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Safework Analysis of M113 Vehicles

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Safework analysis of M113 vehicles

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Safework analysis of M113 vehicles

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Executive summary

The "Safework analysis of M113 vehicles" was conducted in the process of extending the life of the Canadian land Forces M113 Armoured Personnel Carrier (APC) fleet. Its goal was to examine the bench seats in the M113 APC to recommend a more ergonomic design.

The objectives of the study were to reduce vibration's effects, accommodate 95 percentile male and 5 percentile female, increase the comfort and increase the postural stability.

The examination has been performed in three steps. The first one was to collect the pertinent data using interviews, on site measurements and technical drawing review.

The second step was to analyse, using Safework (Genicom's ergonomic analysis software), the actual bench seats in order to elaborate the ergonomic specifications.

The last step was to formulate the recommendations (a total of 11 recommendations). The global concept resulting from the recommendations is a lower bench seat with individual sliding (forward/backward) seat-cushions and with individual lumbar and back rests. A non-slip footrest is included in the bench seats base.

This document presents the analysis results with the recommendations that have been formulated. Illustrations are provided to give a better idea of the recommendations applications.

Introduction

In the process of extending the life of the Canadian Land Forces M113 Armoured Personnel Carriers (APC) fleet, Genicom Consultants Inc has been mandated by DCIEM to conduct an examination of the bench seats in the M113 APC to recommend a more ergonomic design.

This examination involves the analyse and review of M113 seating requirements and then recommendations of ergonomic design specifications.

Performance criterions

For a more ergonomic design of the seats in the M113 APC, the following points were considered.

- Reduce vibration's effects
- Accommodate 95 percentile male and 5 percentile female
- Increase the comfort
- Increase the postural stability

Recommendations

1. Lengthen left seat bench (when looking from the back door) towards the back door;

Extend the left seat bench by 8 inches towards the rear door. This modification allows the passengers to sit closer to the back door and gives more legs room to the passenger who sits beside the turret. (Illustration 1)

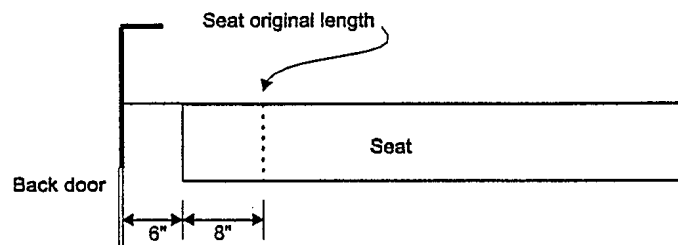


Illustration 1 – Seat length (Top view)

2. Provide individual seat-cushions

By providing individual seats each passenger's position is clearly defined. This way it's faster and simpler for the passengers to adopt the correct position.

As shown in illustration 2, individual seats must be 18 inches wide and 17 inches deep. The space between each seat is 1 inches.

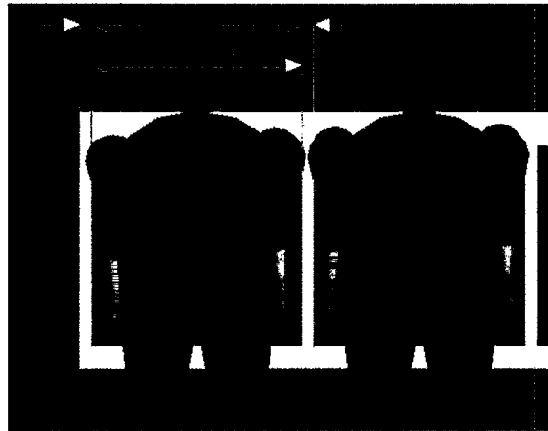


Illustration 2 – Individual seats dimensions

3. Alternate the opposing passengers

As shown in the following illustration (Illustration 3), seats must be positioned so that opposing passengers are slightly offset (3.5 inches). This disposition optimise the space and gives better leg room to each passenger. Note that the passengers represented in illustration 3 are all 95 percentile males. For the analysis, they were all clothed in combats, not including webbing. The fact that we used all 95 percentile males will allow some room for equipment.

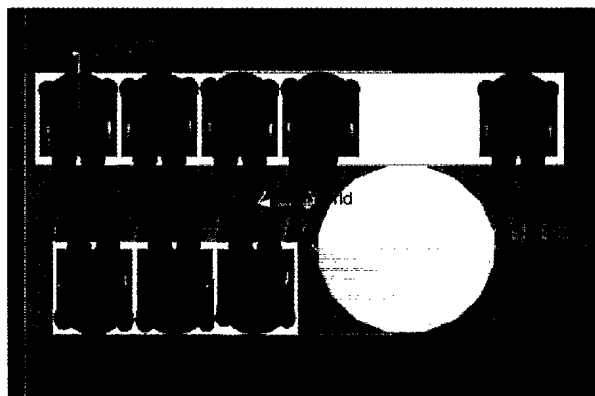


Illustration 3 – Seats disposition

4. Lower the seat height to 10 inches.

The inside height of the M113 vehicle is limited to 47 inches (floor to ceiling). Considering this, we performed a Safework analysis to determine the effects of seat height on torso inclination. The current seat height is 11 inches. Analysis showed that at this height and with torso inclination fixed at 20 degrees, the head-ceiling clearance is only 0.5" for the 95 percentile male. At this height it is impossible to accommodate the 99 percentile. The 20 degrees torso inclination has been selected as a trade-off to accommodate all the passengers on the basis of sitting comfort angles.

Table 1 shows the head-ceiling distance at various sitting heights for 95 and 99 percentile man. Distance head-ceiling is indicated without wearing a helmet.

Sitting height	Torso inclination (degrees)	Head-ceiling distance (no helmet)	
		Man 95 th pc	Man 99 th pc
10"	20	1.5"	0.6"
11"	20	0.5"	-0.4"
12"	20	-0.5"	-1.4"

Table 1 – Head-ceiling distance for various sitting height

To increase the head-ceiling distance without lowering the seat, the torso inclination should be increased. Table 2 shows back inclination for a predetermined head-ceiling distance at three seat heights. We fixed the head-ceiling distance at 1.5 inches in order to provide clearance for the helmet.

Sitting height	Head-ceiling distance	Inclination (degrees)	
		Man 95 th pc	Man 99 th pc
10"	1.5"	20	23
11"	1.5"	23	25
12"	1.5"	25	28

Table 2 – Torso inclination at various sitting heights

Proper seat height is important. If the seat is too high, the accommodated population is small and if the seat is too low, torso inclination is reduced but leg angle (from horizontal) increases. In this posture, the buttocks support all the weight. This can be a cause of increased fatigue and discomfort.

We recommend lowering the seat height to 10 inches to better accommodate taller passengers. At this height, 90 percent of the male and 99 percent of the female population have a head clearance of 2 and 2.5 inches or more respectively (no helmet). More over, it helps keep passengers' posture in the sitting comfort zones.

5. Provide a footrest:

It is important to stabilise the posture by providing a good footrest. We recommend redesigning the seat base to include a footrest. This one must be at an angle of 35 degrees from the horizontal in order to accommodate the largest population. For the same reason, the footrest surface length must be 6 inches. Illustration 4 (not at scale) gives an idea of how to integrate the footrest into the seat base.

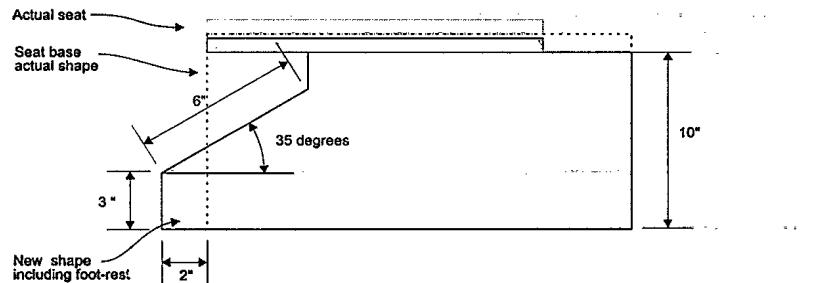


Illustration 4 – Foot-rest

6. Foot-rest surface must be non-slip:

Apply a non-slip material on the inclined surface of the footrest.

7. Moulded seat padding:

The seat padding must be moulded to provide good support to the thighs. Good support reduces fatigue, helps stabilise the posture and reduces sliding.

Considering that a seat height of 10 inches accommodates 90 % of the Canadian army population, we used this height to perform a Safework analysis of the angle of the seat.

Table 3 shows the thigh angle for males and females at 5, 50 and 95 percentile of leg length. We assumed in this analysis that the seat is fixed (no horizontal adjustment). For the results to be considered the passenger must be able to reach the footrest and the thigh angle must be greater than 0 degrees.

	M95	M50	M5	F95	F50	F5
Thigh angle	22.03	15.05	1.46	18.76	1.8	-
Horizontal seat adjustment	0	0	0	0	0	-

Table 3 – Thigh angle with fix seat

Considering this first analyse, we did a second using a fixed thigh angle of 15 degrees and a horizontal seat adjustment to allow the passenger to reach the footrest. Table 4 indicates the seat adjustment necessary to maintain a thigh angle of 15 degrees.

	M95	M50	M5	F95	F50	F5
Thigh angle (degrees)	-	15	15	15	15	15
Horizontal seat adjustment	-	1.24"	5.53"	0"	3.59"	7.19"

Table 4 – Thigh angle with adjustable seat

Thighs must be completely supported to avoid fatigue; a 15 degree seat angle plus seat adjustment accommodates 90 % of the female population and 50 % of the male population. For most passengers the resulting posture respects the most commonly used sitting comfort angles.

Table 5 shows the trunk-thigh and thigh-leg angles compared to their comfort zones

	Comfort zone (degrees)	M95	M50	M5	F95	F50	F5
Trunk-thigh	95 to 98	87	95	97	98	97	97
Thigh-leg	110 to 120	101	117	118	111	110	105

Table 5 – Trunk-thigh and thigh-leg angle compared to their comfort zones

The taller males don't have the thighs completely supported and can begin experiencing discomfort very quickly. But, if we try to accommodate a larger proportion of the male population by providing a larger seat inclination, it becomes uncomfortable for the others because comfort zones can not be respected.

In combination with recommendation number 5, an inclination of 15 degrees to the front part of the seat (first 12 inches) should accommodate the largest portion of the population. The following illustration (not at scale) gives an idea of the suggested shape.

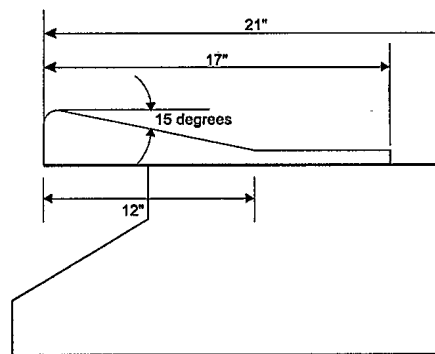


Illustration 5 – Shaped seat padding

8. Provide horizontal adjustment on individual seats:

Fix seats have a direct impact on passenger comfort and posture stability. They do not allow the passenger to correctly position their feet flat on the floor and at the same time maintain a comfortable sitting posture. Moreover, only those passengers with long legs (60 percent male and 95 percent female for leg length) are able to reach the footrest. In order to accommodate the largest population and to respect the sitting comfort angles, we recommend installing sliding forward/backward individual seats.

The seat adjustment range must be a minimum of 7 inches to accommodate all the male population and 75 percent of the female population. A range of 8 inches accommodates 85 percent of the female population and a range of 9 inches accommodates 95 percent of the female population.

However, we recommend an adjustment range of 7 inches, otherwise, tall passengers won't be able to reach the foot rest because the opposite seat will be in their way. Illustration 6 shows the initial and final seat position with a range adjustment of 7 inches.

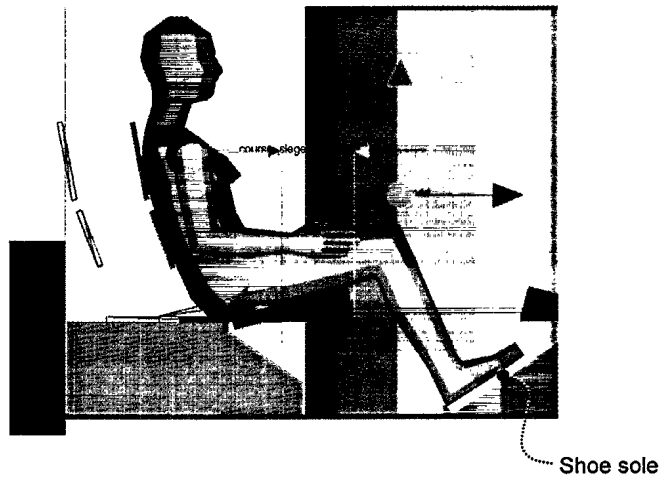


Illustration 6 – 7 inches seat adjustment

9. Back rest angle and size

For the posture to be stable and comfortable, back support should be provided at two points: lower back (lumbar) and upper back.

Tables 6 indicates the position of the centre of the lumbar support and back rest for males and females at 5, 50 and 95 percentile of sitting height according to Safework analysis.

	M95	M50	M5	F95	F50	F5
Back rest height	16.57	16.27	16.08	16.16	16.02	15.79
Back rest distance	20.5	20.5	20.5	20.5	20.5	20.5
Back rest inclination	8	8	8	8	8	8
Lumbar support height	8.02	7.97	7.78	8.91	8.63	8.14
Lumbar support distance	18.12	18.19	18.13	18.43	18.37	18.39
Lumbar support angle	23	22	20	22	20	19

*Total trunk inclination of 20 degrees for all the mannequins

Table 6 – Lumbar support and back rest position

The following illustration indicates measurement references.

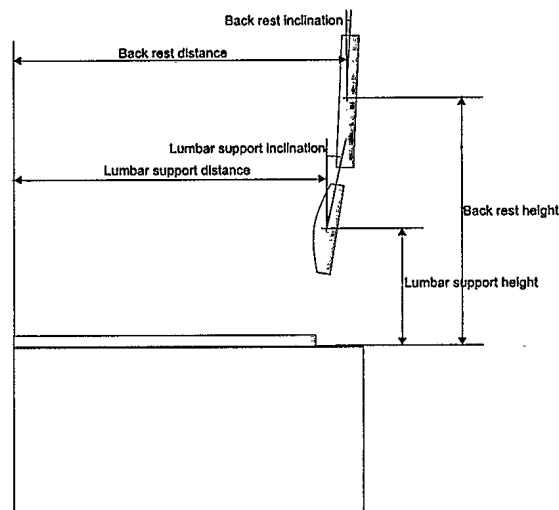


Illustration 7 – References of the measurements

Support at the lumbar level should be provided by the addition of a low backrest. In order to accommodate the largest population we suggest a pivot be placed in the back of the support so its inclination will be automatically adjust to the passenger (Illustration 8).

According to the results of the analysis the centre of the lumbar support must be 8 inches above the seat surface and 18.25 inches from the front of the seat. The lumbar support itself

should be 6 inches high and its surface radius should be 10 inches. The lumbar support must be inclined at 20 degrees and mounted on a pivot to allow automatic adjustment of the inclination (+/- 5 degrees).

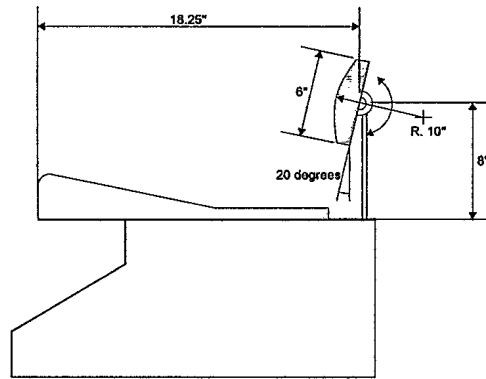


Illustration 8 – Lumbar support

Support of the upper back should be provided by the addition of a backrest. To avoid interference with the storage activities we suggest that the backrest can be fold down over the seat when not used (Illustration 9).

According to the analysis results, backrest centre must be 16 inches from the seat and at a distance of 20.5 inches from the front of the seat. The backrest itself must be 8 inches high and it must be inclined at 8 degrees.

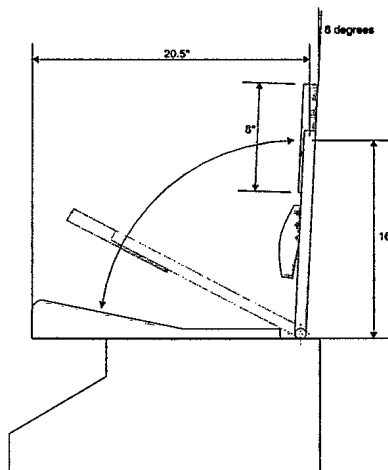


Illustration 9 – Back rest

The following illustration shows the position of the backrest and lumbar support.

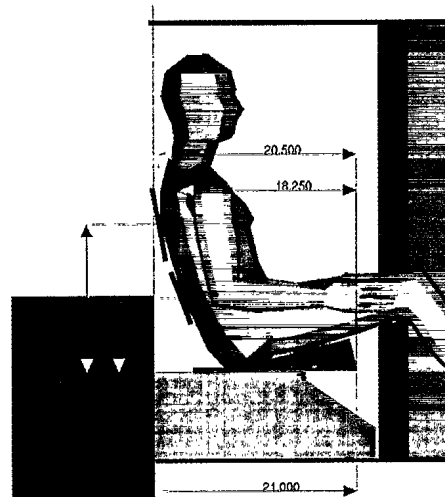


Illustration 10 – Backrest and lumbar support position

10. Lumbar support and back rest must follow the seat displacement;
11. Provide handles on the ceiling or between the seats to stabilise the posture.

Conclusion

The recommendations listed in this report can be apply in totality or partially. However, we believe that the optimal response to the M113 seating problem is to apply all the recommendations. Illustration 11, bellow, shows a view of the configuration incorporating all the recommendations. The passenger represented in the scene is a 50 percentile male.

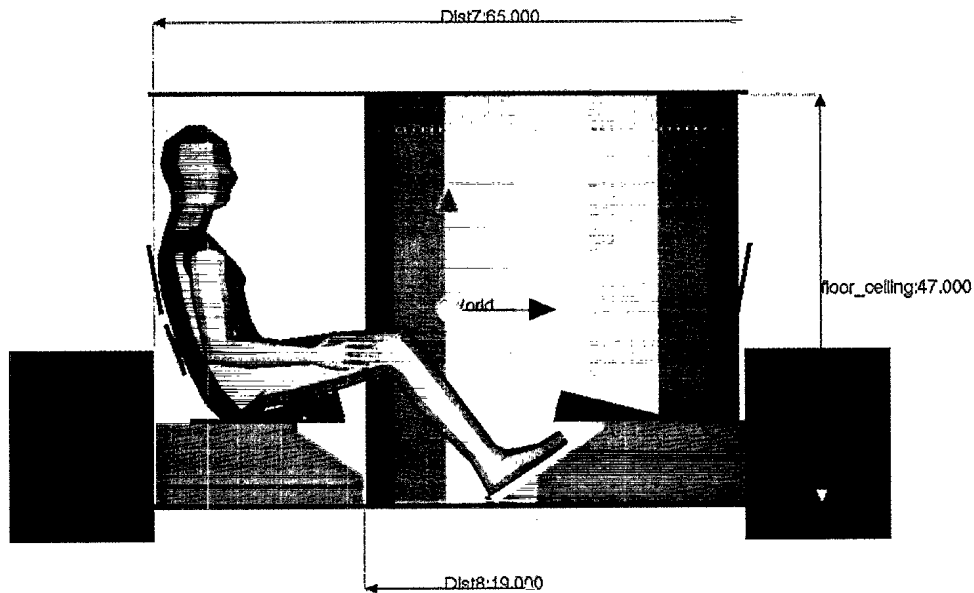


Illustration 11 – General arrangement

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