The effect of T-bar height on air distribution in reefer containers

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1. Objective

The objective of this study is to gain insight in the relation between T-bar height and air flow distribution in reefer containers.

2. Materials and methods

Collect data from 4 experiments: 2 containers x (covered floor + empty container). The containers are as much as possible identical except for the T-bar floor. In that way it is assured that if different air speeds are observed then these differences are the consequence of the differences in T-bar floor. In each experiment airspeeds are measured in the centre of two T-bars, in case of SUDU 471502[2] even in two low and two high T-bars.

Table 1, experimental conditions

condition	value
ventilation	100%
fan speed	high
ambient temperature	± 20 °C
temperature setpoint	15 °C
doors	fully opened
windspeed	moderate (± 3-4 Beaufort)
pallet type	2-way euro pallets
pallet dimensions	100x120 cm
power	50 Hz/400V
location	Waalhaven terminal, Rotterdam, Netherlands
date	July 1, 2003

Table 2, information about the reefer containers used.

box manufacturer	MCI Qingdao	CIMC
container identification no.	SUDU 471502[2]	SUDU 470597[6]
reefer unit model	69NT40-531-02	69NT40-531-02
date in service reefer unit	July '02	Sept. '02
model no. box	MQRS-40HS-001B	1AAA-S-18C
manufacturing date box	May '02	Aug. '02
int. dimensions (LxWxH)	11.51x2.305x2.56 m	11.475x2.30x2.57 m
T-bars (height, pitch, opening)	16 T-bars at sides: 59x63.5x35 mm 19 middle T-bars: 45x63.5x35 mm (Fig. 1).	55x64x35.5 mm

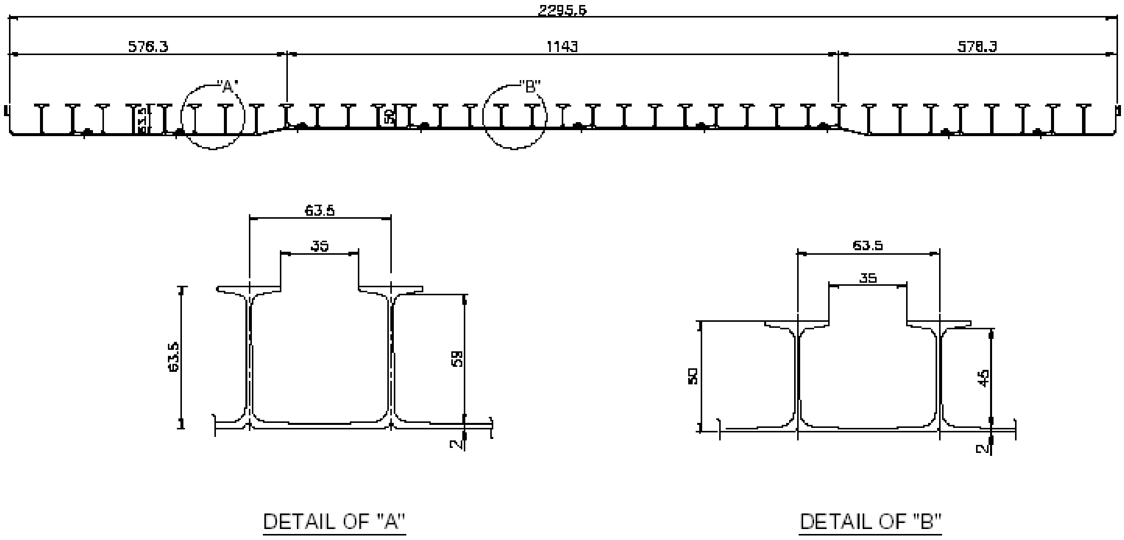


Fig. 1, design drawing of T-bars in SUDU 471502[2].

Two containers are positioned side by side (Fig. 2). Fig. 3 illustrates the way the floor is covered in the experiments with floor coverage. 20 two-way pallets of 100x120 cm (Fig. 4) are laid in the empty containers. The pallets are covered with hardboard panels (Fig. 5). Air chinks are closed at sides (Fig. 5, Fig. 6), unit end (Fig. 7) and door end (Fig. 8, dashed area in Fig. 3), only the T-bar end (in vertical plane) is left open (Fig. 9, Fig. 10). The hardboard panels contain 220 holes (∅ 5 cm), 110 holes for the left 11 pallets and 110 holes for the right 9 pallets. The holes have been drilled by ATO such that the airflow resistance of the hardboard panels approximates the airflow resistance of a cargo of pallets with boxed bell peppers with 2 cm vertical gaps between pallets and walls, and between pallets mutually as well. Note that a fair comparison between right and left half of the container is hampered now by the fact that the right half contains more holes per pallet than the left half.

Air speeds are measured with a so-called hot bulb NTC, manufactured by Testo (Fig. 11) with calibration certificate valid through Dec. '03.

Fig. 2, the two containers used in the experiments.

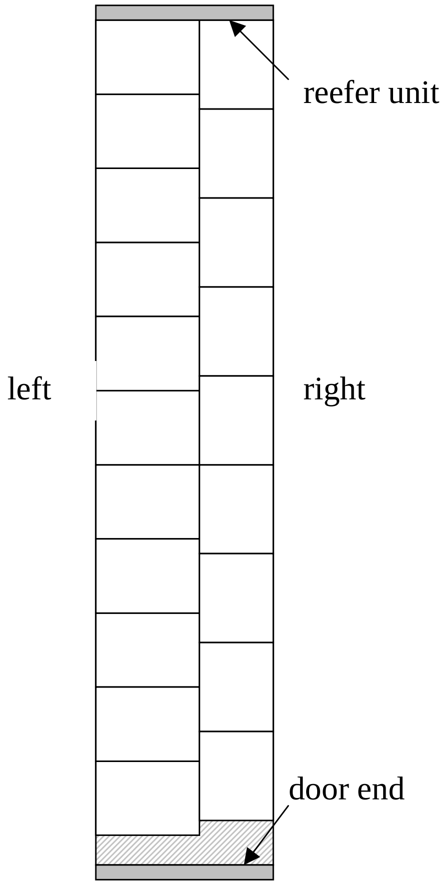


Fig. 3, schematic top view of container stowage

Fig. 4, two-way pallets used.

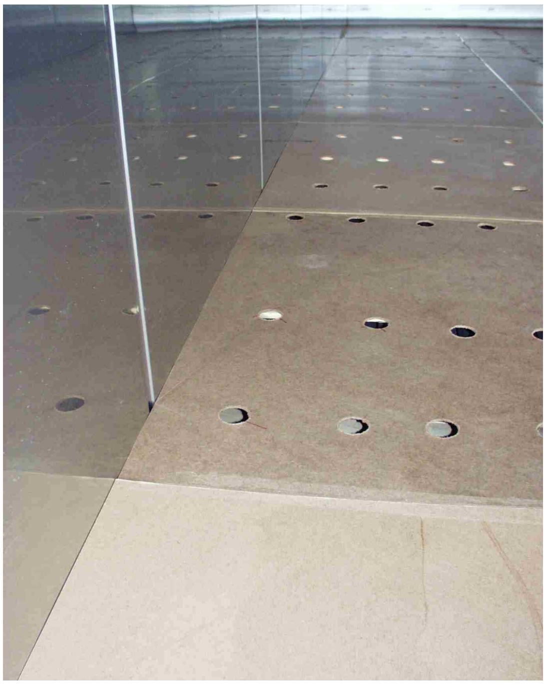


Fig. 5, floor covered with hardboard panels

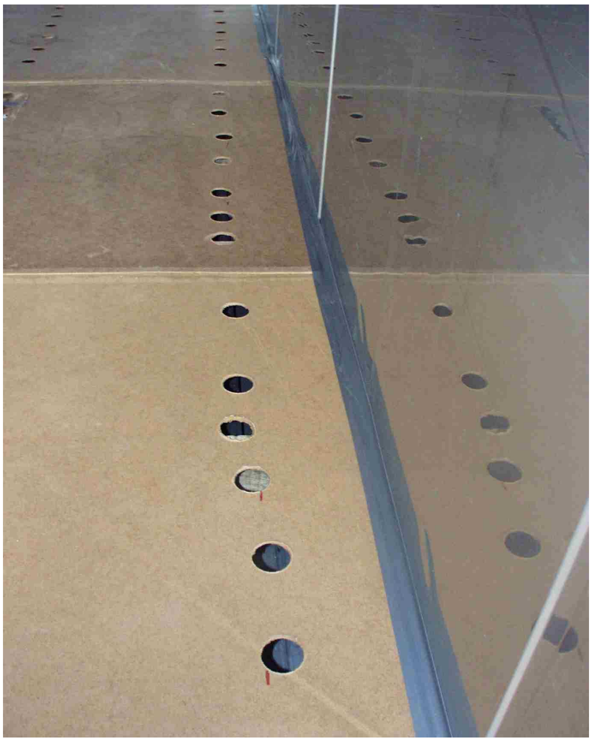


Fig. 6, side chink closed with adhesive tape.

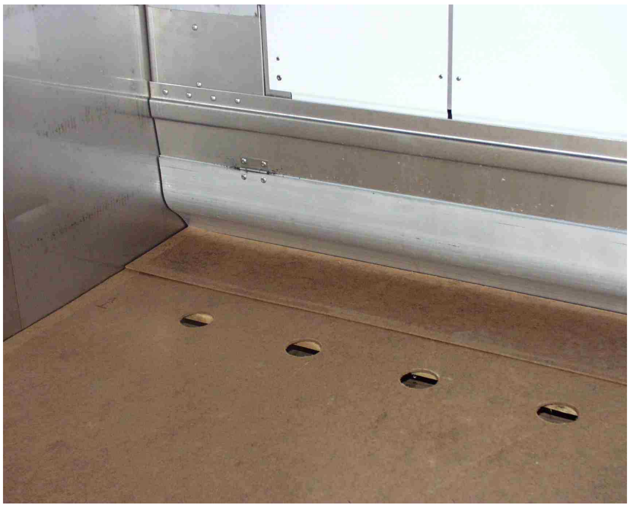


Fig. 7, chink at unit end closed with board.

Fig. 8, chink at door end closed with (bell pepper) boxes.

Fig. 9, CIMC T-bars.

Fig. 10, MCI T-bars.

Fig. 11, air speed measurement device used.

3. Results

The measurement results are shown in Fig. 12 through Fig. 15. With respect to the figure legends note that T-bar 1 is defined as the left-most T-bar, while T-bar 35 is the right-most T-bar (for left and right see Fig. 3). In Fig. 14 and Fig. 15 the numbers 1 to 4 indicate the row of holes in the floor coverage where measurements are taken. Row 1 is the row of holes at about 0.5 m from the left side of the container, while row 2 is situated 0.9 m from the left side of the container etc.

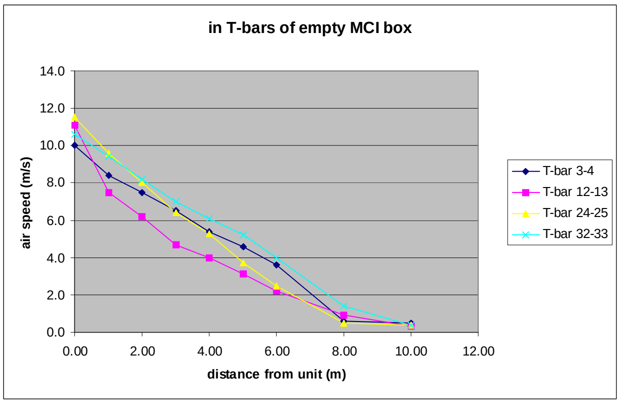


Fig. 12, air speeds in T-bars of SUDU 471502[2] while empty.

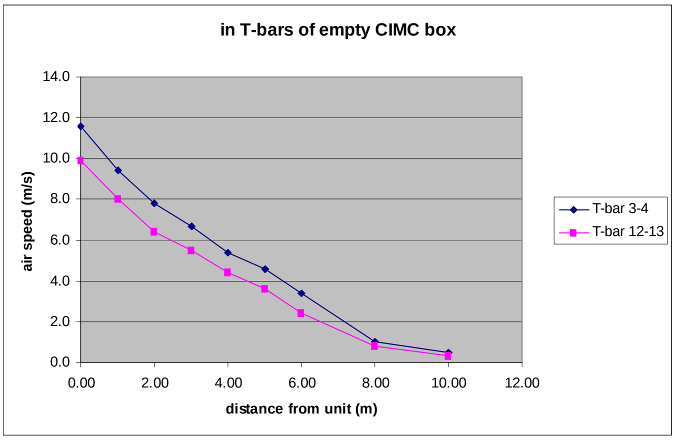
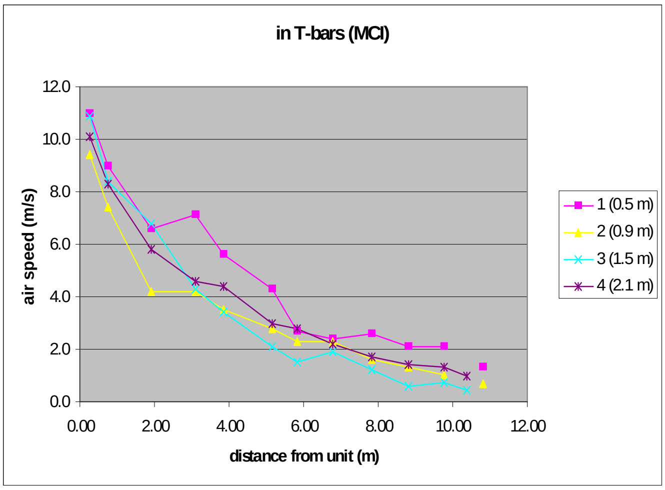
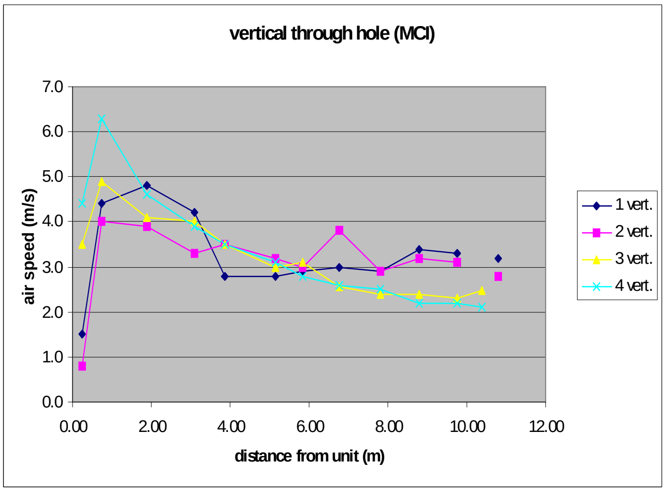


Fig. 13, air speeds in T-bars of SUDU 470597[6] while empty.





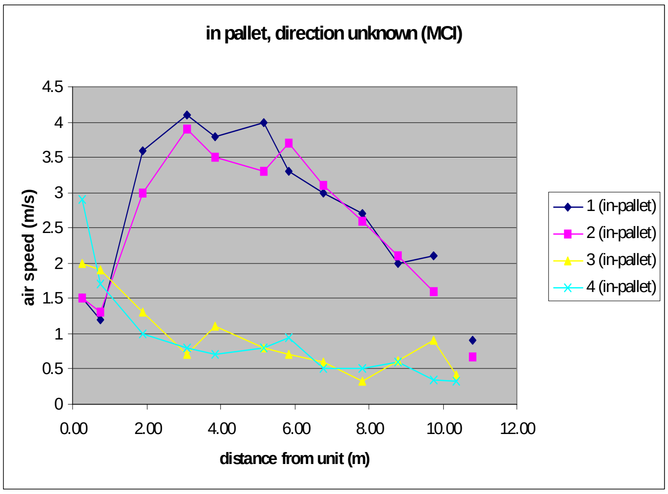


Fig. 14, air speeds in MCI box with floor coverage.

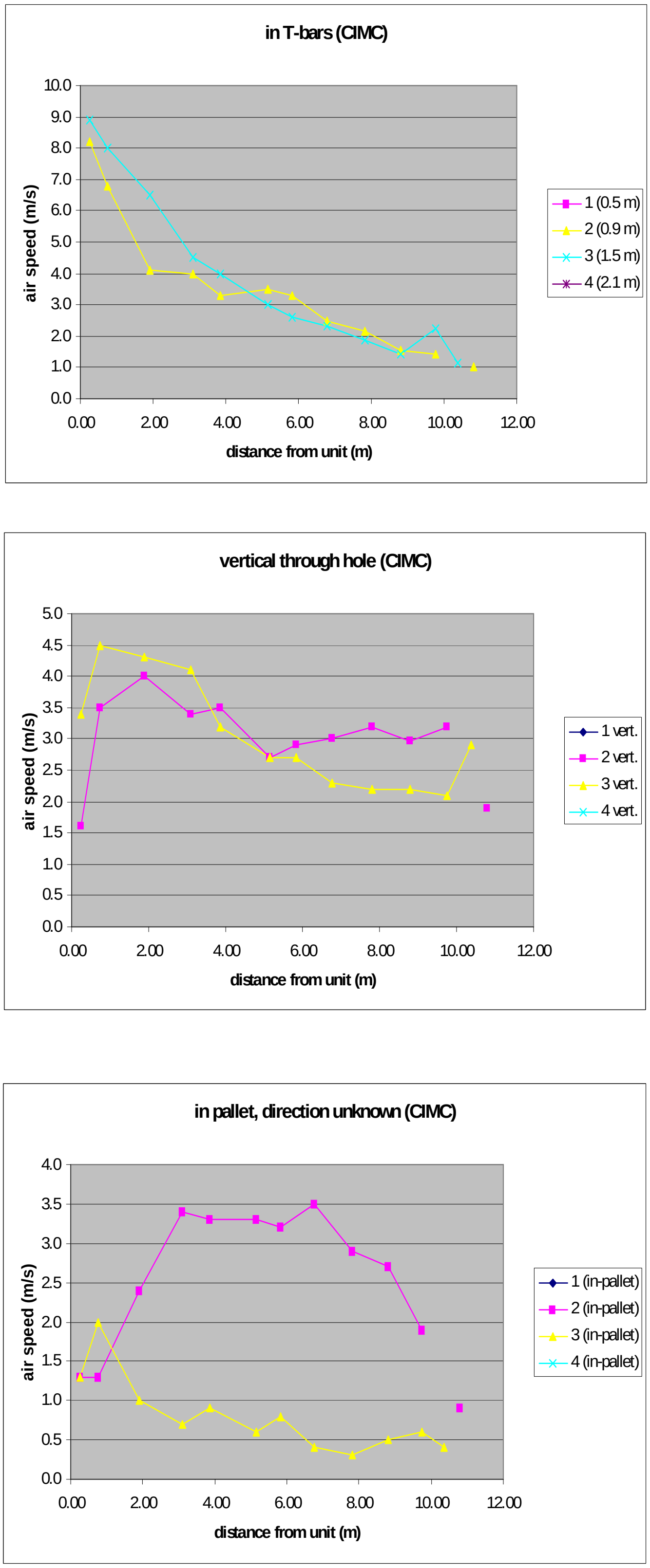


Fig. 15, air speeds in CIMC box with floor coverage.

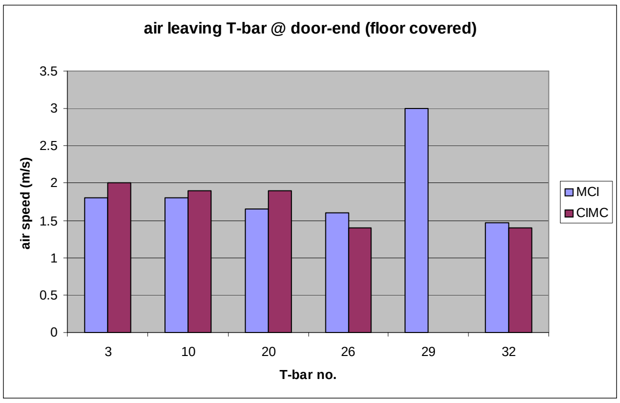


Fig. 16, air speeds leaving the T-bars at door-end

4. Discussion

In the empty containers a noticeable difference occurs between air speeds in low and high T-bars: the lower T-bars 'lose their air' more rapidly than the higher T-bars (pink and yellow in Fig. 12 are 45 mm T-bars, light - and dark blue in Fig. 12 are 59 mm, Fig. 13 is 55 mm). Note that differences in air *speeds* (m/s) are only a part of the truly occurring differences, as in case of equal air speeds (m/s) the delivered *airflow* (m^3/h) of high T-bars is higher than that of low T-bars due to its higher cross-sectional area (m^2)!

Also in the MCI-container with floor coverage the lower T-bars 'loose their air' slightly more rapidly than the higher T-bars (compare row 2+3 with 1+4 in Fig. 14a), like in the empty container (Fig. 12). And again, when looking at airflow (m^3/h) this difference is amplified by the difference in cross-sectional area. Yet the observed difference does not result in a noticeably lower vertical air speed through the holes in the two middle rows (Fig. 14b, Fig. 15b), apparently the pallets act as air ducts allowing for sufficient smoothening of differences originating from the T-bars. Also a mutual comparison of the vertical air speeds through the holes in the two containers does not reveal a distinct difference (compare Fig. 14b with Fig. 15b). In this comparison it must be noted that the mean T-bar heights of both containers are nearly equal (55 mm for CIMC and 51.4 mm for MCI).

In the containers with floor coverage it is interesting (but obvious) to observe that only the two-way pallets in the left half of the container serve as air duct (Fig. 14c, Fig. 15c). Although it goes beyond the scope of this project it is intriguing to observe that there is only a minor difference between the airspeeds coming through the holes in the left and right half of the container. As the pallets in the left half create an air duct while the ones in the right half don't, it would be natural if less air reaches the door-end in the right half. The unequal left-right distribution with respect to number of holes per pallet prohibits being conclusive with respect to air speed differences between left and right pallet-row.

5. Conclusion

1. The lower T-bars 'loose their air' more rapidly than the higher T-bars, regardless of the presence of palletised cargo.
2. No difference in air speeds through the holes (i.e. cargo) is observed between the containers from CIMC and MCI in case of pallets + floor coverage with pressure drop equal to the pressure drop over a cargo of palletised boxed bell peppers with 2 cm gaps around each pallet.

The interpretation of the two above conclusions is that the lower MCI T-bars have no adverse effect on temperature distribution throughout the cargo provided that the containers are properly stowed with palletised cargo with at least a usual air flow resistance, as in that situation the pallets will take over the air duct function. However, in case the MCI container carries produce with large autonomous heat production and with only little vertical pressure drop over the cargo (poor stowage or open packaging) a detrimental effect on temperature distribution will occur.

6. Acknowledgements

ATO thanks MCI for its financial support of the project, and both Hamburg Süd and Waalhaven terminal Rotterdam for facilitating the project.