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IMPACT TESTING OF ALLIED CHEMICAL "INFLATABAND" WITH DUMMIES AND HUMAN VOLUNTEERS

Volume 1: Summary Report

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Final Report

SwRI Project No. 11-4020

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16. Abstract

The objectives of the testing program were:

(a) evaluate the effectiveness and performance of the "Inflataband" restraint system as a viable method of occupant protection in a simulated head-on automotive crash, and

(b) evaluate the kinematic performance of anthropometric dummies and human volunteers under simulated impact conditions when restrained by the "Inflataband."

The program formulated to satisfy the objectives consisted of 69 dynamic sled tests (30 dummy tests and 39 human tests). Test results indicate that (1) the "Inflataband" provides acceptable restraint for the impact mode utilized and (2) that the dummy response to impact is more exaggerated than that observed with the human volunteers, but the discrepancies diminish with increasing impact severity.

17. Key Words Anthropometric dummy, human volunteer, trauma, erythema, ecchymosis	18. Distribution Statement

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

I. INTRODUCTION

The objectives of this program as stated in the work statement have been:

1. Evaluate the effectiveness and performance of the "Inflataband" restraint system as a viable method of protecting drivers and passengers involved in the head-on automotive crash environment.

2. Evaluate the kinematic performance of the anthropometric dummies and volunteer human subjects under simulated impact conditions when restrained by the system mentioned above.

In any program involving the use of human volunteers, every effort must be made to ensure the rights and welfare of the subject above and beyond the successful completion of program objectives. To accomplish the task, a test program was designed containing many essential features of previous successful human volunteer programs.

The information contained in the final report describes work accomplished during the chronological interval of February 21, 1975 to May 16, 1975. This volume summarizes the results of 69 dynamic sled tests representing 30 dummy tests and 39 human tests.

II. SUMMARY AND CONCLUSIONS

The program was conducted to completion as planned without major incident. In every test, the primary system functioned in a satisfactory manner and displayed the essential characteristics required of an effective restraint system. System activation and restraining forces were accomplished with minimal expenditure of time. As witnessed by the absence of significant trauma in the human volunteers, impact loads were effectively distributed over the chest and abdomen. Occupant kinematics were controlled by the system in such a manner that submarining during impact was minimal, and the displacement of vulnerable body elements were within the interior constraints of the vehicle simulated.

Injuries to the human subjects consisted primarily of mild erythema to the face and neck; at the higher impact severities, some residual neck soreness was documented in the post-impact evaluation forms completed by the volunteers. In terms of existing human tolerance criteria (head severity index - HSI, chest severity index - CSI, and head injury criterion - HIC) and observed injury, the Inflataband^{TM} provided effective occupant restraint in simulated head-on collisions for which the total velocity change was equivalent to a 30 mph barrier collision; however, conditions were so precisely controlled that the results represent the best possible situation which in reality may rarely exist. The influence of such variables as occupant physical condition, age, size, pre-impact position, muscle tone at impact, impact direction, etc. cannot be overemphasized. It must also be recognized that the system as tested was purely a prototype and was not without operational problems as observed during the program. To be a production item, modification will be required.

When comparing the results of dummy tests with the results of human tests, the first notable discrepancy occurred in the kinematic response to impact. Because of the presence of muscle tone, the typical human response to impact was more subdued than that of the dummy. The test results (HSI, CSI, HIC, belt loads) for the low and intermediate impact severities indicate that the anthropometric dummies' response to impact were conservative estimates of human response; however, at the higher levels (31 mph/49.9 kph sled total Δv), the dummy and human severity indicators converged to similar values indicating a potential threshold (for the system tested) above which muscle tone may not be as significant as at the lower impact severities.

III. EVALUATION PROGRAM

The program as conducted at SwRI was divided into three (3) phases. The first phase consisted of the review of system testing results with dummies conducted at NADC, Philadelphia and a design review of the Inflataband TM. Prior to the first human test, all pressure components were proof tested to 10,000 psi (7031 kgs/mm^2). Critical load carrying components were tested to failure on tensile testing machines to document strength characteristics. These initial efforts were followed by sled tests for the purpose of qualifying the system for human testing. Dummy tests using three (3) dummy types (5th percentile female, 50th percentile male, and 95th percentile male) were conducted at a nominal total velocity change of 32.5 mph (52.3 kph) and peak sled deceleration of 20 g's. Test results were carefully reviewed in order to ascertain potential hazards and operational problems.

The second phase was devoted to volunteer selection and indoctrination. In order to satisfy the doctrine of informed consent, all medically approved volunteers were given the opportunity to view the high speed film of a representative dummy test and experience a dynamic test (with deployment) at a nominal 8.5 mph (13.7 kph) sled velocity change.

The third phase, denoted as production testing, incorporated the stepped-severity technique in which human subjects were exposed to increasingly severe impact environments. Beginning at 12.5 mph (20.1 kph), tests were conducted at nine different impact severity levels, each step being 2.5 mph (4.0 kph) greater in velocity change than the previous step. Each test series contained five (5) tests; the first two tests were conducted with anthropometric dummies followed by three (3) human tests.

IV. PROGRAM RESULTS

Program results are presented in the form of tabulated data sheets (Table 1), and curves indicative of occupant response as a function of impact (Figure 1). These items summarize information derived from the analog transducer signals. Medical observations are documented in Tables 2 and 3.

Table 1

Human Volunteer Data Summary

Run No.	Vol. No.	Sled Acc. g's	Sled Δv mph/kph	HSI	CSI	HIC Interval ms	Head 3 ms Max. Acc. g's at t_2*	Chest 3 ms Max. Acc. g's at t_2*	Left Lap Belt Load, lbf	Right Lap Belt Load, lbf	Shoulder Belt Load, lbf	Toe Pan Load, lbf Left/Right
884	16	6.8	12.3 19.8	45	33	32.4 19-210	18.0 at 37	20.0 at 25	575	350	250	320 302
886	36	6.8	12.3 19.8	61	16	42.5 18-50	23.1 at 23	13.2 at 25	400	300	350	394 372
887	33	6.8	12.2 19.6	71	19	39.8 13-159	31.9 at 149	11.4 at 37	600	200	400	371 498
898	1	8.2	14.9 24.0	52	27	42.1 20-107	17.3 at 41	14.6 at 29	425	225	375	620 492
900	42	8.3	15.0 24.2	63	37	44.6 19-88	26.4 at 27	15.6 at 24	550	250	450	533 419
901	41	8.2	14.9 24.0	45	24	37.6 21-109	15.5 at 76	12.0 at 29	500	200	325	550 417
909	13	10.2	17.7 28.5	92	44	70.8 18-128	19.7 at 89	16.8 at 29	500	200	200	732 506
913	21	10.0	17.6 28.3	87	45	68.5 31-118	18.6 at 85	15.6 at 34	640	280	300	671 544
914	40	10.0	17.5 28.2	81	39	62.2 19-117	18.4 at 79	15.6 at 34	700	325	Sig. Loss	468 376
922	28	11.2	20.5 33.0	81	42	68.9 17-119	18.6 at 32	14.5 at 33	800	210	450	552 465
924	24	11.1	20.5 33.0	75	42	60.1 24-117	17.2 at 84	15.1 at 62	675	200	450	939 570
925	35	11.6	20.8 33.5	74	41	61.4 17-116	19.3 at 30	15.8 at 32	600	250	450	642 571
932	13	13.0	22.4 36.1	131	61	103.8 19-128	22.2 at 87	17.6 at 30	800	250	350	696 532
934	1	13.5	Accel. Break-up	112	53	82.7 17-113	22.4 at 31	17.0 at 63	750	300	700	541 566

* g level for 3ms interval where t_2 is the time at the end of the interval

Table 1

Human Volunteer Data Summary (cont'd)

Run No.	Vol. No.	Sled Acc. g's	Sled Δv mph/kph	HSI	CSI	HIC Interval ms	Head 3ms Max. Acc. g's at t_2*	Chest 3 ms Max. Acc. g's at t_2*	Left Lap Belt Load, lbf	Right Lap Belt Load, lbf	Shoulder Belt Load, lbf	Toe Pan Load lbf Left/Right
937	21	12.7	22.1 35.6	128	40	102.2 34-115	23.2 at 92	15.3 at 32	900	350	535	605 778
943	41	14.7	24.4 39.3	164	79	113.9 18-187	26.7 at 79	18.8 at 80	1050	500	635	551 534
945	40	14.7	24.3 39.1	248	95	189.5 16-203	26.4 at 182	20.5 at 60	1325	400	500	597 387
946	16	14.7	25.1 40.4	148	85	115.6 17-123	21.5 at 34	20.3 at 34	1025	250	350	546 505
955	24	15.7	27.1 43.6	123	79	97.3 16-121	21.7 at 83	19.0 at 60	1000	300	850	958 461
957	35	16.1	28.2 45.4	154	53	126 16-118	23.2 at 31	15.2 at 32	800	300	600	S.L. 585
958	28	16.0	27.6 44.4	232	107	169.9 23-207	27.1 at 198	19.2 at 77	1560	400	710	563 543
966	16	18.3	30.2 48.6	253	126	173.2 63-125	31.8 at 92	21.6 at 57	1200	350	400	452 579
968	40	17.6	29.3 47.2	291	100	208.4 18-205	33.6 at 188	20.6 at 65	1250	475	1000	862 491
969	1	17.8	29.3 47.2	216	66	174.4 16-122	27 at 23	17.8 at 72	1075	325	850	894 760
976	13	19.6	32.3 52.0	371	120	244.0 25-203	40.4 at 194	20.5 at 107	1600	350	500	712 888
978	24	19.7	32.3 52.0	308	137	220.2 15-200	28.9 at 86	21.3 at 66	1700	425	800	1123 611
979	28	19.6	32.1 51.7	361	164	238.7 27-199	42.0 at 181	22.9 at 89	1540	480	740	686 507

* g level for 3ms interval where t_2 is the time at the end of the interval

Table 1

Dummy Data Summary

Run No.	Dummy %	Sled Acc. g's	Sled Δ v mph/kph	HSI	CSI	HIC Interval ms	Head 3ms Max. Acc. g's at t_2**	Chest 3ms Max. Acc. g's at t_2**	Left Lap Belt Load, lbf	Right Lap Belt Load, lbf	Shoulder Belt Load, lbf	Toe Pan Load lbf Left/Right
881	50	7.2	13.5 21.7	83	32	49.8 14-87	33.9 at 26	20.0 at 18	800	Sig. Loss	450	344 424
882	95	6.9	13.2 21.3	66	33	50.9 16-93	18.2 at 31	15.5 at 29	750	425	600	392 541
895	50	8.4	13.5 24.5	76	44	48.2 12-97	27.2 at 23	20.7 at 17	560	175	220	427 667
897	95	8.2	14.8 23.8	115	53	84.7 13-90	25.2 at 29	19.3 at 28	750	230	550	428 473
906	50	10.3	17.9 28.8	126	43	80.0 11-99	37.1 at 21	22.6 at 17	750	275	210	430 570
908	95	9.9	17.4 28.0	133	48	96.3 17-110	21.7 at 45	15.6 at 35	890	350	700	508 499
918	50	11.2	20.5 33.0	138	83	101.9 11-150	25.6 at 24	24.1 at 16	825	300	360	447 599
920	95	11.1	20.2 32.5	161	Sig. Loss	108.0 13-112	29.2 at 24	Sig. Loss	1200	500	725	427 526
929	50	12.1*	20.0* 32.2*	121*	77*	84.5* 12-205	27.6* at 28	29.8* at 16	1050	350	600	S.L. 605
931	95	12.7	22.1 35.6	202	59	134.8 11-110	33.4 at 23	19.6 at 25	1450	525	850	490 507

* Signal Break-up Experienced

** g level for 3ms interval where t_2 is the time at the end of the interval

Table 1

Dummy Data Summary (cont'd)

Run No.	Dummy %	Sled Acc. g's	Sled Δ v mph/kph	HSI	CSI	HIC Interval ms	Head 3ms Max. Acc. g's at t_2 *	Chest 3ms Max. Acc. g's at t_2 *	Left Lap Belt Load, lbf	Right Lap Belt Load, lbf	Shoulder Belt Load, lbf	Toe Pan Load lbf Left/Right
940	50	15.1	25.2/40.6	214	107‡	143 10-205	36.4 at 197	34.4‡ at 16	1250	Sig. Loss	500	S.L./676
942	95	14.9	24.3/39.1	220	125‡	171.8 11-124	27.2 at 28	22.2‡ at 27	1550	700	1100	523/578
952	50	15.7	27.5/44.3	266	101	178.6 11-119	42.3 at 23	25.4 at 16	1150	450	550	472/606
954	95	15.9	27.1/43.6	236	65	171.9 13-121	32.9 at 24	15.6 at 41	1725		1150	510/614
963	50	18.2	30.8/49.6	424⊘	111	264.5⊘ 11-200	55.4⊘ at 192	21.8 at 15	1760	490	800	489/631
965	95	17.7	29.7/47.8	256	114	181.5 15-123	28.9 at 81	21.7 at 99	1950	850	1200	474/686
973	50	19.9	32.9/53.0	286	130	202.3 11-210	36.2 at 202	19.9 at 24	1935	600	1250	439/693
975	95	19.3	32.0/51.5	326	Sig. Loss	243.7 12-121	30.7 at 79	Sig. Loss	2000	950	1450	565/856

‡ Signal Loss on Chest Z Axis

⊘ Dummy May Have Had Broken Neck

* g level for 3ms interval where t_2 is the time at the end of the interval

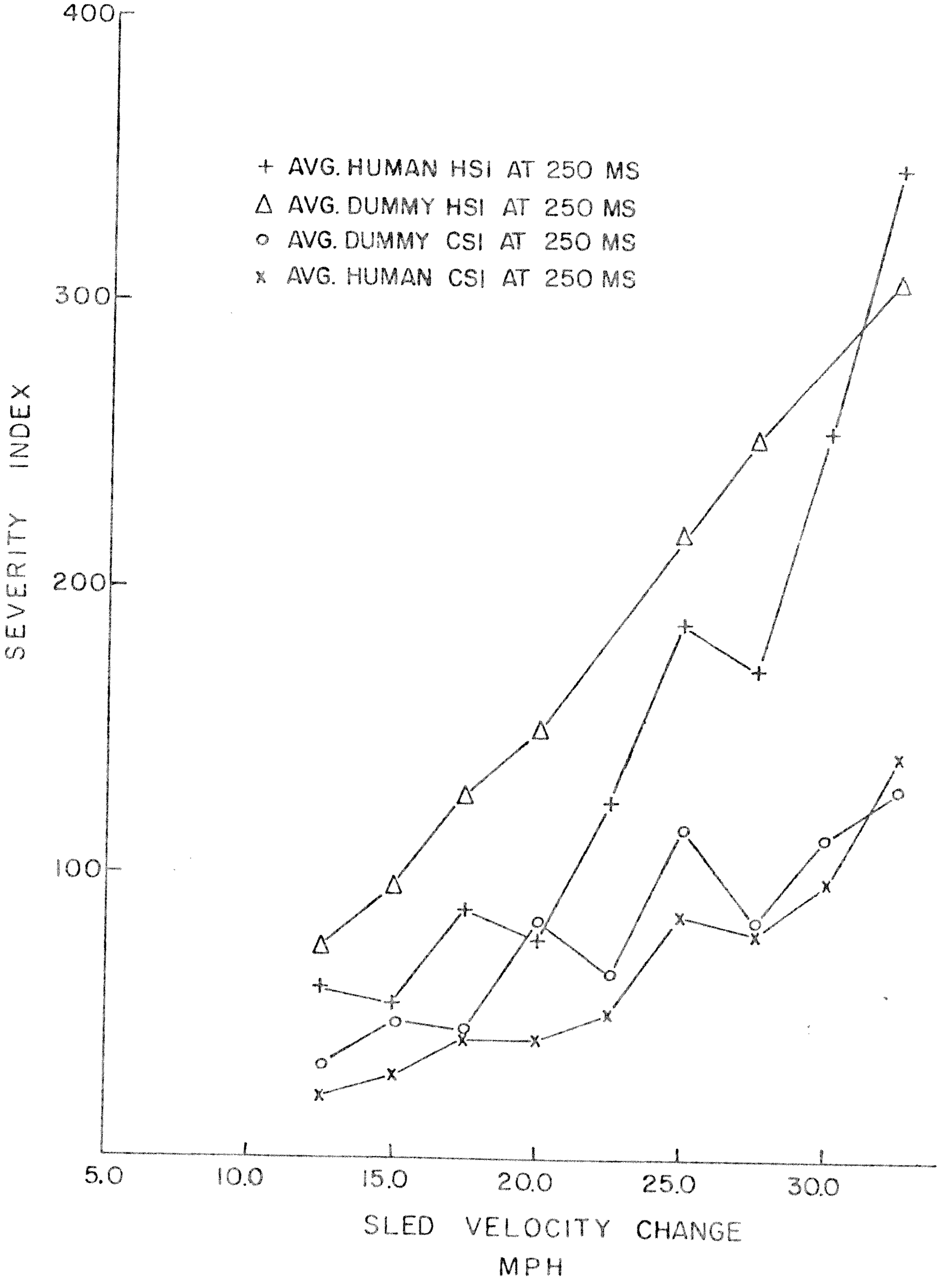

Figure 1. Aver [illegible] Severity Index vs. Sled Velocity Change

TABLE NO. 2 BLOOD PRESSURE RECORDINGS FOR VOLUNTEERS AT VARIOUS VELOCITY CHANGES

Vol. #	1				13				16			
Velocity	10	14.9	22.5	29.3	10	17.7	22.4	32.3	10.1	12.3	25.1	30.2
Pretest 1	140/92	132/80	140/90	144/70	128/80	132/82	132/88	146/78	140/80	140/94	138/82	114/80
Pretest 2	142/80	132/80	142/96			134/94	144/90	146/96	140/88	140/90	144/98	132/88
Post impact	140/80	132/90	140/90	146/70		136/98	142/90	146/86	120/80	134/96	138/88	132/98
Vol. #	21				24				28			
Velocity	9.9	17.6	22.1		10.1	20.5	27.1	32.3	10	20.5	27.6	32.1
Pretest 1	125/80	124/80	130/88		120/74	116/78	126/78	138/76	138/85	128/104	140/100	142/100
Pretest 2		128/90	138/90		124/70	124/72	140/82	138/78		140/96	146/110	148/110
Post impact		132/90	140/96			136/78	142/76	136/80		142/108	146/100	146/108
Vol. #	33				35				36			
Velocity	9.5	12.2			10.1	20.8	18.1		10.2	12.3		
Pretest 1	126/82	132/80			115/75	132/80	130/70		138/76	132/90		
Pretest 2	130/94	134/82				134/68	136/76			134/81		
Post impact	142/94	134/100				142/92	140/76			136/86		
Vol. #	40				41				42			
Velocity	9.9	17.5	24.3	29.3	10.3	15.0	24.4		8.5	15.0		
Pretest 1	140/96	134/90	142/96	146/106	140.80	130/84	136/76		130/80	134/84		
Pretest 2	140/91	132/94	144/98	146/98	138/68	132/80	140/80		140/81	132/90		
Post impact	140/96	132/90	144/91	144/98	140/80	132/82	142/80		140/85	134/84		

TABLE 3

MEDICAL DATA SUMMARY FOR INFLATABAND™ TESTS WITH HUMAN SUBJECTS

Run No.	Vol. No.	Sled Accel. (g)	Sled Vel. (mph)	Main Complaint	ECG Changed
854	42	—	8.5(nom.)	—	N/T
856	1	4.5	10.2	C3, I3	T flat → N/T
857	16	4.5	10.1	K6, C4	N/T
858	40	4.4	9.9	B5, K2	N/T
859	21	4.4	9.9	B7, L6, I5, M5	N/T
860	24	4.6	10.1	B7, E6, K6	T flat → N/T
865	33	4.3	9.5	I7, K6	T flat → N/T
866	13	4.6	10.0	I3, C2, G2	N/T
867	28	4.5	10.0	B2, C2, K2	T flat → N/T
868	35	4.8	10.1	—	N/T
871	36	4.8	10.3	C6, D6, H5, I5	N/T
872	41	4.7	10.3	C4, I4, D3, E3, L3, M3	N/T
881	16	6.8	12.3	C4, K4	N/T
886	36	6.8	12.3	K5, C4	N/T
887	33	6.8	12.2	K2	T flat → N/T
898	1	8.2	14.9	L4, C3	T↓ → N/T
900	42	8.3	15.0	—	N/T
901	41	8.2	14.9	I4, C3	N/T
909	13	10.2	17.7	D2, I2	N/T
913	21	10.0	17.6	D5, C4, E4, G4, J4	T flat → N/T
914	40	10.0	17.5	—	N/T
922	28	11.2	20.5	—	N/T
924	24	11.1	20.5	J6, K2	N/T
925	35	11.6	20.8	—	T↓ → N/T
932	13	13.0	22.4	D2, L2	N/T
934	1	13.5	22.5(nom.)	C3, I3	T flat → N/T
937	21	12.7	22.1	I4, J3, F2, G2	Premature ventricular contraction x 2 preimpact → N/T post-impact
943	41	14.7	24.4	C4, I3, J3	N/T
945	40	14.7	24.3	A2, K2	N/T
946	16	14.7	25.1	B4, C4, I2	N/T
955	24	15.7	27.1	—	T flat → N/T
957	35	16.1	28.2	C2	T flat → N/T Premature ventricular contraction x 3 post-impact
958	28	16.0	27.6	—	→ N/T
966	16	18.3	30.2	C4, J4, I3	N/T
968	40	17.6	29.3	K2	N/T
969	1	17.8	29.3	C3, D2, E2, F2. J2	T flat → N/T
976	13	19.6	32.3	C2, L2	N/T
978	24	19.7	32.3	B2, C2, R2	N/T
979	28	19.6	32.1	—	N/T

T ↓ = T wave inversion
→ N/T = Returned to normal/trace

V. DISCUSSION

A. Dummy/Human Performance

Prior to its usage in a test, the dummy's joints were checked for operation and adjustment. Each limb joint was set for the standard one g threshold when extended horizontally. Because of the limited joint resistance, several distinct differences were observed between human and dummy kinematic response as listed below:

1. Torso rotation. Particularly with the 50th percentile ATD, the torso rotates about the shoulder band. During impact, the left shoulder is not braced sufficiently to counteract the moment created by the band reaction loading on the right shoulder.

2. Lateral displacement. Because of torso rotation and the reflection of the head as it rebounds from the band, the dummies rebound to the left of the seat center line. For the 32.5 mph (52.3 kph) series, the observed maximum and minimum lateral excursions were those of the dummies: the extreme being that of the 50th percentile dummy and the minimal excursion being that of the 95th percentile dummy.

3. Combined belt loads. The data summarized in Table 1 (toe pan loads) indicate that the load transmitting capacity of the legs for both dummy types is much less than that of the volunteer.

4. Rebound deceleration. Typically, the dummies experienced larger deceleration values on rebound than did the volunteers. Above 27.5 mph (44.3 kph), the differences in rebound levels between humans and dummies are less pronounced contributing to the convergence of the human and dummy parameters plotted in Figure 1. These results indicate the existence of a threshold above the 32-34 mph (51.5 - 54.7 kph) region in which the effect of muscle tone is not as significant as it is at the lower impact severities.

The review of the photographic records reveals that subjectively hose volunteers similar in size and weight to the 95th percentile dummy xhibit similar kinematic responses. In addition, it appears that the nflataband$^{\mathrm{TM}}$ is best suited for the 95th percentile occupant as it more ffectively controls the kinematics of impact. As observed in the 32.5 mph 2.3 kph) series head flexion (as well as rate of change in head angular osition) and lateral displacement are minimal, the reason being that the in overides the deployed band providing head support. For smaller cupants, the head is pushed to the left as the body begins to respond to the impact; the chin slides down and then into the band producing head rotation and allowing greater head flexion.

Unlike the dummies, whose response was reasonably repeatable and predictable, each human reacted differently to impact. Some displayed better riding abilities than others where the abilities are functions of subject experience, coordination, mental attitude, muscular build, etc. Success in extrapolating impact severities for a given volunteer was marginal probably because of the "volunteer learning curve." After each ride, the volunteer may learn something to improve his next ride or depending on his reaction, he may become more apprehensive. Either result affects riding ability.

For the reasons discussed above, the comparison of human/dummy performance would have been improved had a volunteer matching dummy anthropometrics been exposed to impacts at each severity level since no volunteer participated in more than three (3) production tests.

B. Restraint System Performance

The performance of Inflataband^{TM} in providing protection for occupants involved in direct frontal impacts simulated in the laboratory is entirely adequate. In no case did the observed severity indicators (HSI, CSI, HIC) approach or exceed the existing human tolerance levels for these indicators. Injuries to the human subjects were minimal consisting primarily of mild erythema to the face and neck; at the higher impact severities, some residual neck soreness was documented as noted in the medical section of this report. Impact forces on the upper torso and abdomen were effectively distributed without major discomfort. Some volunteers, however, depending on their position (slouching or high in the seat) would receive a sufficient blow to knock their breath away momentarily. The control of head rotation and flexion by the Inflataband^{TM} appears to be dependent upon the initial amount of chin overide of the shoulder band and initial head position.

In every test, the Inflataband^{TM} was fully deployed before the subject began to translate forward. The duration of deployment is short (7-8 msec after impact detection) making the system advantageous for small cars. Not only does deployment occur at a rapid rate, but the very act of deployment also restrains the occupant due to the foreshortening of the bands during inflation. Consequently, the occupant utilizes the available stroke and vehicle ride down more efficiently than would a conventional belt restraint system. Submarining was minimal and observed primarily with the 95th percentile dummy.

A significant portion of the total Head Severity Index at the higher levels (20 to 25% for the human riding at 32.5 mph) was accumulated during rebound. Reduction in the severity response could be obtained by reducing the amount of impact energy stored in the system. The utilization of orficies (in the form of band material porosity for example) to throttle system gases or load absorbers at the attachment points would be two approaches both of which would result in increasing the required occupant deceleration distance or stroke.

As a secondary consideration, volunteers repeatedly expressed concern for not having a structure against which to brace the arms. The integration of a collapsible steering column or instrument panel would have been advantageous solely to increase the occupant's mechanical advantage in bracing against the impact. The Inflataband^{TM} as tested works well; however, the use of selected subsystems could perhaps enhance the performance to an even greater extent.

C. Medical Observations

1. Hearing. All volunteers had noise attenuation ear plugs placed in their external ear canals during their run. All volunteers, with only two exceptions stated that they either had not heard the sould of the pyrotechnic device which inflated the belt, or that the sould was so insignificant as not to be important. One volunteer (#21) in his indoctrination run stated that the report of the pyrotechnic device was "loud and distracting." In two subsequent runs at 17.6 mph (28.3 kph) and 22.1 mph (35.6 kph), the same volunteer had no complaint about the noise.

2. Blood Pressure. All blood pressure recordings taken showed a minimal elevation of both systolic and diastolic pressure coincident with sitting down in the buck. A second pretest B/P normally recorded at 4 minutes before sled release showed a small rise in pressure apparently associated with the increase in tension as the impact approached. Almost without exception, the post-test B/P returned to early pre-impact levels. No sustained pathological B/P levels were recorded although in volunteer #28, diastolic pressures above 100 mm Hg were transiently recorded both pre- and post-impact at velocities of 20.5 mph (33.0 kph), 27.6 mph (44.4 kph) and 32.1 mph (51.7 kph).

In all individuals tested on multiple occasions, there was a tendency for the blood pressure to be higher as the test speed rose and to be highest in the run with the highest velocity change. On four occasions however, the B/P on the second run was lower than on the first test. It is possible that having overcome the initial apprehension of the unknown with the first test, the second was associated with less tension for these four individuals (See Table 2).

3. Pulse Rate. All subjects had an increase in pulse rate as the anticipated impact approached. No pathological elevations occurred

during the time of the test and all rates returned to pre-test levels after impact. Increasing sled velocity and/or acceleration influenced P.R. so that the higher the anticipated test velocity, the higher the P.R. rose to a maximum P.R. in one volunteer of 166 bpm at 32.3 mph (51.8 kph).

4. ECG. No pathologically significant ECG abnormalities could be demonstrated in any volunteer during the course of these tests. The most frequent change in ECG pattern encountered was either a flattening or an actual inversion of the "T" wave. This occurred within 1 or 2 seconds post impact, persisted for approximately 5-10 seconds, and returned to normal before the ECG electrodes were disconnected. Flattening of the "T" wave occurred in ten subjects while inversion of the "T" wave occurred in two (See Table 3). These changes were neither velocity nor acceleration connected.

The "T" wave flattening and inversion noted in other subjects were all stress induced and reverted to normal patterns within a few seconds post-impact. Obviously, they were not produced by any organic heart changes. They were completely benign in nature.

In two instances, premature ventricular contractions (PVC) occurred. One of these occurred in the pre-impact period in volunteer #21, Run #937 at 22.1 mph (35.8 kph) and consisted of 2 PVC. The other occurred in the post impact period in volunteer #35, Run #957 at 28.2 mph (45.4 kph) and consisted of 3 PVC. In both instances there was no coupling of these beats in any pattern and in both instances normal ECG pattern was quickly restored. These aberrant heart rhythms were without organic basis, were benign in nature, and represented no significant heart conduction abnormalities.

5. Trauma. Main complaint (Table 3) was derived from the physical symptom survey filled out by the test subject immediately post-impact. Nine individuals indicated they had no symptoms whatsoever. These individuals had been tested at velocity changes ranging from 8.5 mph (13.7 kph) to 32.1 mph (51.7 kph). The main complaints of subjects who listed symptoms in the immediate post-impact period varied from sensations of mild pressure to those who listed moderate pain. Only three individuals recorded moderate pain as one of their symptoms and each of these occurred in the indoctrination runs at 10.1 mph (16.3 kph) or less. Five individuals in the group of indoctrination runs listed mild pressure in various areas as their main complaint. This compares with only one individual in all subsequent runs who listed any complaint as severe as mild pressure.

None of the listed complaints (mild as they were) was in any way associated with the decelerative force. Instead the pattern of complaint seems to be indicative of contact with the expanding inflataband as a slap of bag against body area involved or as pressure produced by the expanding bag against body area. The areas of complaint most frequently named were the right side of the neck and the lower part of the right face (25 instances); the upper right chest, shoulder and base of the neck (10 instances); and the lower abdomen and the base of the right groin and thigh (29 instances). In several instances (five volunteers) the left forearm was slapped by the expanding Inflataband.

6. Physical Findings. These were derived by actual observation post-impact and were recorded immediately post-impact by the examining physician. As could be anticipated from the results recorded in the section "main complaints," erythema, involving the base of the right neck, the lower face (right) and the right clavicular region leads all other findings. Erythema of the abdomen was minor in extent, was found only occasionally and occurred less frequently than erythema of the base of the right thigh. This lower incidence of erythema of the abdomen could have been caused by the wearing of the chamois over the lower chest and abdomen by each volunteer. The erythema noted in each of these areas was minimal in degree and probably disappeared within an hour or two post-impact although these volunteers were not observed for that lengthy period. It was not unanticipated that the erythema was most marked in the areas listed. This coincided with the "main complaints" listed by the volunteers and was, of course, the body areas mainly subjected to slapping contact by the expanding Inflataband.

One volunteer (#1 at 14.9 mph/24 kph) had ecchymosis develop because of the severity of bag contact on the base of the right thigh and volunteer #24 at 20.5 mph (33 kph) developed ecchymosis of the left forearm due to contact. Because we noted in our motion picture review that in certain individuals the expanding Inflataband struck the left forearm, we began to caution all volunteers to brace their left arm at a position somewhat wider from the wide than was true on the right and this alleviated this problem. In order to minimize slapping contact of the Inflataband with the base of the right thigh, a small styrofoam pad was placed at this point beneath the pajamas of each volunteer. This decreased the complaints.

Two volunteers (#28 and #36) stated immediately post-impact that they had had the breath knocked out of them by the impact deceleration. This occurred in a ride at 12.3 mph (19.8 kph)(#36) and in volunteer #28 in a ride at 27.6 mph (44.4 kph). Three volunteers stated either that they were "shook up" or "saw stars." In volunteer #36 this occurred at 12.3 mph (19.8 kph) while volunteer #21 saw stars at 17.6 mph (28.3 kph) and volunteer #40 was stunned for a moment at 29.3 mph (47.2 kph).

The only significant complaint which surfaced after the volunteers had left the impact facility and was reported on the Subjective Report was that of stiff neck. Volunteer #1, after a ride at 29.3 mph (47.2 kph), stated he had developed a stiff neck within 24 hours of the test and that it remained mildly stiff for 72 hours and gradually resolved. Volunteer #13 developed a sore neck approximately 5-6 hours after impact at 32.3 mph (52 kph). Within 3 hours he found he couldn't turn his head to the right without pain. In 72 hours he found he had only residual soreness in turning his head to the right. Volunteer #16 who was impacted at 30.2 mph (48.6 kph) developed onset of neck pain within 24 hours of impact and this continued for 48 hours. He also developed a bruise of the right cheek which lasted for 3 days. All three volunteers had remission of all neck symptoms within 96 hours after impact.