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TR-02-92
***Development of an Integrated Protective
Suit for Riot Police
Phase A: Jacket Design***

Biokinetics and Associates Limited

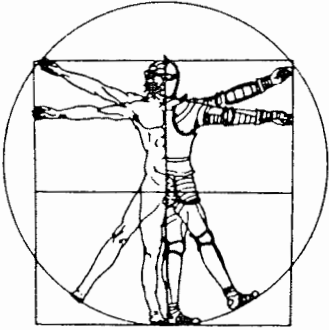
TECHNICAL REPORT

March 1992

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DEVELOPMENT OF AN INTEGRATED PROTECTIVE SUIT FOR RIOT POLICE

PHASE A: JACKET DESIGN

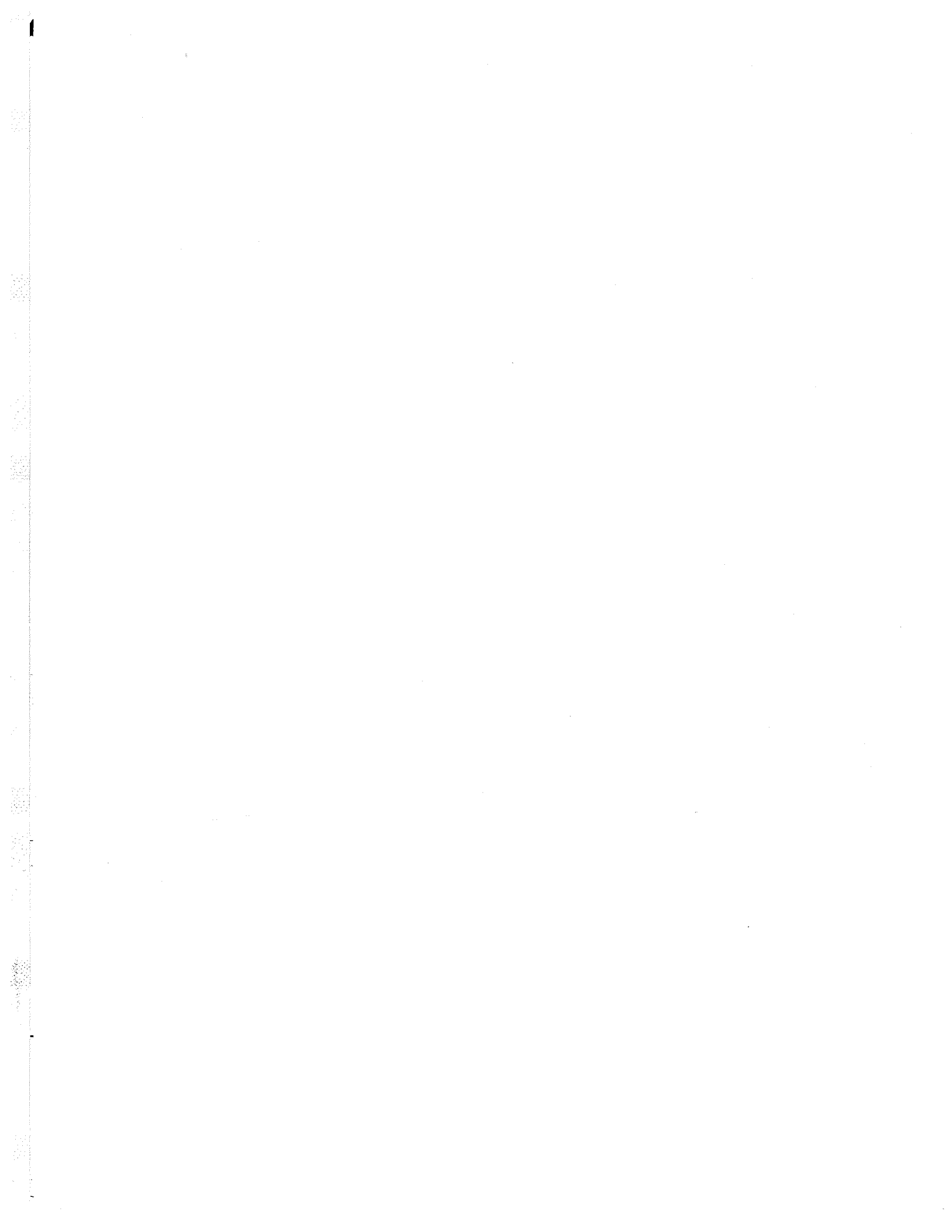
prepared for

Science and Technology Branch
Royal Canadian Mounted Police

by

Biokinetics and Associates Ltd.

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1. Introduction

Police officers in crowd control situations currently wear various adaptations of hockey or football padding to protect their upper body, knees, thighs, groin and shins under standard issue coveralls. Such equipment is often cumbersome, uncomfortable and the true protective value of such accessories in riot situations in Canada is largely undefined.

The current project involved the design of a protective jacket to meet the specific protective needs of Canadian riot police without effecting mobility. Drawing on modern technology and the latest in protective materials, the jacket was designed to provide protection against direct blows, thrown objects and ricocheting projectiles as well as threats associated with penetrating or cutting devices and with "Molotov cocktails". At the same time the jacket was designed to take into account the range of body sizes it will have to accommodate, the need to interface with existing equipment, as well as the need for lightness, comfort and flexibility.

The long term objective to the proposed project is the development of an integrated two piece protective suit. The first phase described herein is the design of a protective jacket. To facilitate the design and development process, a first generation wearing model of the protective jacket was fabricated to fit an Ottawa-based RCMP riot officer.

This prototype jacket was fabricated outside the contract requirements, however, it will be available to assess the fit and comfort of the new jacket design as well as compatibility with existing equipment. Accordingly, the jacket may be modified before final patterns are prepared for the fabrication of pre-production units in all sizes. The pre-production jackets shall need to be evaluated in the field and subjected to laboratory tests as completion of the design process.

The work was conducted with regular input from the client. This was done through "team meetings" between Biokinetics research staff and representatives from the Canadian Police Research Centre, CPRC, and the Royal Canadian Mounted Police, RCMP.

2. Identification of Criteria

Members of the Ottawa-based RCMP police riot troop were interviewed to establish their views of the deficiencies of current apparel. A general set of specifications was prepared from their comments and presented to the project team for review and input. This preliminary set of design and performance criteria, and the minutes of the meeting summarizing the input from the project team are presented in Appendix A. The final set of primary criteria which were so established, are listed below.

Design Criteria

Size	Fit males (XL to tall) to small females Individual fit
Colour	Dark navy blue with other colours available.
Comfort	Comfortable for 3-5 hours sitting/waiting time and 30 minutes in-action. Light weight. Comfortable in temperatures -10°C to +25°C
Flexibility	Flexible for all riot situation activities, viz. <ul style="list-style-type: none">- shield use- running- walking over debris- operating shoulder to shoulder- recovery after fall- in push-pull rioters
Appearance	Consistent with RCMP style Not too "aggressive" looking
Cleaning	Stain resistant Washable, using home washer/dryer <ul style="list-style-type: none">- no shrinkage- no colour loss
Maintenance	Routine repair without reducing protective level

Life expectancy

Minimum 5 years

Interface

Interface with existing equipment specifically.

Performance Criteria

Fire retardant

Acid splash resistant

Direct impacts

Low mass, high velocity (eg. sling shot golf balls)

High mass, low velocity (eg. ricocheting piece asphalt)

3. Design Concepts

Concepts to provide the required level of protection without significantly effecting mobility and comfort were generated. Different concepts for the overall look and styling of the jacket as well as individual component concepts were presented to the project team and their input sought. In this way, a preliminary concept was identified for further consideration by the research team. The preliminary design concept included the following features:

Appearance

Similar to the new patrol jacket in navy with possibly leatherette trim (see - below).

Expanding back vent.

Materials

Exterior in navy "Nomex III" with reinforced shoulder and zip cover in fire retardant leatherette. For consideration, reinforced areas for cutting resistance, eg. "kevlar" collar.

"Nomex" fitted with interior padding in stretch "nylon" envelopes (as per hockey girdle) for arms of jacket,

Padding - double density cross-linked polyethylene foam.

Jacket lined with black "Coolmax" cloth, permanently secured to "Nomex III" with separation along base.

Zipper and "Velcro" front fastening and snap adjustment for lower band and cuffs.

Machine washable (including padding).

Other Design Considerations

Sleeve loop over thumb

Pocket size

Padding coverage confined to back, sides of jacket, over shoulders, elbows and lower arms (ie., limited front padding).

Loose lower band to allow jacket return after arms raised.

Interior pocket for drink bottle.

As the concept design was developed, it was reviewed by the project team and accordingly, some modifications were implemented. Extracts from the minutes of the project team meetings which summarize these design consideration are included as Appendix B of this report.

4. Material Testing

Fabric and foam samples of potentially suitable materials were obtained, and selected materials were tested to assess such critical features as flammability and energy absorbing characteristics. A summary of these tests as presented to the project team is given in Appendix C.

Staining and shrinkage tests were also conducted on a sample of "Vulkan" fabric. The sample was stained with eggs, dried overnight and then subjected to a normal machine wash and dry. The material washed clean and the overall shrinkage was less than 3%.

As a result of the testing and given the colour options, costs and availability of the different materials, the following materials were selected for use in the fabrication of the first prototype:

Jacket Shell	-	"Vulkan"
Jacket Liner	-	Torso lined with "Coolmax"
	-	Sleeves lined with "Spandex"
Foam Padding	-	Padding inserts of a foam laminate " $\frac{1}{2}$ LD70 + $\frac{1}{4}$ HD80"

Local suppliers of these materials (excluding "Spandex") are given in Appendix D.

5. **New Jacket Design**

The new jacket includes the following primary design features:

Exterior shell

Double-end zipper

"Velcro" front overlap (in case of zipper failure)

Lower edge designed to promote jacket return (no permanent "ride-up")

No shoulder seams

No sleeve cuffs (for improved glove interface)

Thumb loop (to keep sleeves down)

Back vent for full range of movement

Front pleat for full range of movement

Exterior expandable pocket for radio

Interior pocket for water bottle.

Padding Units

Single padded unit covering upper back, over shoulders, over clavicles and covering down to lower ribs. Padding secured inside to exterior shell.

Upper arm and elbow/lower arm padded units - fitted in envelopes in "Spandex" sleeve liner.

Lining

Torso lining of "Coolmax" for comfort and perspiration absorption

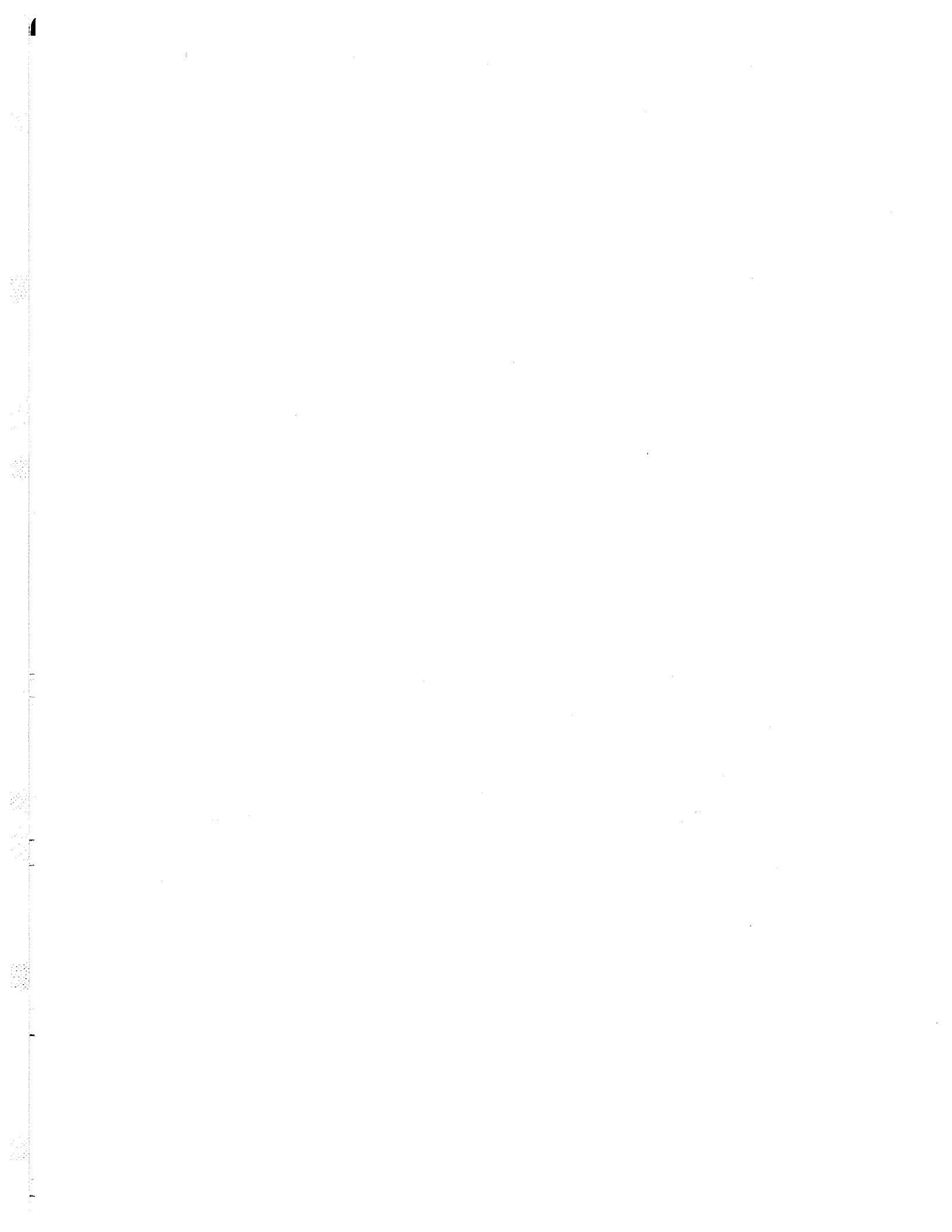
Sleeve lining of "Spandex" to retain padded units in position.

6. Conclusions

A new protective jacket has been designed specifically for police riot officers. A first generation prototype of this jacket has been fabricated and patterns prepared to fit a male subject (size large). Evaluation of this complete new design should be undertaken to complete the design process before the jacket patterns are finalized and prepared in all sizes for large scale production of the protective suit.

APPENDIX A

PRELIMINARY CRITERIA AND INPUT FROM PROJECT TEAM



**Minutes of Meeting at Biokinetics and Associates Ltd.
December 16, 1991**

**RE: Development of Integrated Protective Suit for Riot Police
New Jacket Design**

Attendees:

Phillip Banks	Security Engineering Branch, RCMP
Rick Bowlby	Services and Supply, RCMP
Jacques Fontaine	Information Access Directorate, RCMP
Tom Gibson	Biokinetics and Associates
Jocelyn Pedder (chair)	Biokinetics and Associates
Al Pilon	General Enforcement Branch, RCMP
Pat Shafer	Health Services, RCMP
Terry Smith	Biokinetics and Associates
Monique Stenhouse	Science and Technology Branch, RCMP
Andrew Wardroper	Material Development and Specifications Section, RCMP

Introduction

This meeting between Biokinetics' research staff and representatives from the Royal Canadian Mounted Police was held to initiate a project to develop a new protective jacket for riot police. The proposed work was outlined by J. Pedder as follows:

Project Outline

The long term objectives of the work is to develop an integrated two piece protective suit to meet the specific protective needs of Canadian riot police without effecting mobility. It is anticipated that the suit will replace the various add-on protective elements currently worn by riot police such as hockey and football padding for the elbows, shoulders, knees, thighs, groin and shins. The first phase of the project is the design of a protective jacket. This phase of the project is scheduled for completion by March 31, 1992 with the preparation of patterns (size large only) and material specifications for the new jacket design.

The project shall be conducted by Biokinetics and Associates Ltd. with regular input from the client (RCMP) through "team meetings". The proposed work plan was summarized at the meeting. [For clarification a copy was appended to the original copy of the minutes].

It was agreed that present members would comprise of the project team and that Monique Stenhouse (presenting the client), would liaise with Jocelyn Pedder of Biokinetics in the coordination of project meetings and critical design decisions. A team meeting will be scheduled at the completion of each of the four major activities.

Identification of Criteria

A preliminary set of design and performance criteria (prepared during previous meetings with the RCMP), was distributed. Each item was discussed and the following comments deemed pertinent.

- | | |
|--------|---|
| Sizes | <ul style="list-style-type: none">• Fit males and females from males (38 regular, 56 tall) to small female.• Individual fit for personal issue.• A. Wardroper will supply available sizing data. **** |
| Colour | <ul style="list-style-type: none">• RCMP, dark navy blue |

- Interface
 - Ballistic vest copy requested for design team. ****
 - T-shirt
 - Riot Helmet
 - Gas mask
 - Gas bag and vest, copy requested for design team. ****
 - Gloves, broom ball (SERT wear officer's dressing glove)
 - Baton, leather loop held around thumb and then around hand.
 - Shields
 - Gas gun
 - fire arms, "cover team" only

- Comfort
 - Troops may be deployed all day, but sitting in bus much of the time, typically active 35 minutes - 2 hours maximum.

- Items Carried
 - At present 2 breast pockets - 1 for radio (side depends on individual), wiring on inside.
 - Note pads, pen
 - In belt handcuffs (plastic ties)
 - Commanders carry wire-cutters in trouser legs.
 - Water bottle (M. Stenhouse to supply sample). ****

- Cleaning
 - Equipment used at least once per month training.
 - Preferred if troop member can self-clean suit.
 - No staining
 - No shrinkage
 - No colour loss

- Maintenance
 - Available
 - Once damaged can't be repaired? (Biokinetics to answer).

- Life Expectancy
 - Target minimum 5 years.

- Light Weight
 - Important

- Mobility
 - Activities in riot situation:
 - running
 - move fast at a jog
 - sitting on a bus
 - dismounting bus
 - push and pull with rioters
 - no sharp turns
 - "spotters" may need to climb ladders
 - walking over debris, barricades
 - operate shoulder to shoulder with "fighting room" - solid block not critical.
 - If fall, get up from front or rear.

Insignia/Identification

- No identification or rank, just word "Police" front or back, vertical or horizontal, removable. Whether reflective or not, not an issue.

Appearance

- Not too bulky, not too "aggressive" looking
- Not excessive padding
- Look should be consistent with RCMP style.
- New patrol jacket - ?prototype at headquarters. ****
- New coveralls plus interim buy of Vulcan shirt looks too aggressive and bulky.
- Riot jacket should be consistent in styling/looks with patrol jacket.
- Riot jacket needs to be long enough or designed to stop jacket riding-up, eg., crotch strap.

Performance Criteria

Fire retardant - YES, eg. Mototov cocktails.

Ballistic (including cross bow and sling shot) - NO

Acid Splashes - YES

Other thrown hazards experienced in Canada:

ball bearings	15 feet range,
rocks	horizontal (most common) or
marbles	lobbed, projected, ricocheting
golf balls	projectiles, (in cities overhead
tennis balls	hazards possible).
asphalt	
bricks	

Direct contacts:

- Baseball bats
- 2 x 4's, wood
- Steel tip
- Knives, cutting, exception - secondary hazards.

Temperature Range

- -20° to +40°, October to February riot uncommon.
- Rain, waterproofing possible need.

Miscellaneous Points

- Jewellery, watches etc. - all removed
- Fluid intake important, flat plastic water bottles worn.
- May eat on bus when wearing suit
- Speed of donning - some seconds available for final dressing.
- Speed of removal - able to strip fast if hazard exposure to skin, zipper rather than buttons.
- Minimum padding re-emphasized, prefer padding not easily removed, cushion fitting a possibility on first wear.

Date of Next Meeting: Monday January 20, 1992 at 1:00 p.m. at Biokinetics and Associates Ltd.

The minutes were prepared by J. Pedder and are subject to confirmation at the next project team meeting.

PRELIMINARY SET OF CRITERIA AS DISTRIBUTED

Design Criteria

Light weight

Flexible

- for high mobility

Comfortable

- over long periods in all temperatures
- kneeling and standing

Interface with existing equipment, shield, helmet, gas mask

Maintenance

- easy to clean and repair

Colour fast when worn

Sizes

- minimum sizes to fit full range males (and females)

Appearance

- colour, look, style

Performance Criteria

Fire retardant

- eg., Molotov cocktails

Impact protection

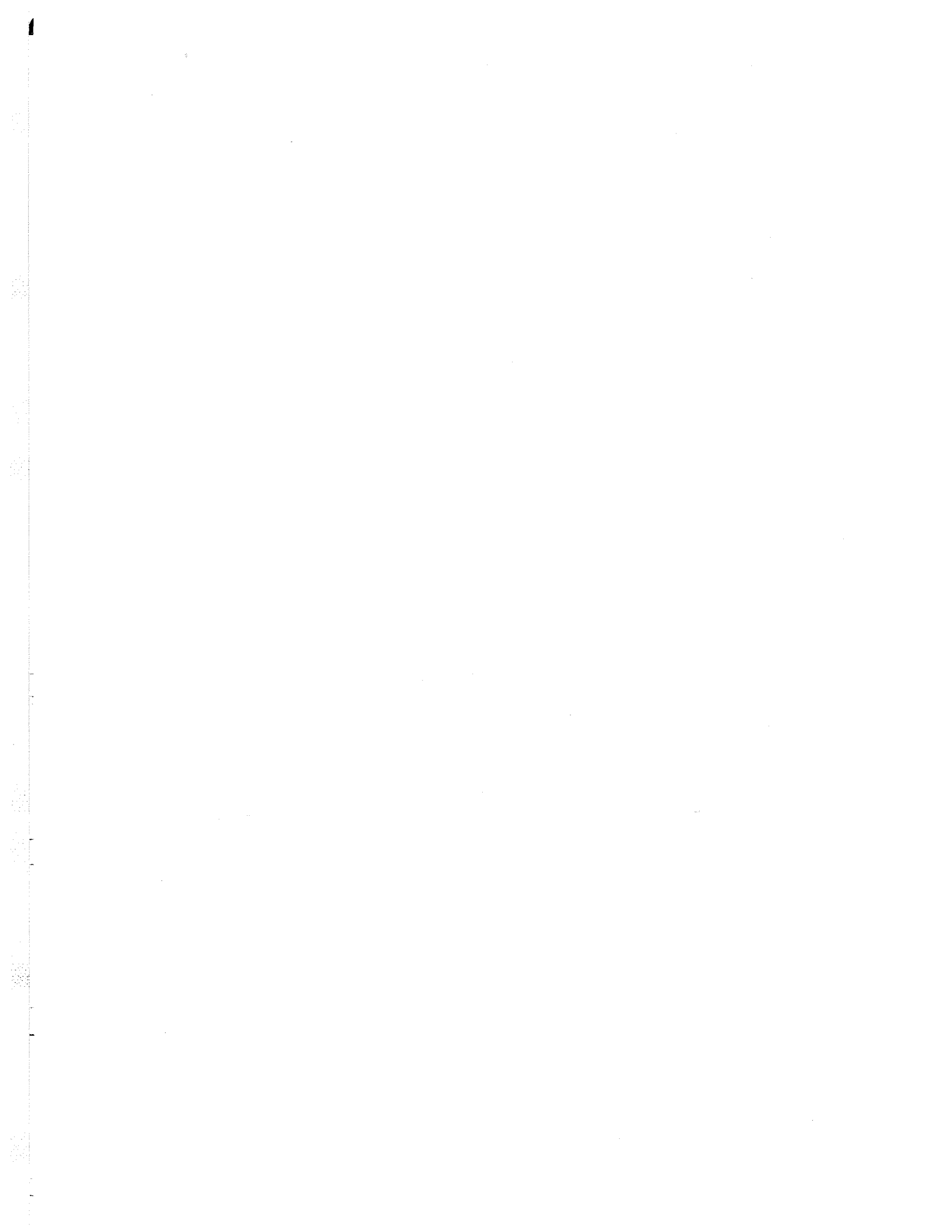
- thrown objects
- ricocheting projectiles
- direct blows

Tear/puncture resistance

- eg., broken glass, sharp projectiles, "Ninja Stars"

Temperature range

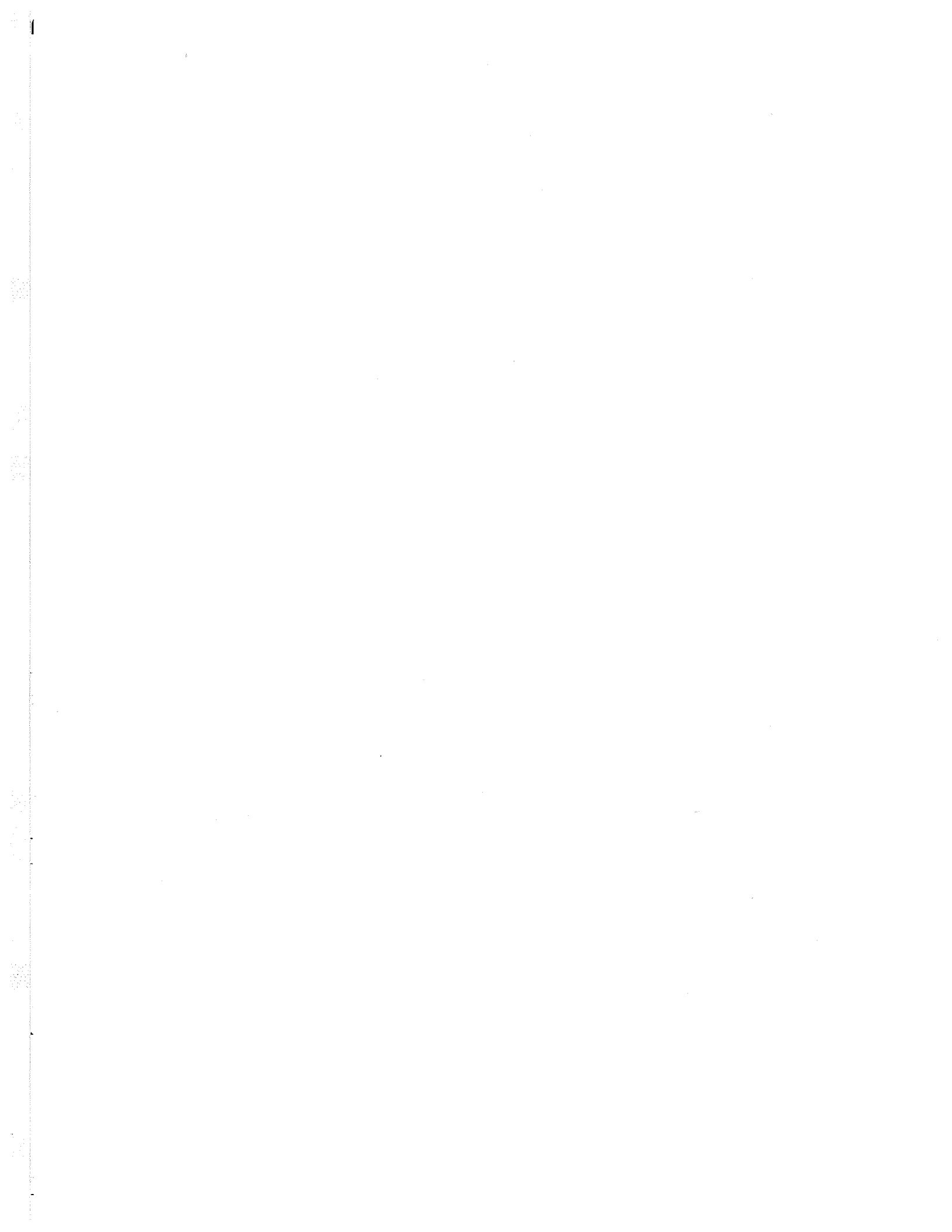
- effective -40° - 40°C



APPENDIX B

EXTRACT FROM MINUTES OF PROJECT TEAM MEETING

JANUARY 20, 1992



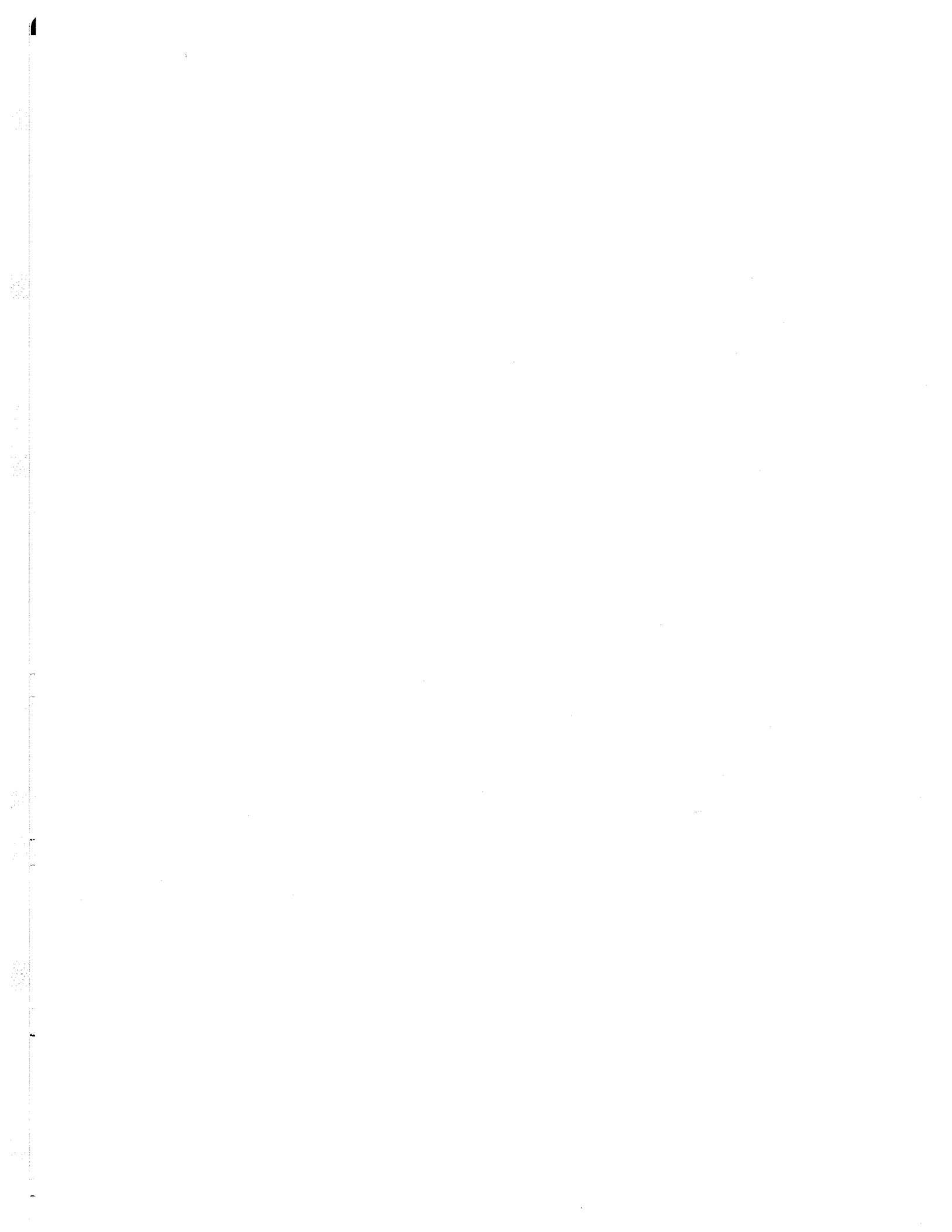
Design Concept

Discussed preliminary design concept - comments:

- expanding back vent, known as "bi-swing" back
- prefer no leatherette
- neck will be covered by hockey neck - guard incorporated in collar.
- water proofing not a problem (post-meeting conversation with A. Pilon who reported BC officers request for rain protection).

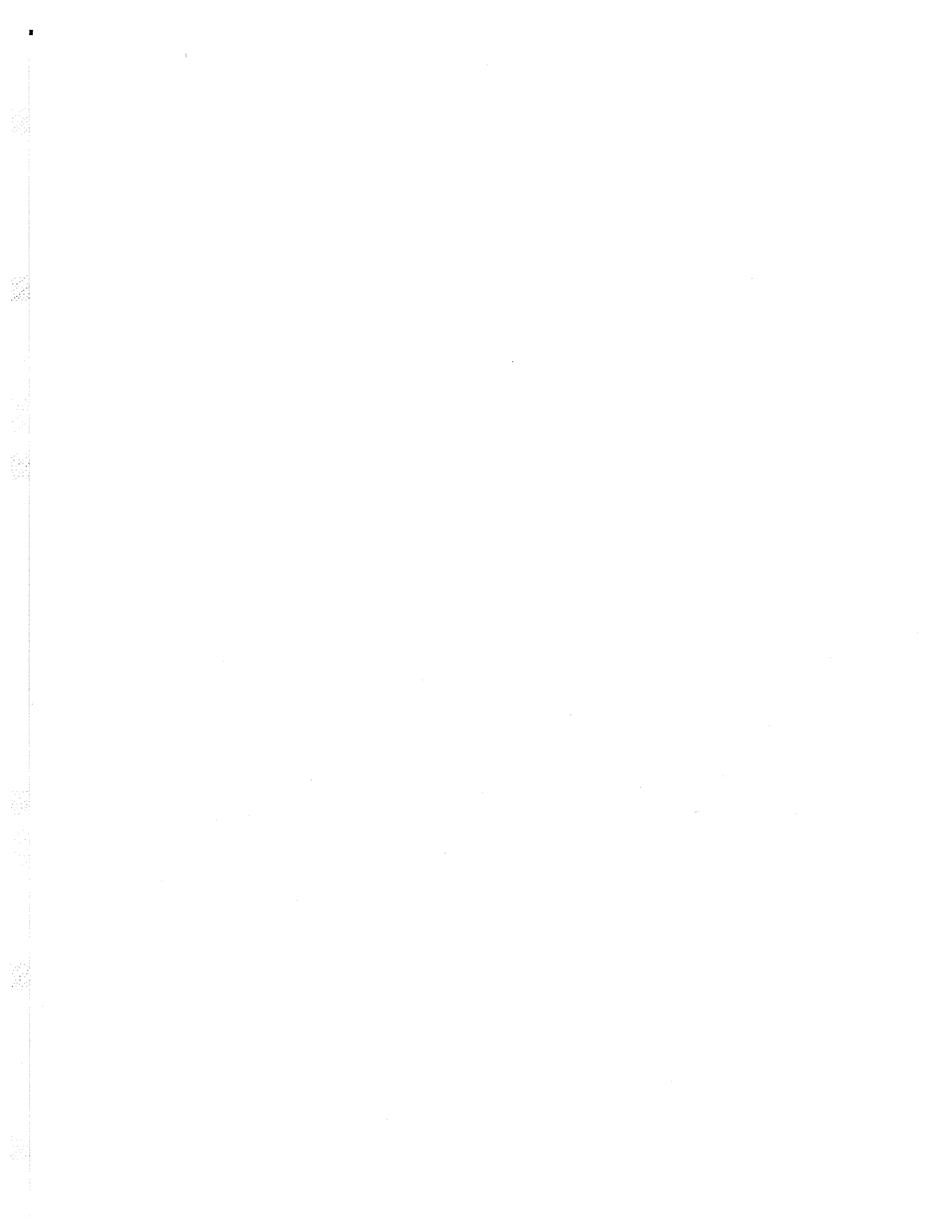
Areas to be Padded

- Head blows biggest problem, blunt more than slash, eg. hockey sticks.
- Primary body areas to be protected from blows are upper shoulders, forearms, hands, neck, major targets being upper shoulder and forearms.
- Padding must stay in position, concern about padding in "envelope" is fit and moves out of position.
- Bullet proof vest provides some chest impact protection. Available to all RCMP troops, worn by 95%. Agreed future vest with energy absorbing padding for other police forces. Chest also more likely to be defended by self. In summary, at this stage, assume vest will provide sufficient chest padding.
- Back padding - falls biggest concern, not blows to back. Tail bone injuries do occur, sitting comfort important - hockey girdle tail-bone padding ok.



APPENDIX C

SUMMARY OF MATERIAL TESTS



Riot Suit Impact-Absorbing Foam Tests

1. High-mass/low-velocity impact

Foam samples were impacted with a 2.85kg, 7.62cm (3.0in.) diameter impactor at energy levels of 14J (3.1m/s), 21J (3.8m/s) and 28J (4.4m/s). The impactor was equipped with a linear accelerometer to measure the deceleration of the impactor upon striking the foam sample. "Super-low-pressure" Fuji-film was used under the foam sample as a comparative pressure distribution indicator. Total thickness was constrained to less than 20mm (0.8in.).

14J impacts

foam	peak g
1/4LD45 + 1/4HD80	127
1/4LD45	504
1/4LD70 + 1/4HD80	207
1/4LD33 + 3/8HD80	105
1/4LD45 + 3/8HD80	108
1/4LD70 + 3/8HD80	100

21J impacts

foam	peak g
.33LD70 + 1/4HD80	162
3/8LD33 + 1/4HD80	218
3/8LD45 + 1/4HD80	178
1/2LD70 + 1/4HD80	113
1/2LD70	180
1/2EVA75 + 1/4HD80	148
1/2EVA75	343
1/4LD33 + 3/8HD80	151
1/4LD45 + 3/8HD80	137
1/4LD70 + 3/8HD80	146

28J impacts

foam	peak g
1/2EVA75 + 1/4HD80	197
9/16LD33 + 1/4HD80	278
9/16LD45 + 1/4HD80	172
9/16EV50 + 1/4HD80	278
1/4LD70 + 1/4HD80	401
1/4LD33 + 3/8HD80	213
1/4LD45 + 3/8HD80	261
1/4LD70 + 3/8HD80	257
3/8LD33 + 3/8HD80	286
3/8LD45 + 3/8HD80	205

The lowest deceleration values for each impact level are noted with an asterisk. All lowest values corresponded with two of the three foams LD45, LD70 and HD80. A repeat of the tests at all available combinations of the LD and HD foams (keeping the total thickness under 20mm (0.8in.)) was performed at each energy level. In the above tests, the Fuji-film indicated a direct correlation between g-levels and load spreading. For this reason, Fuji-film was not needed nor was it used in the following tests.

foam	14J impact peak g	21J impact peak g	28J impact peak g
3/8LD45 + 1/4HD80	116	235	363
3/8LD45 + 3/8HD80	95	162	188
9/16LD45 + 1/4HD80	86	159	253
1/4LD70 + 1/4HD80	132	310	471
1/4LD70 + 3/8HD80	111	143	294
1/2LD70 + 1/4HD80	83	118	167

The last entry, the combination of 1/2LD70 + 1/4HD80, gave the best energy absorption at all severity levels.

2. Low-mass/high-velocity impact

The six combinations of foams that performed best in the high-mass/low velocity impacts were then tested in low-mass/high-velocity impacts. A high-powered hunting sling-shot was used to propel 3/8in., 1.4gm hunting shot and a standard 45.1gm golf ball at foam samples at a distance of 2.0m. The sling-shot was stretched 25.0cm in each case at a draw load of 7.5kg. The exit velocities were estimated to be 74m/s for the hunting shot and 20m/s for the golf ball. "Super-low pressure" Fuji-film was inserted between the foam and a solid flat surface in each test. The ballistic vest lent to Biokinetics was tested in this set for comparative purposes

The results based on the Fuji-film are subjectively arranged from best to worst as follows:

BEST	3/8LD45 + 3/8HD80
	1/2LD70 + 1/4HD80
	9/16LD45 + 1/4HD80
	3/8LD45 + 1/4HD80
	1/4LD70 + 3/8 HD80
	ballistic vest
WORST	1/4LD70 + 1/4HD80

The top two combinations, however, were so close as to almost be indistinguishable.

Conclusion

Based on the best performance in the high-mass/low-velocity impact test and the virtual tie for best performance in the low-mass/high-velocity impact test, the 1/2LD70 + 1/4HD80 foam laminate is chosen as the best combination for the riot suit.

Riot Suit Fabric Testing

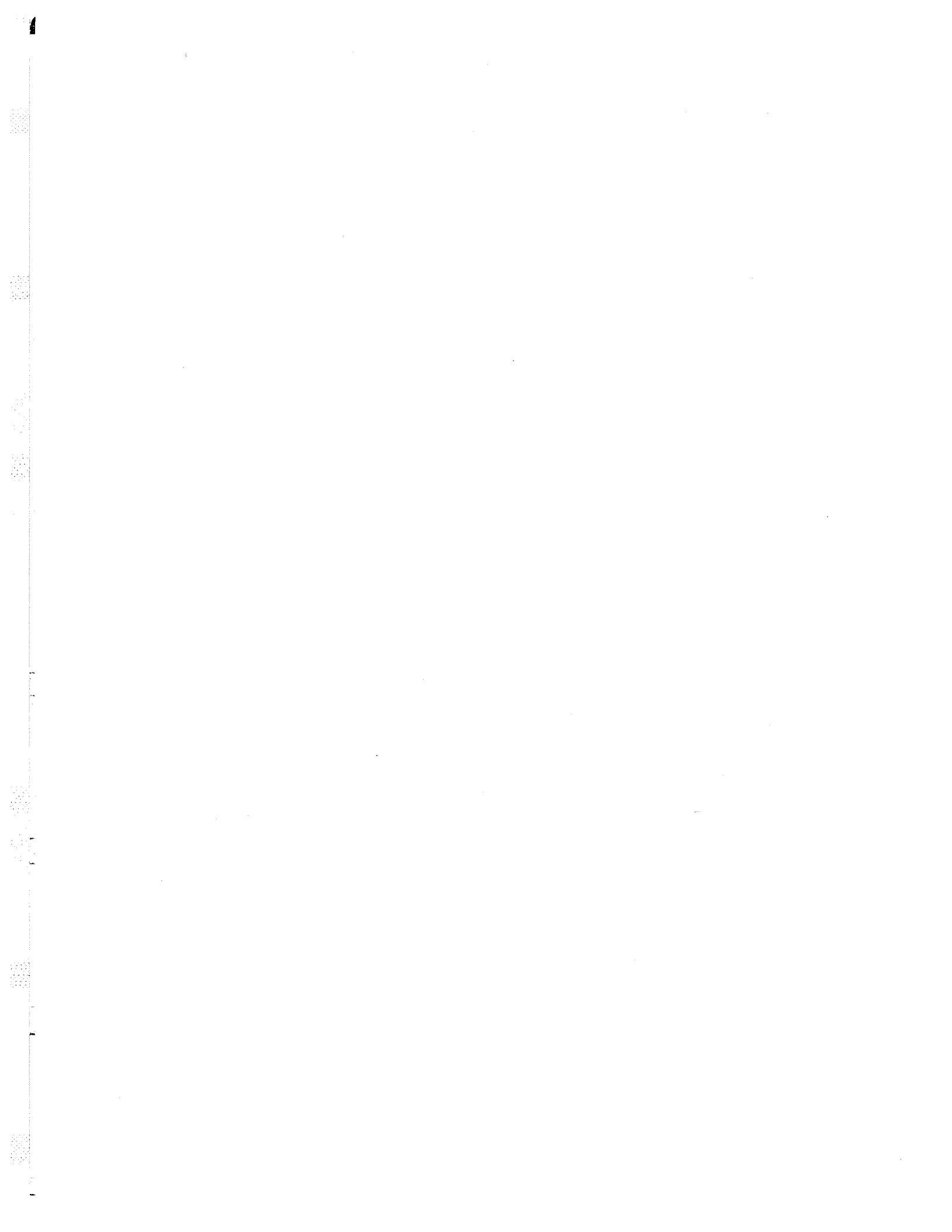
Fabrics claiming various degrees of flame resistance were tested for use in the riot suit. All testing was conducted using a jig which securely held a sample at an inclination of 45 degrees. The first test was a tear test in which a hook was inserted through the fabric and pulled with a spring scale until tearing occurred. The load required to tear the fabric was noted. The second test was a flame test in which the flame of an ordinary butane cigarette lighter was held to the fabric for 5 seconds and then removed. The fabric passed the test if no subsequent burning or smouldering of the fabric was experienced. The third test subjected the fabric to a solution of 2.5ml toluene and 2.5ml iso-octane. Any run-off was collected and removed and the fabric was ignited. The fabric passed the test if no burning or smouldering of the fabric was experienced after the solution had burned away.

Fabric	tear load (N)	butane flame	solvent solution
"Nomex III / Dermoflex" 410-1-FR 200g/m ² (Consoltex)	100	pass	pass
"Vulkan" (Dominion Fabrics)	120	pass	pass
"Flamex"	70	pass	fail
"Nomex III" 6 oz./yd. ² (Lincoln Fabrics)	110	pass	fail
"Nomex III" 7.5 oz./yd. ² (Lincoln Fabrics)	140	pass	pass
Polyester with "Gore-Tex" (Gore-Tex Industries)	110	fail	N/A
"Nomex III" Stain Resistant 7.5 oz./yd. ²	120	pass	pass

Comments

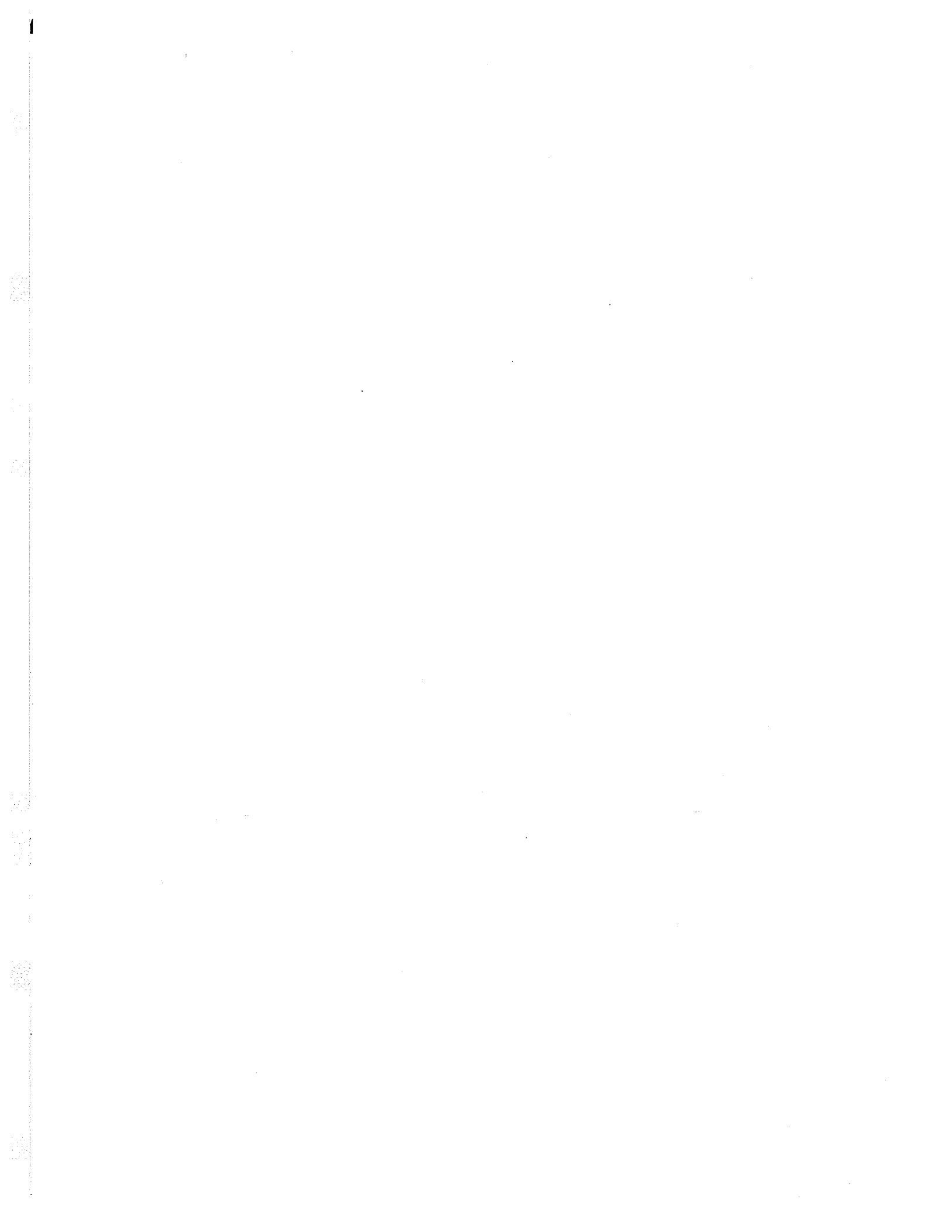
With the exception of the "Gore-Tex" polyester, all fabrics did well in the butane flame test. The "Gore-Tex" polyester was consumed by a self-propagating flame.

The "Nomex/Dermoflex" and the "Vulkan" fabrics performed best in the solvent flammability tests as they remained intact and flexible after the test with no significant damage. The "Nomex" samples with no "Dermoflex" backing soaked up the solvent and burned to a char that crumpled and flaked away. This was in direct contrast to the "Vulkan" which also soaked up the solvent but was not significantly deteriorated by the flame.



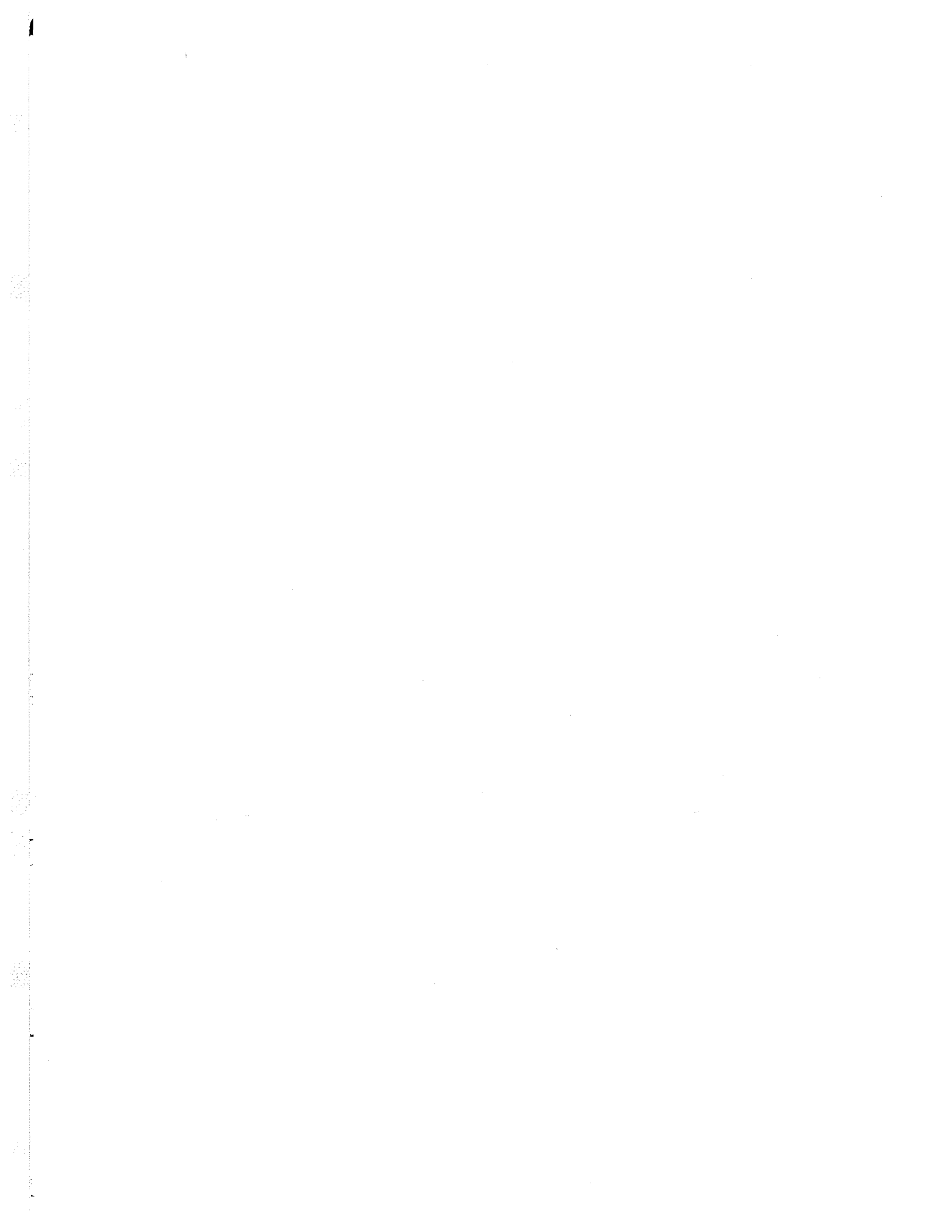
Fabric/Foam Test for Police Riot Jacket

The chosen foam combination of $\frac{1}{4}$ HD80 + $\frac{1}{2}$ LD70 foam was placed flat on a surface with the $\frac{1}{4}$ HD80 on top. This was covered with a sample of Vulkan fabric. A solution of 2.5 ml toluene and 2.5 ml iso-octane was poured onto the fabric where it covered the foam and was immediately ignited. When the fire had extinguished, the fabric was removed to reveal minor distortion of the upper layer of foam but no significant damage.



APPENDIX D

LOCAL SUPPLIERS OF MATERIALS USED IN JACKET



Material	Supplier
"Vulkan"	<p>Dominion Fabrics Company 1950 Sherbrooke Street West Montreal, Quebec</p> <p>The continued availability of this fabric in Canada is now unlikely, however it appears it will be available from Europe through:</p> <p>Klopman International 142-150 Wardour Street London, England</p>
"Coolmax"	<p>Meridian Knitting Ltd. 110 Robinson Road South Granby, Quebec</p>
$\frac{1}{2}$ LD70 / $\frac{1}{4}$ HD80 foam laminate	<p>Kristofoam Industries Inc. 120 Planchet Road Concord, Ontario</p> <p>or</p> <p>PolyFab 62 Bartor Road Weston, Ontario</p>

Estimated Material Costs to Fabricate One Jacket

Materials

3.5 metres "Vulkan"	@	\$26.50	per metre
1 metre "Spandex"	@	\$21.00	per metre
2 metres "Coolmax"	@	\$6.75	per metre
1 metre "Velcro"	@	\$4.00	per metre
60 cm 2-way zipper	@	\$3.75	
Padding inserts	@	\$25.00	

Total Material Costs¹ \$160.00

¹Material costs are based on estimates only and are likely to be less for large volume orders.

