Thermal Protection. Aerospace Med. 40 (11):1232-1237, 1969.

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APPENDIX A

ILLUSTRATIONS OF EACH ASSEMBLY
BEFORE AND AFTER EXPOSURE

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Figure 1 95/5 Nomex/Kevlar Coverall:4.5oz
Before



Figure 2 95/5 Nomex/Kevlar Coverall:4.5oz
After

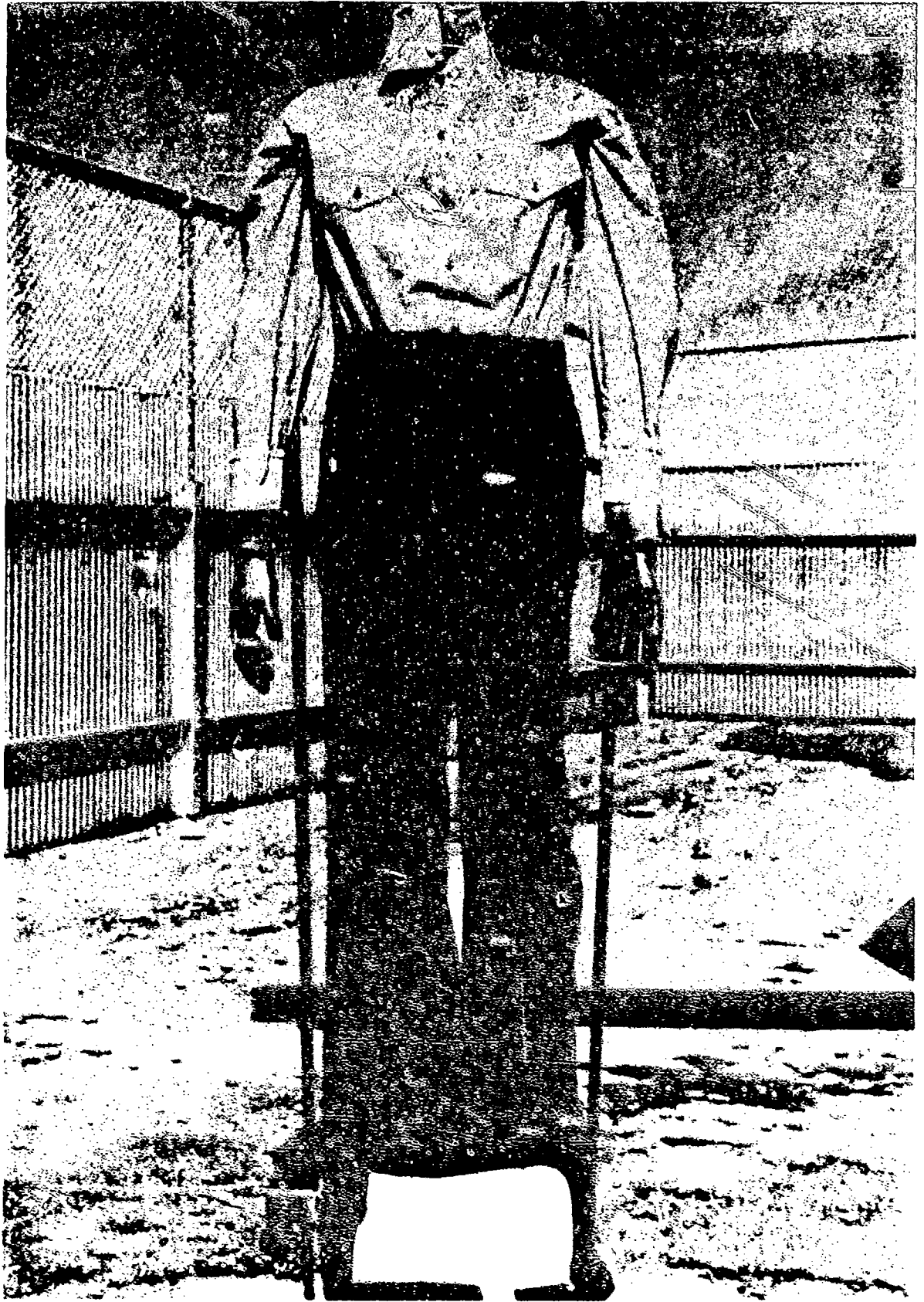


Figure 3 100% F.R. Cotton Chambray Shirt:6.5oz, Denim Trouser:12oz
Before



Figure 4 100% F.F. Cotton Chambray Shirt:6.5oz, Denim Trouser:12oz
After



Figure 5 80/20 Rayon/Nomex Twill Coverall:6.5oz
Before

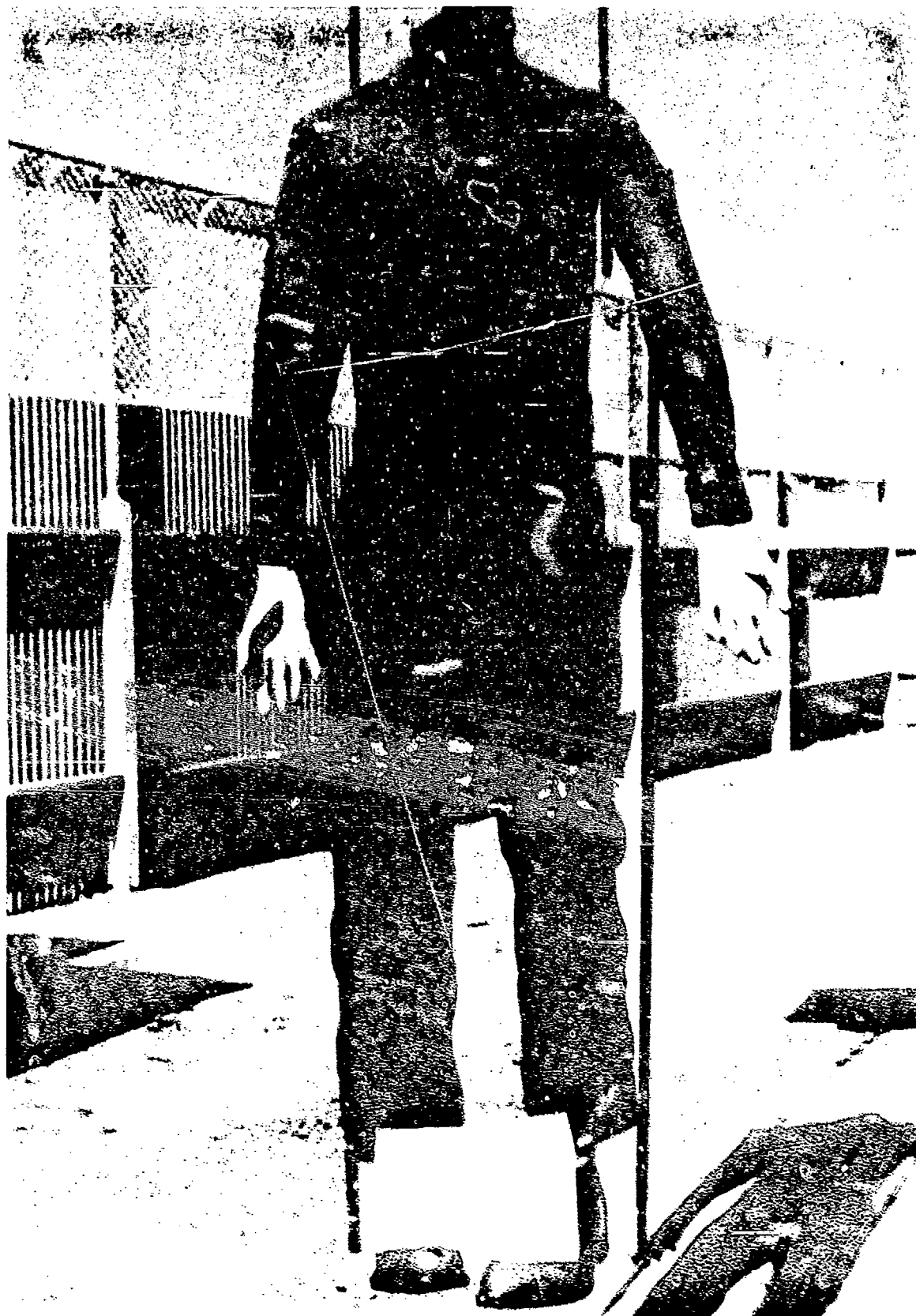


Figure 6 80/20 Rayon/Nomex Twill Coverall:6.5oz
After



Figure 7 95/5 Nomex/Kevlar Cloque Coverall:4.5oz
Before



Figure 8 95/5 Nomex/Kevlar Cloque Coverall:4.5oz
After



Figure 9 95/5 Nomex/Kevlar Enhanced Coverall: 4.5oz
Before



Figure 10 95/5 Nomex/Kevlar Enhanced Coverall:4.5oz
After

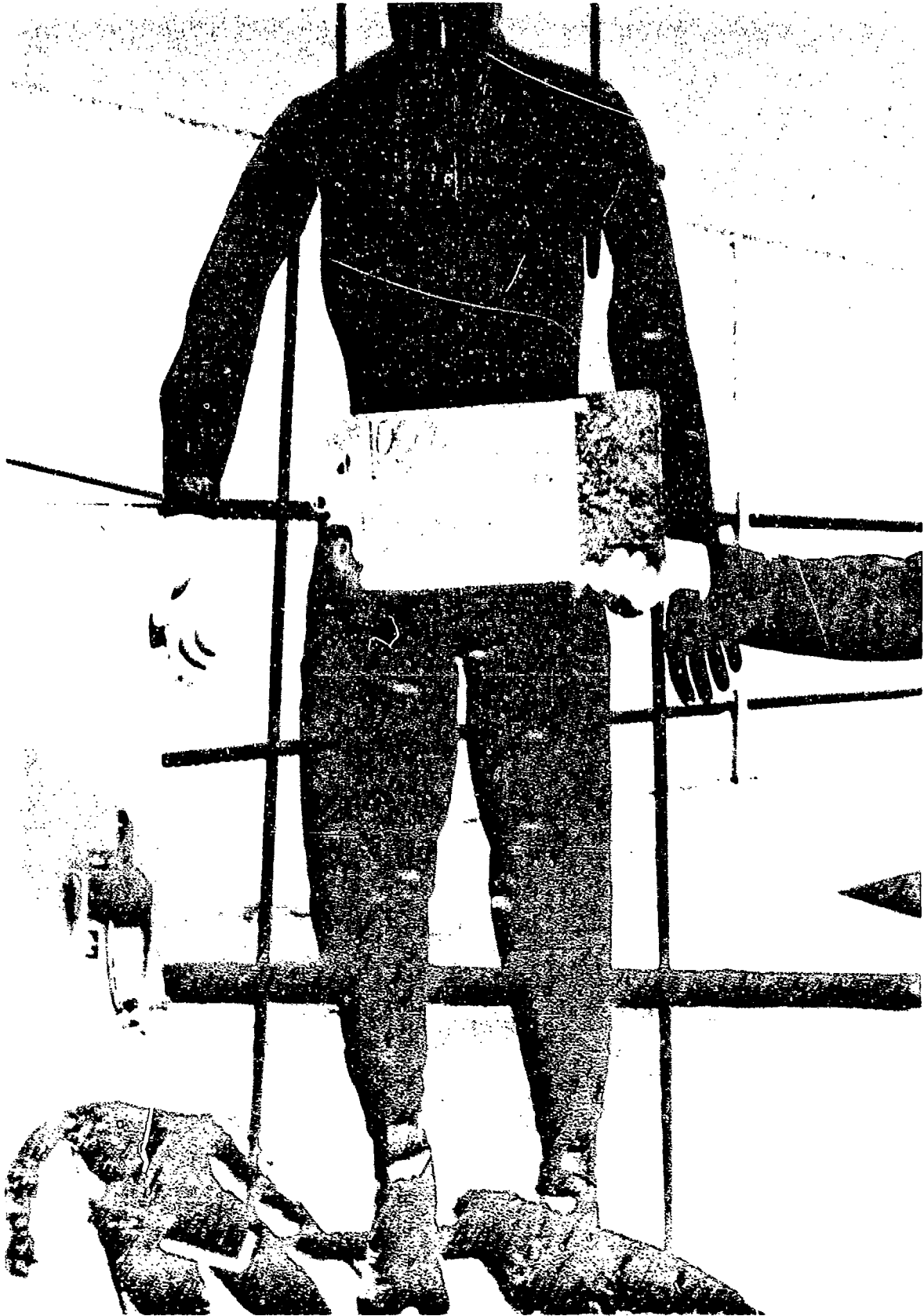


Figure 11 100% F.R. Cotton Coveralls: 6.5oz
Before



Figure 12 100% F.R. Cotton Coverall:6.5oz
After



Figure 13 95/5 Nomex/Kevlar Flight Suit Coverall:4.5oz
Before

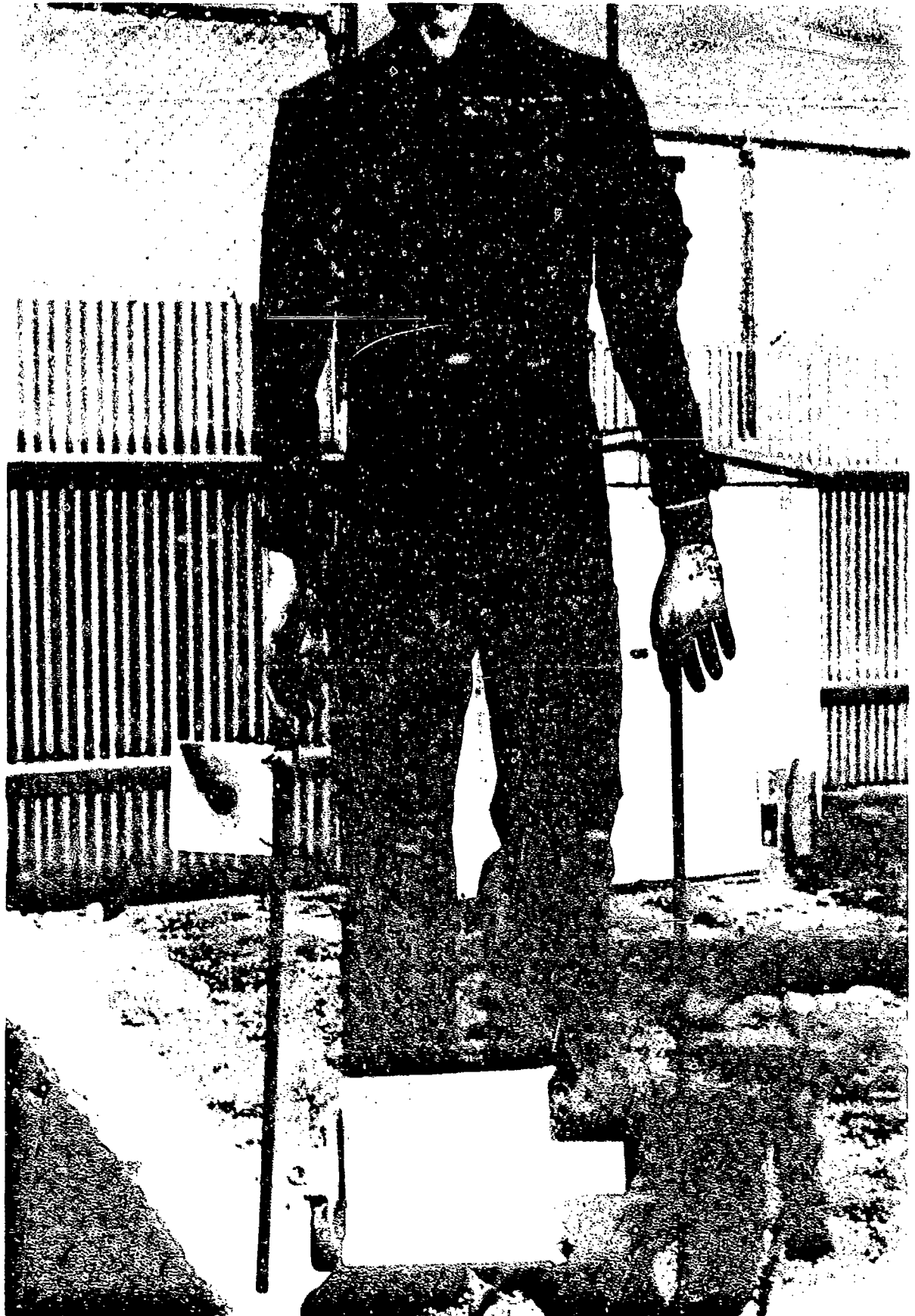


Figure 14 95/5 Nomex/Kevlar Flight Suit Coverall:4.5oz
After

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APPENDIX B

RESULTS FROM STILL PHOTOGRAPHS 035 THROUGH 056

- NKC 035 95/5 Nomex/Kevlar Coverall, 4.5oz. Overall: Considerable shrinkage as indicated by a loss of folds and wrinkles that existed before the exposure. Legs and arms are smooth and tight. The torso is less so. Anklets of strips of Velcro were effective in preventing creeping up the legs. No discoloration or other evidence of burning.
- NKC 036 Same (no photo).
- CCD 037 100% F.R.T. Cotton Chambray Shirt, 6.5oz. Denim Trousers, 12oz. shirt shows slight discoloration on the near torso and the left sleeve. Trousers little if any evidence of the exposure, perhaps a very slight, almost non-discernible brownish discoloration.
- CCD 038 Burned results from 037.
- RNT 039 80/20 Rayon/Nomex Twill Coverall, 6.5oz. Some shrinkage and brownish discoloration on front legs; front torso little affected. Rear torso and legs body scorched as indicated by brownish discoloration. Left leg is burned through.
- RNT 040 Same (no photo). Emerged in flames until stop (1-2 seconds).
- NKCC 041 95/5 Nomex/Kevlar Cloque Coverall, 5.5oz. Shrinkage as indicated by loss of wrinkles and tightening of folds, most prominent in legs, present in the lower torso is almost absent in the shoulders. These effects are much less discernible from the rear. Photo with the coverall unzipped shows no effects on the underwear.
- NKCC 047 95/5 Nomex/Kevlar Cloque Coverall, 5.5oz. Practically no effects, shrinkage hardly discernible, front and back. Photos of exposed leg sensors show spotty changes (these will be recorded as changed despite the small area). Photos of underwear show no changes. All of sensors reported changed on this run were spotty.
- NKCC 048 95/5 Nomex/Kevlar Cloque Coverall, 5.5oz. Clear rippling shrinkage entire front, torso, arms and legs. Much less so from the rear. Somewhat fewer sensors changed than 048.
- NKCC 049 95/5 Nomex/Kevlar Cloque Coverall, 5.5oz. Coveralls altogether unscathed, no sensors changed.

- NKCC 054 95/5 Nomex/Kevlar Cloque Coverall, 5.5oz. Rippling shrinkage, slightly indicated in front legs, is more pronounced in the back of legs. However records show that the front sensors were more affected, the entire indicator turning black. It could be that the coverall shrunk against the sensor in front, exposing it to the high temperature.
- NKCC 055 95/5 Nomex/Kevlar Cloque Coverall, 5.5oz. Most severe exposure for the Cloque. Severe shrinkage front and back. Some discoloration on the right leg with creeping of material up the manikin leg exposing it. (Velcro fasteners were used).
- NKEC 042 Nomex/Kevlar Enhanced Coverall, 4.5 oz. Considerable shrinkage over the entire body with creeping up the leg. Underwear shorts appear scorched in front.
- NKEC 043 Nomex/Kevlar Enhanced Coverall, 4.5oz. Much less shrinkage: front shows some, back shows none.
- NKEC 050 Nomex/Kevlar Enhanced Coverall, 4.5oz. No discernible change after.
- NKEC 051 Nomex/Kevlar Enhanced Coverall, 4.5oz. Shrinkage in legs.
- NKEC 052 Nomex/Kevlar Enhanced Coverall, 4.5oz. Extreme discoloration and shrinkage front and back on torso arms and legs. Underwear discolored by the coverall green to brown, the latter indicating scorching front.
- CLC 044 100% F.R.T. Cotton Coverall, 6.5oz. Left, front, torso, arm and leg shows scorching (brown) and areas of charring principally on the leg. Back is much less effected. Underwear is intact.
- CLC 045 100% F.R.T. Cotton Coverall, 6.5oz. Left, front, torso, arms and leg shows scorching (brown) and areas of charring more extensive than 044. Material burned away left leg, back leaving a hole. Underwear discolored in places on the left side, torso. E.F. slight. Slight flaming on emergence from the pit.
- CLC 046 100% F.R.T. Cotton Coverall, 6.5oz. Left, front, torso, arms and leg shows scorching (brown) and areas of charring, less extensive than 044. Back is much less effected. Underwear intact and unmarked.
- FSC 053 95/5 Nomex/Kevlar Flight Suit Coverall, 4.5oz. Discoloration of left, torso, arm and leg, front and back (brown). Shrinkage all over with creeping up the arms and legs. Underwear discolored on left side back (worse) and front.
- FSC 056 95/5 Nomex/Kevlar Flight Suit Coverall, 4.5oz. Considerable discoloration at the legs front and back and the lower torso, back. Underwear discolored extensively back, buttocks and torso.

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SUPPLEMENTARY

INFORMATION

AD-A125820

Subj: Addendum to NADC Report No. 82121-60

1. Table I of the subject report lists the manikin sensor sites. To further assist with their identification, an amended Table I is enclosed which includes anatomically descriptive words. Attached also is a diagram showing the location of the sites.

GEORGE H. KYDD

84 01 26 005

Table 1. Sensor Sites

<u>Current</u>	<u>Past</u>
1. UT2F Upper Torso 2 Front, left breast	T1
2. UT2B Upper Torso 2 Back	T2
3. UT3F Upper Torso 3 Front, right breast	T3
4. UT3B Upper Torso 3 Back	T4
5. UT6F Upper Torso 6 Front, naval	T5
6. UT6B Upper Torso 6 Back	T6
7. LT1F Lower Torso 1 Front, pelvic area right	T13
8. LT1B Lower Torso 1 Back	T14
9. LT2F Lower Torso 2 Front, pelvic area left	T15
10. LT2B Lower Torso 2 Back	T16
11. RA1F Right Arm Upper 1 Front	A10
12. LA1F Left Arm Upper 1 Front	A11
13. RL1F Right Leg 1 Front, thigh	L6
14. RL1B Right Leg 1 Back	L7
15. RL3F Right Leg 3 Front, lower leg	L8
15. RL3B Right Leg 3 Back	L9
17. LL1F Left Leg 1 Front, thigh	L27
18. LL1B Left Leg 1 Back	L18
19. LL3F Left Leg 3 Front, lower leg	L19
20. LL3B Left Leg 3 Back	L20

SENSOR MOUNTING SHEET
SHOWING MANIKIN SENSOR LOCATIONS

Code	Julian Date	Run Number
Right Left		
Description		Front (page 1)
Front 2 Front (page 2)		

Sensor Mounting Sheets for the front side of the manikin.
Two for the backside are similar except that the arms are not represented.