Informal Document N° 21
(30th GRSP, 3-6 December 2001,
Agenda item 1.4)

Draft amendments to Regulation N° 17 Correlation Between Dynamic and Static Tests of Station Wagon Barrier Nets.

Brief synopsis of Test Results and Calculations used to generate in house testing procedures for Butz-Ieper Automotive Barrier Nets.

T. Sam Crisp.
20th Nov. 01

Contents

Purpose of this report.

This report is an explanation of the sequence by which we in Butz-Ieper Automotive developed our in house testing of flexible barrier nets and the equipment to test them during development and production. For clarity this report is kept brief but is based on selected results from 8 years of development of the barrier nets that we produce for the European auto industry.

Reasons for static testing.

As an original equipment supplier to the auto industry we are frequently asked to develop components and barrier net assemblies for vehicles that are in an early stage of development. To develop these components it has always been vital to know the loads to which they may be subjected so that components can be cost effectively developed and that we are confident that they will exceed the requirements of use.

Dynamic testing is applied by us where it is essential, such as in the anti-inertia testing of locking systems, but it is much cheaper, convenient, controllable and reproducible to conduct static tests to prove the strength of our products. It is important to our customers that when they conduct expensive dynamic tests on their prototype vehicles that they can be confident that our prototype parts will perform adequately.

Our experiences obviously can be applied to the improvement of the R17 regulation as proposed.

Development of correlation-ship between static and dynamic testing.

In initial studies transient non-linear finite element analysis was employed to study in depth the dynamic response of a fixed barrier net. This was compared with the results obtained from a dynamic test of a net restraining the upper 10 Kg. mass and the resulting net damage. Thus the basic strength requirements of the net components could be defined. (see report on pages 5, 6, 7, 8 and 9).

Based on these results Butz-Ieper Automotive built a static compression test fixture that could be mounted inside a Zwick computer controlled test machine and nets, designed to restrain the upper 10 Kg. mass, were successfully developed for a long period with our customers dynamic test results showing a good correlation ship with our predictions. (see photo on page 6).

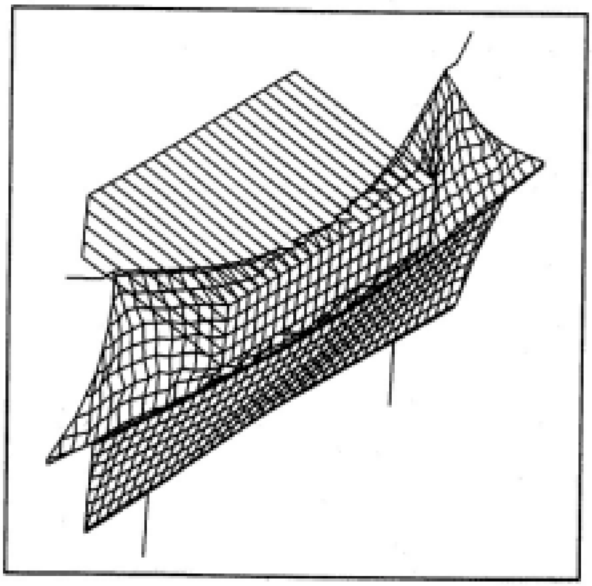
Later it became apparent that when we had to design safety barriers that extended from the vehicle floor to the roof further analysis was required. When one of our customers conducted dynamic tests with a tri-axle accelerometer in the 10 Kg. mass we were able to make a direct comparison between a static test and a dynamic test on identical components. (See report on page 10 and 11).

The correlation between results was such that a series of dynamic tests at T.U.V. were run in 1998 with the express aim of developing an internal company static test requirement that would allow the development through static testing of barrier systems capable of restraining both the 10Kg. upper load and the two 18 Kg. lower loads of the R17 proposal with no assistance from the seat backs. These results were analysed (see pages 14, 15, 16 and 17) and a test equipment designed for our internal development work and production verification (see photo on pages 19, 20 and 21).

This is the equipment described in the proposed amendment to the R 17 regulations.

A Finite Element Study

LG-R-008-TC



February 1994

SUMMARY

A transient non linear finite element analysis performed to simulate the behavior of the safety net under impact conditions and verify earlier crash tests.
At the time of a crash the following predefined conditions are observed:

(1) Speed at crash = **30 Km/h = 8.33 m/s**
(2) Dimensions of impacted object onto the net:
Width (side column to side column) = **0.5 m**
Height (car floor to car ceiling) = **0.128 m**
Depth (net to rear) = **0.35 m**
(3) Mass of impacted object = **10 Kg**
(4) Original position of object behind the net = **0.2 m**
(5) An additional mass of **1 Kg** was distributed over the net for solution stability and also to add a degree of conservatism in the analysis results.

The acceleration curve during the car crash is taken as follows:

(1) Constant acceleration of **120 m/s²** from **t = 0** to **t = 90 ms.**
(2) Linearly dropping to **zero** from **t = 90 ms** to **t = 120 ms.**

The findings from this work are presented below.

(1) Maximum Net Displacement = **249 mm** at time = **105 ms**

(2) Maximum Tensile Force in a Net Fiber = **1047 N**

(3) Maximum Tensile Force in the Trim = **1193 N**

(4) Maximum Slider Force = **0 N** (Does not close).

(5) Maximum Reaction Force on the Car Ceiling = **3000 N** (one side).

(6) Maximum Reaction Force on the Car Floor = **2100 N** (one side).

The maximum net fiber forces quoted above are only indicative. Any of those values greater than the fiber strength, which is 50 Kg (= 500 N), will cause the fiber to brake and as consequence redistribution of forces in the nearby fibers is expected. The finite element solver used can only consider cable elements as linear ones with no plasticity.

4.0 Physical Crash Test

The only available information at this stage are two photos taken after a net crash test. These scanned pictures are shown in Figures CR1 and CR2 below.

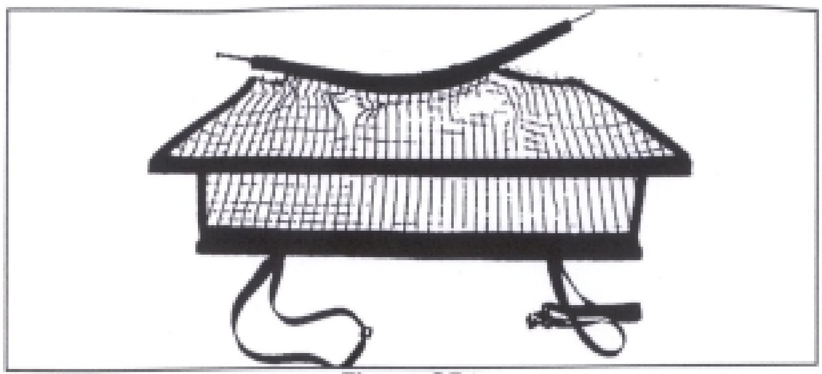


Figure CR1

Net after a Crash Test at 30 Km/h

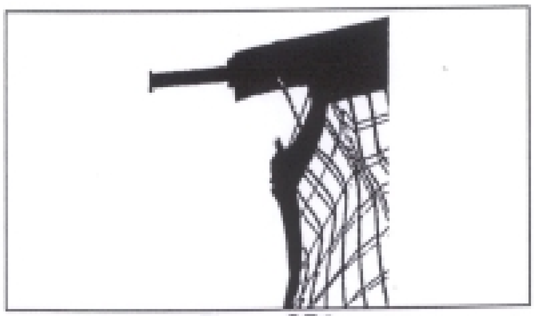


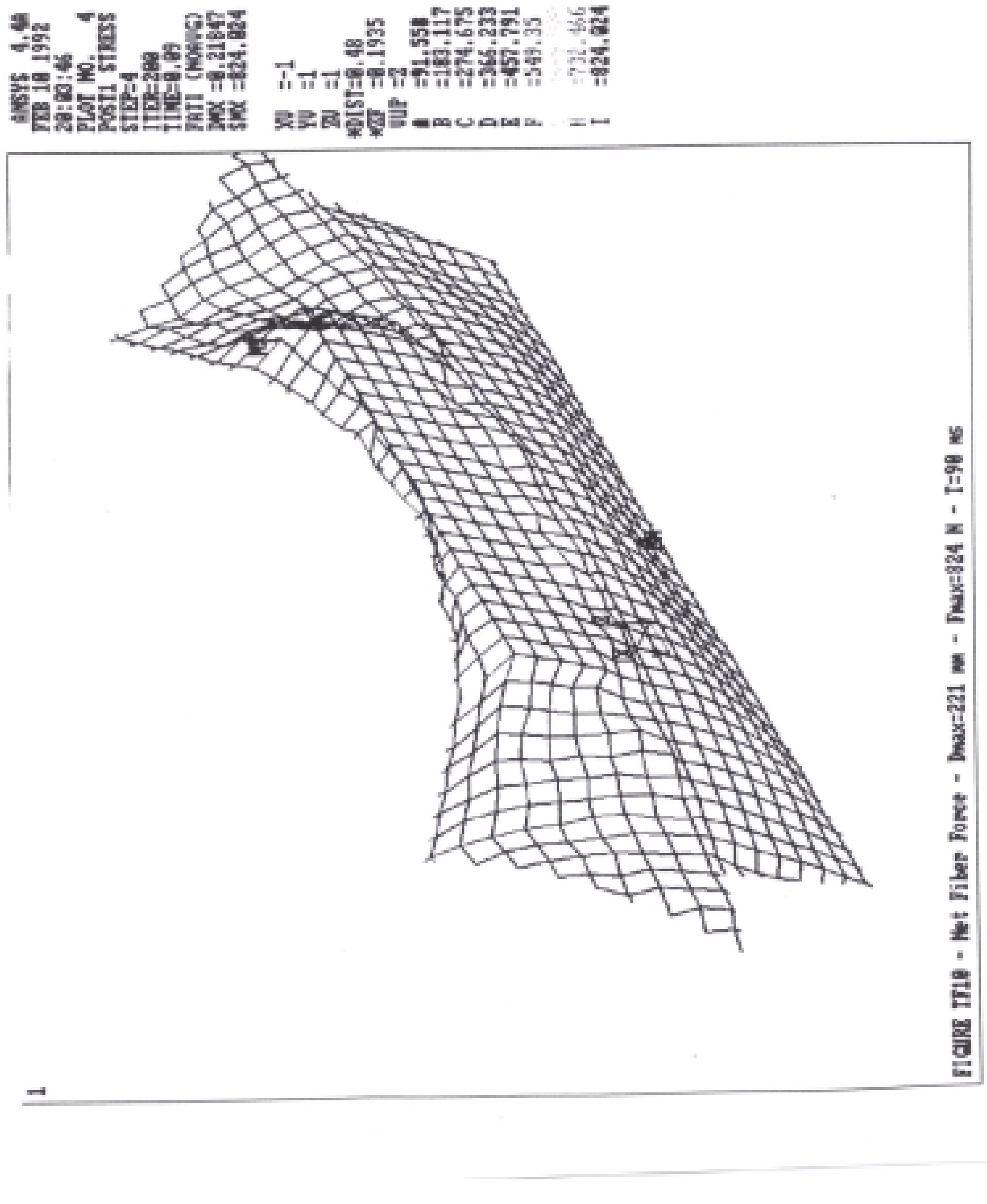
Figure CR2

Net after a Crash Test - Top Corner

There are two points which are noticeable. The top trim has been tared and the fibers adjacent to the top corners of the impact area have been tared as well. One may correlate pictorialy Figure CR1 with Figures TF10 through TF14.

Another point to be made is that the slider in Figure CR2 does not seem to be bended or being pulled out. This enhances the view of section 3.6 where it was stated that the slider does not close during impact.

Notice the curvature of the top tube which has gone plastic compared to Figures B9 to B14.


ANSYS 4.4A
FEB 10 1992
20:03:46
PLOT NO. 4
POST1 STRESS
STEP=4
ITER=300
TIME=0.09
DMX =0.21847
SMX =824.024
XV =-1
YV =1
ZV =1
*DIST=0.48
*XF =0.1935
VUP =2
A =91.558
B =183.117
C =274.675
D =366.233
E =457.791
F =549.35
H =732.466
I =824.024
FIGURE TF10 - Net Fiber Force - Dmax=221 mm - Fmax=824 N - T=90 ms
1

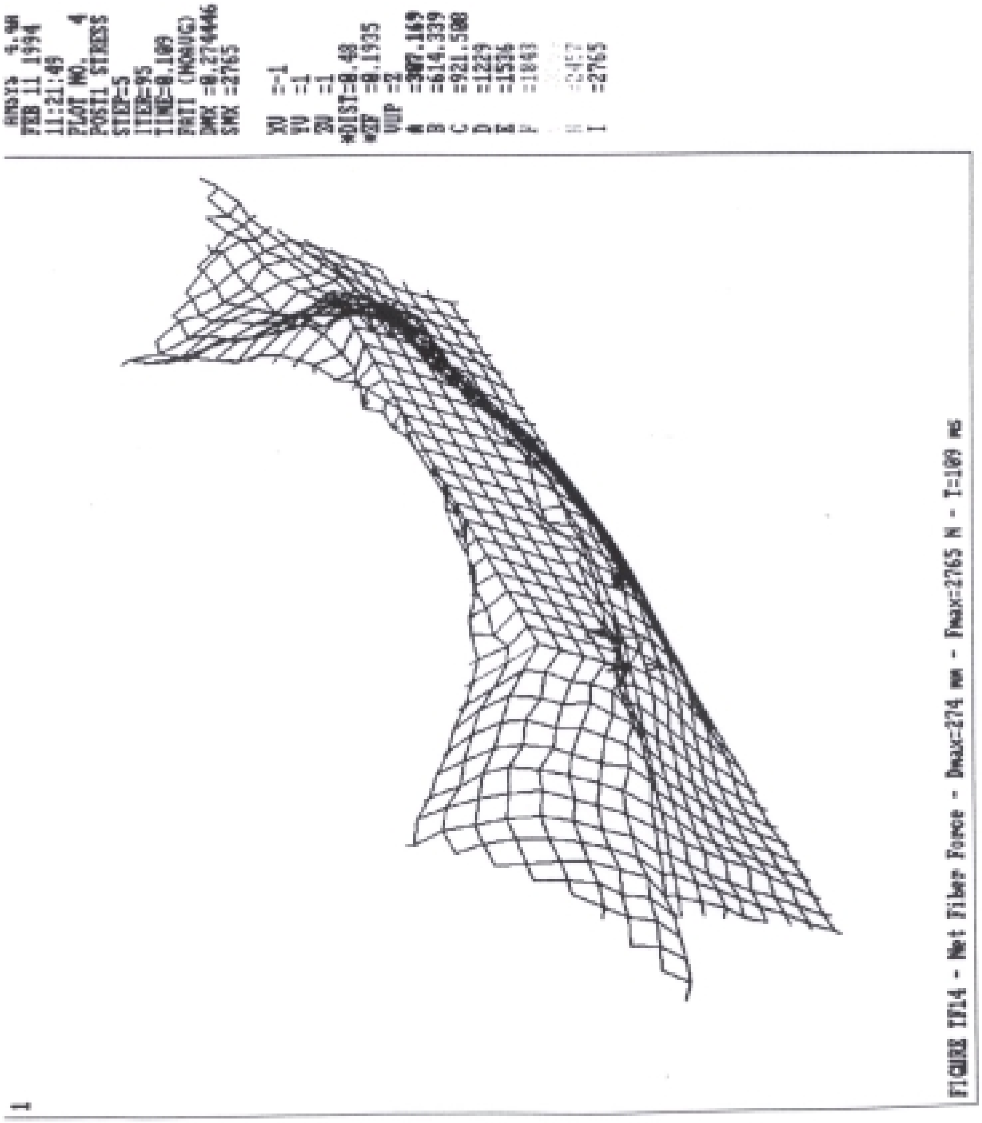


FIGURE TF14 - Net Fiber Force - Dmax=274 mm - Fmax=2765 N - T=109 ms

Comparison of static and dynamic tests.

barrier nets.

Data source:

Test results were made available from a dynamic test conducted by one of our customers where a plot existed of the longitudinal deceleration of the 10 Kg. mass. This was measured by the sighting of an accelerometer within the mass. The vehicle deceleration was that of a car in a frontal impact at 40 Km. Per hr. The seat was in its normal position and only the 10 Kg. mass was used.

Static tests were conducted on identical barrier nets from our production.
These tests were conducted in the computer controlled Zwick compressive test machine where the net was supported in a rigid steel frame. To deform the net a block having the same form as the leading edge of the 10Kg. mass used in dynamic tests was pressed into the locked net at a speed 100 mm. per minute. The graph of the load against deflection was generated.

Calculation:

The graph of deceleration against time supplied from the dynamic test enabled the calculation of the displacement against time of the mass. As the test was conducted on a ´Hi-G-sled, where the test configuration starts at rest and is accelerated backwards, it also was possible to calculate the force exerted on the mass by the net

By combining the results of these two calculations it was possible to draw a graph of the force deflection curve of the net during the dynamic test.

Results:

The two graphs of load / deflection were matched together to ascertain the starting point of the load application and are to be found attached.

A very close similarity was found both in the form and values of the two deflections in the region of loading experienced during the dynamic test.

The loads on the net during dynamic test were much higher than previously thought (+/- 600 Kg.).

The net deflection under load was relatively low. (+/- 100mm.)

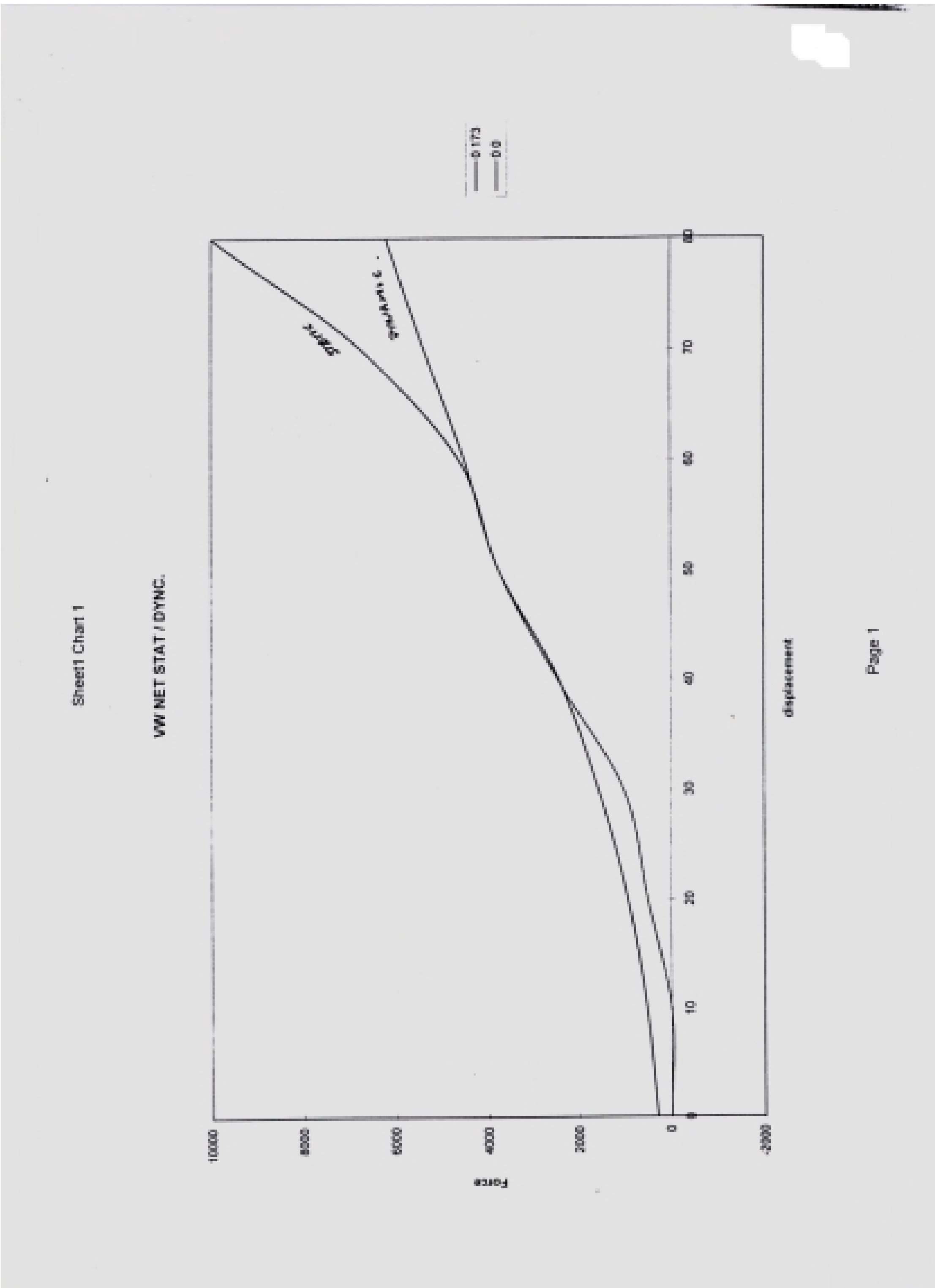
The net deflects a fair distance with a very low force. (+/- 40 mm.)
Failures of the safety net in static tests were similar to those in dynamic testing.

Conclusions:

During safety net development the use of the extensive static testing on the equipment that exists within our company can give a fair indication of the performance that we can expect when our products are tested dynamically by our customers.

Comparative static tests of different materials and constructions can give a good indication of future performance from our products.

Further tests should be carried out with accelerometers in the test blocks to increase our confidence in these results.


Sheet1 Chart 1
VW NET STAT / DYNC.
Force
10000
8000
6000
4000
2000
0
-2000
0
10
20
30
40
50
60
70
80
displacement
Page 1

Evaluation of dynamic test results.

Test Configuration.

The tests were conducted at T.U.V. Rheinland on 24/07/98.

Net Configuration: Full size Butz-Ieper static net.

Deceleration Pulse: ECE-R44 (ECE R17) 47 kmph.

Test Loads: 2 X 18 Kg. + 1 X 10 Kg. as R17.

Instrumentation: Tri-axial accelerometers in each load block

Results.

T.U.V. supplied the resultant deceleration of each test block (see page 14) which could be translated to an instantaneous load on the net as shown in the attached strength calculations. (see pages 15 and 16) The energy verses time graph shown on page 17 gives a smoothed out indication of the total load applied to the net by the test blocks in relationship to time. The flexibility of the net material means that peak values measured in the accelerometers must be filtered to give a meaningful equivalent static load.

Force Applied To Net By Loads (Averaged)

Upper (1X10Kg.) =	1620N.
Lower (2X18Kg.) =	4300N.

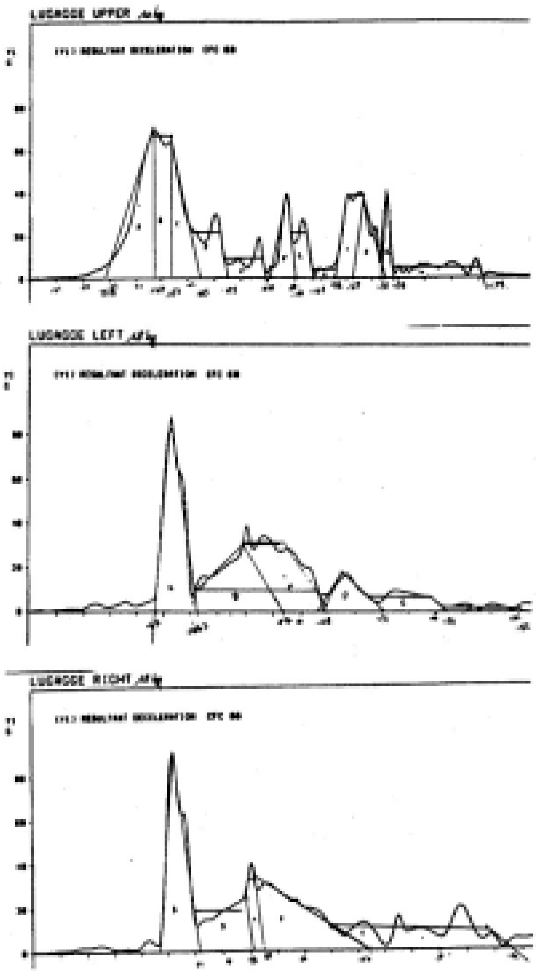
Force Applied To Net By Loads (Peak)

Upper (1X10Kg.) =	3700N.
Lower (2X18Kg.) =	9500N.

1. STRENGTH CALCULATIONS

1.1 SLED TEST

Based on the crash test done with 2 blocks of 18 kg next to each other, plus a 10 kg block on top of them.



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1.2 SLED TEST CALCULATIONS

Direct pull on fabric to test the capability of the mechanism.

ENERGY / TIME CALCULATION

	Area Code	Mean Time mm durat.	Accel. mm durat.	Volume	Time Mean	G 's	Force N	Time until
								0.028
UPPER 10 kg	A	38	115	2185	0.040	34.85	3419	0.047
	B	13	110	1547	0.050	72.11	7074	0.053
	C	22	103	1092	0.057	30.08	2951	0.065
	D	20	35	700	0.067	21.21	2081	0.075
	E	28	15	435	0.080	9.41	923	0.089
	F	23	63	640	0.095	16.86	1654	0.101
	G	14	34	442	0.103	19.13	1877	0.107
	H	16	7	114	0.112	4.31	423	0.116
	I	13	62	806	0.120	37.57	3686	0.123
	J	23	60	775	0.128	20.42	2003	0.135
	K	10	65	330	0.137	19.99	1961	0.138
	L	67	8	536	0.155	4.84	475	0.172
				9602				

Mass	Area Code	Mean Time mm durat.	Accel. mm durat.	Volume	Time mean	G 's	Force N	Time until
								0.047
LEFT 18 kg	A	31	143	2272	0.052	44.41	7842	0.063
	B	70	48	1692	0.075	14.65	2587	0.094
	C	30	51	1530	0.095	30.90	5456	0.106
	D	50	28	700	0.117	8.48	1497	0.131
	E	45	10	450	0.140	6.06	1070	0.154
	F	55	3	181	0.165	1.99	351	0.180
				6825				

Mass	Area Code	Mean Time mm durat.	Accel. mm durat.	Volume	Time mean	G 's	Force N	Time until
								0.047
RIGHT 18 kg	A	30	146	2190	0.053	44.24	7812	0.061
	B	38	30	1170	0.070	18.66	3295	0.081
	C	8	53	424	0.082	32.12	5672	0.085
	D	80	54	2172	0.095	16.45	2905	0.124
	E	105	18	1921	0.145	11.09	1958	0.176
				7877				

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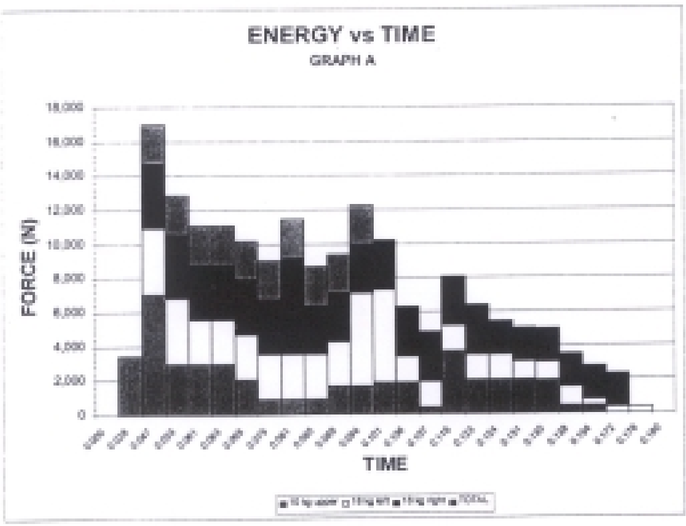
1.2.1 GRAPH A :

Smoothing to reduce the peaks caused by 18 kg blocks hitting the sled brackets.
We reduced the data of "LEFT" & 'RIGHT" to 3842 N & 3812 N for 0.47 to 0.61 duration.
We increased the total by 2240 N for 50 millisecs from 0.47

Time	Force N			
	UPPER	LEFT	RIGHT	TOTAL
0.028				
0.047	3,419	3,842	3,812	2,240
0.053	7,074	3,842	3,812	2,240
0.061	2,951	3,842	3,812	2,240
0.063	2,951	2,587	3,295	2,240
0.065	2,951	2,587	3,295	2,240
0.075	2,081	2,587	3,295	2,240
0.081	923	2,587	3,295	2,240
0.085	923	2,587	5,672	2,240
0.089	923	2,587	2,905	2,240
0.094	1,654	2,587	2,905	2,240
0.101	1,654	5,456	2,905	2,240
0.106	1,877	5,456	2,905	
0.107	1,877	1,497	2,905	
0.116	423	1,497	2,905	
0.123	3,686	1,497	2,905	
0.124	2,003	1,497	2,905	
0.131	2,003	1,497	1,958	
0.135	2,003	1,070	1,958	
0.138	1,961	1,070	1,958	
0.154	475	1,070	1,958	
0.172	475	351	1,958	
0.176		351	1,958	
0.180		351		



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1.2.2 GRAPH B :

We removed the period 0.47 to 0.53 as this is basically an impact and reversal of loading energy.

(7842 – 2587) x (0.063–0.047) = 84.08 Nsecs

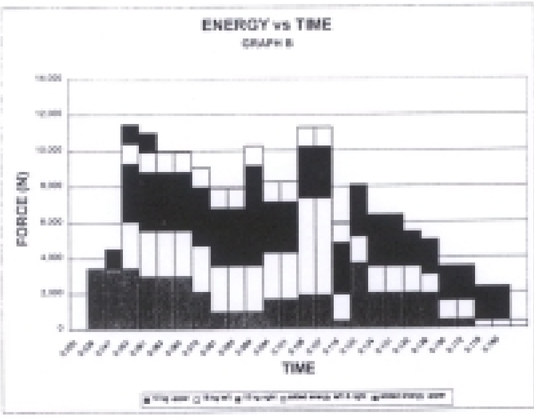
(7812 – 3295) x (0.061–0.047) = 63.24 Nsecs

added between 0.47 & 0.11 millisecs = 0.63 msecs = 1087 N

(7074 – 3419) x (0.053–0.047) = 21.93 Nsecs

added between 0.4 & 0.6 millisecs = 1096 N

Time	Force N				
	UPPER	LEFT	RIGHT	ADDED	ADDED
0.028	3,419				
0.047	3,419				1,096
0.053	3,419	2,587	3,295	1,087	1,096
0.061	2,951	2,587	3,295	1,087	1,096
0.063	2,951	2,587	3,295	1,087	
0.065	2,951	2,587	3,295	1,087	
0.075	2,081	2,587	3,295	1,087	
0.081	923	2,587	3,295	1,087	
0.085	923	2,587	3,295	1,087	
0.089	923	2,587	5,672	1,087	
0.094	1,654	2,587	2,905	1,087	
0.101	1,654	2,587	2,905	1,087	
0.106	1,877	5,456	2,905	1,087	
0.107	1,877	5,456	2,905	1,087	
0.116	423	1,497	2,905	1,087	
0.123	3,686	1,497	2,905		
0.124	2,003	1,497	2,905		
0.131	2,003	1,497	2,905		
0.135	2,003	1,497	1,958		
0.138	1,961	1,070	1,958		
0.154	475	1,070	1,958		
0.172	475	1,070	1,958		
0.176		351	1,958		
0.180		351	1,958		
		351			



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