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MODIFICATION KIT TO UPGRADE DOMESTIC REFRIGERATORS FOR VACCINE STORAGE

Design, methodology and test results

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SUMMARY

Domestic refrigerators are unsuitable for storing vaccines. They are, however, used for this purpose in some developing countries.

On behalf of WHO/EPI, the *Camara Ambiental* of the *Universidad del Valle* in Colombia has developed a modification kit to improve the performance of domestic refrigerators. The kit:

- ensures that domestic refrigerators meet WHO/UNICEF requirements for vaccine storage;
- is simple enough to be implemented by staff with little training;
- is made of materials which can be purchased locally.

This report describes the design of the kit, how it works and the results achieved with it installed in a range of domestic refrigerators.

1. INTRODUCTION

Immunization programmes require that potent vaccines be delivered to women and children all over the world.

Vaccines are damaged by long exposure to heat so must be maintained at temperatures between 0 °C and 8 °C from the place of manufacture to the immunization site. Equipment for the transport and storage of vaccines has to comply to Standard Performance Specifications established by WHO and UNICEF[1].

Some developing countries choose locally made domestic refrigerators, primarily for economic reasons, to store vaccines in health centres. Tests conducted at the *Camara Ambiental* laboratory in accordance with WHO/UNICEF Test Procedures demonstrate, however, that the capacity of domestic refrigerators to maintain adequate internal temperatures is very poor. Power failures and variations in ambient temperatures cause drastic changes in refrigerator temperatures which can damage the vaccines.

The first stage in the development of the Modification Kit was completed during 1990 - 1991 by the *Camara Ambiental* within the project: "Domestic refrigerator improvements for vaccine storage". They achieved significant improvements with the preliminary design but it did not meet all the WHO/UNICEF Specifications.

In the next stage, the *Camara Ambiental* staff started off with the preliminary design and conducted a series of trials to refine their initial approach. Finally they arrived at a design which succeeded in establishing a thermally uniform and stable system.

1 EPI Performance Specifications, 1991 (WHO/EPI/LHIS/91.1)

2. OBJECTIVES

To make domestic refrigerators suitable for the storage of vaccines by developing an upgrade kit which would be :

- Universal, i.e. could be used with all types of domestic refrigerators;
- Simple enough to be installed by untrained staff; and
- Made of cheap locally available materials.

3. DESIGN

The kit, as shown in **Figures 1 and 2**, comprises:

- **A closed container** made of aluminium sheeting, with a door at the front.
- **Three vaccine shelves** made of square type aluminium grid, mill finish ½ x ½ x ½"; positioned within the closed container and designed to allow free movement of air.
- **Water-packs** placed at the bottom of the container, each pack resting on its narrow side.
- **An open tray**, made of aluminium sheeting, located on the outside top of the container, directly below the refrigerator freezer compartment. The tray holds three layers of icepacks and constitutes the "main cold tank" of the system.
- **A bi-metal thermometer** installed on the **outside of the container door.**

4. METHODOLOGY

4.1 Within the container space:

The free movement of air within the container and the highly conductive qualities of the aluminium facilitate heat transfer. This accelerates the rate at which temperatures within the container become more uniform.

The groups of water-packs and ice-packs, on the other hand, increase the thermal inertia within the enclosed space and operate as "stabilizers".

The water packs at the bottom always remain liquid and prevent excessive cooling. If, for any reason, the internal temperature drops, cold air flows downwards. The water packs warm the air up and prevent temperatures from dropping below 0°C (see **Figure 3**).

4.2 Within the refrigerator space:

Heat transferred through the insulating walls of the refrigerator elevates the temperature of the air in the space between the container and the refrigerator. This creates a free convection current. As the air rises, it passes the frozen icepacks which absorb the heat. Temperatures within the refrigerator space thus remain stable.

4.3 Temperature surveillance:

The bi-metal thermometer on the container door allows the operator to adjust the thermostat and check internal temperatures without opening the container (see **Figure 1**).

5. RESULTS

To demonstrate the efficiency of the kit, three domestic refrigerators at the *Camara Ambiental* were used. Two of them, the ICASA E3-2037 and the ICASA E3-2064, successfully passed the tests with the kit installed; the third, the General Electric E3-2078, failed due to a burnt compressor and was withdrawn.

Figures 4 and 5 show the location of the sensors installed to monitor temperatures in each refrigerator during the tests.

Table 1 describes WHO/UNICEF requirements.

Table 2 provides a comparison between the performance of the original refrigerator:

- with no modifications;
- with the preliminary modification;
- with the final successful kit installed.

The minimum and maximum temperatures (Tmin and Tmax) reflect the lowest and highest values recorded inside the vaccine load. The results, as summarized in **Table 2**, show that:

- The original refrigerator design and the first modification do not pass the tests.
- The same equipment ***with the kit installed, does meet the requirements.***

With the kit installed:

- **All temperatures are kept within the acceptable range,** with a reasonable margin, under all circumstances.
- **Excellent temperature control is achieved,** even during the most severe test -- (day/night 43/15°C) -- a condition which was never achieved before.
- **The refrigerator run time is reduced** in all cases so energy consumption decreases.
- **The even distribution of temperatures within the container is substantially improved** during stable running conditions and the range of temperatures inside the refrigerator drops from 4.6/5.3 °C to 1.4/2.7 °C. This is an additional guarantee for safe vaccine storage because conditions remain uniform with no cold or hot zones.
- **The safe freezing capacity increases**—doubled for E3-2037 and quadrupled for E3-2064. This is slightly more than WHO requirements.
- **The ability to maintain suitable temperatures improves.** During the holdover test (one of the most important for developing countries) it improved fourfold, surpassing WHO requirements. These successful results were achieved without the use of additional icepacks. Tests carried out with 9 kg of extra ice showed 16 and 20 hours of holdover time, i.e. 10 and 13 times the original capacity, triple the WHO requirements.

Finally, it should be noted that the thermostats on all the refrigerators tested were set at medium. This suggests that there is **still capacity for temperature adjustments.**

6. CONCLUSIONS

The results achieved with the kit confirm the predictions based on initial theoretical assumptions.

- The kit is simple and easy to implement in any domestic refrigerator.
- Components of the kit can be made from locally available materials.
- The kit can be put together with simple tools and by untrained staff.
- The homogeneity of the temperature range permits the storage of vaccines within acceptable limits.
- The use of a dial thermometer mounted on the container door facilitates the inspection and adjustment of internal temperatures.
- **The kit works successfully and should be installed in domestic refrigerators used in the Cold Chain.**

TABLES AND FIGURES

Table 1: WHO/UNICEF STANDARD REQUIREMENTS FOR REFRIGERATOR PERFORMANCE[2]

TESTS	DAY/NIGHT (43/15 °C)	FREEZING CAPACITY (kg./24 hours)	HOLDOVER TIME (hours)
VALUES	0 to 8 °C	2.5 kg/50 l of Gross Refrigerator Volume / 24 h. 2037→ 1.3 kg/24 h 2064→1.3 kg/24 h	≥ 6 h

[2] EPI Performance Specifications, 1991 (WHO/EPI/LHIS/91.1).

TEST AT 43 °C ENVIRONMENT TEMPERATURE													
TEST→		DAY/NIGHT (43/15 °C)			STABLE			FREEZING CAPACITY			HOLDOVER TIME		
EQUIP. ↓	STATE→ ITEM ↓	ORIGINAL	1st.Modification	KIT INSTALL.	ORIGINAL	1st.modification	KIT INSTALL.	ORIGINAL	1st.modification	KIT INSTALL.	ORIGINAL	1st.Modification	KIT INSTALL.
ICASA E3-2064	Tmax.[°C]	9.6	7.3	7.7	5.6	6.9	5.9	6.2	6.0	7.2	6.2INITIAL	6.0INITIAL	3.9INITIAL
	Tmin.[°C]	-3.0	-1.0	1.1	1.0	1.0	4.5	0.6	-0.2	4.1	2.1INITIAL	2.1INITIAL	2.6INITIAL
	Duration [h]	N.A.									1.6	1.7	6.15
	Charge[kgH2O]							1.6	2.24	6.4			
	Running Time [%]				69.7	60.6	56.2						
	Power consum. [kWh/24h]				2.72	2.58	2.47	3.27	2.73	3.69			
	Thermostat	5	3	3	6	5	4	6	5	4	6	6	4
ICASA E3-2037	Tmax. [°C]	7.0	N.A.	7.0	8.5	N.A.	5.0	11	N.A.	5.7		N.A.	2.9INITIAL
	Tmin. [°C]	-2.5		1.2	2.8		2.3	2.5		0.7			1.0INITIAL
	Duration [h]									18.5	1.5		6.0
	Charge[KgH2O]							2.2	2.24	4.4			
	Running Time [%]				45		42.85						
	Power Consum. [kWh/24h]				2.92		2.73			4.13			
	Thermostat	3.5	3	3.0	3.5		4.0	3.5		4.0	3.5		4.0

Table 2: Comparison of performance between unmodified and modified domestic models. Unmodified versus models with (i) first modification and (ii) final kit installed.

FIGURE 1. General view of the kit

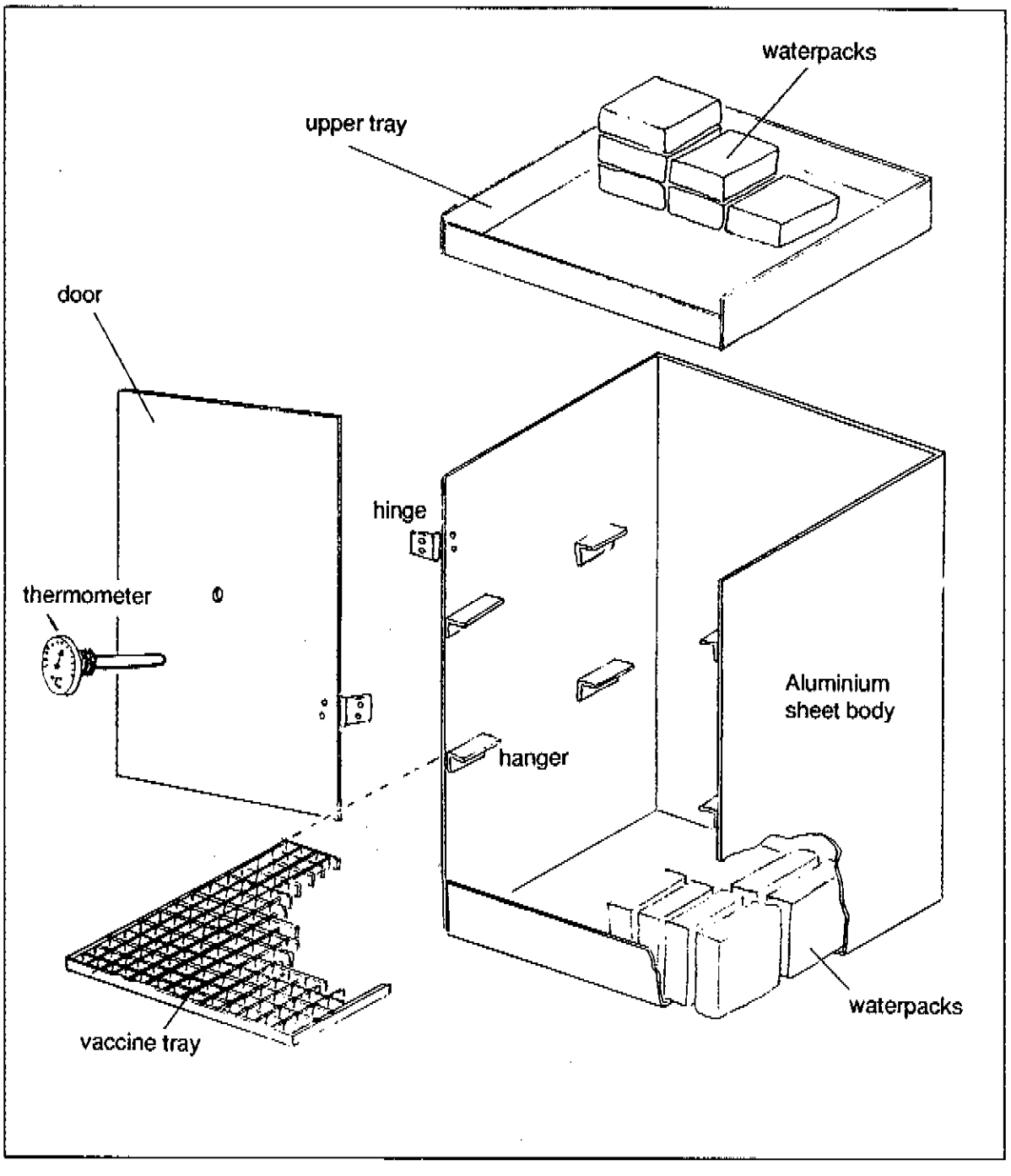
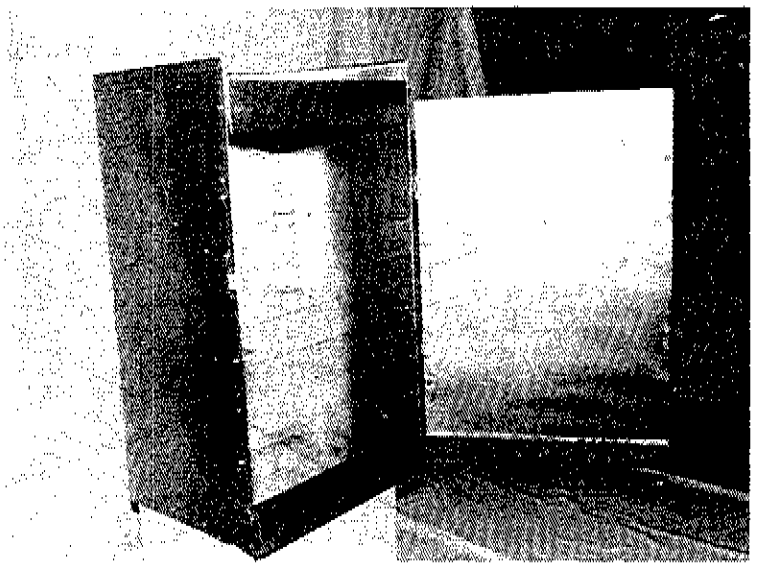
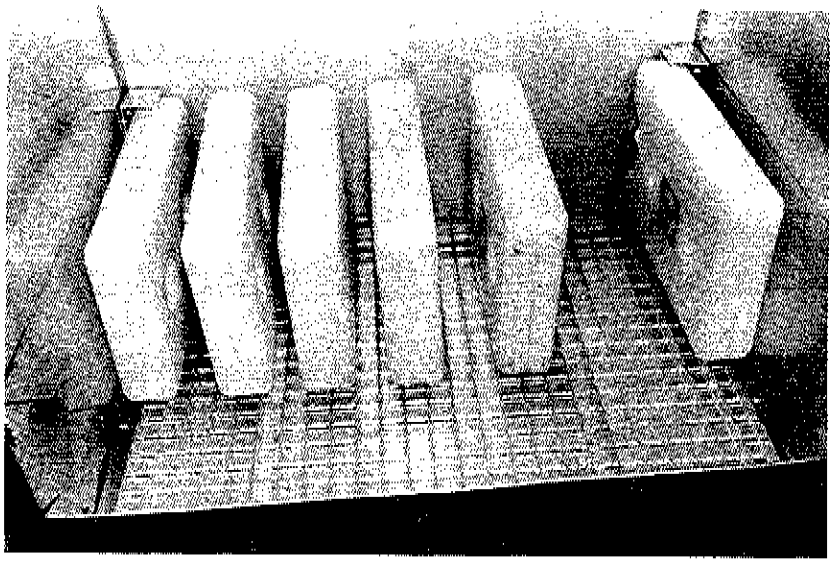


FIGURE 2a. Structure of the kit



continued/...

FIGURE 2a. Structure of the kit *(continued)*



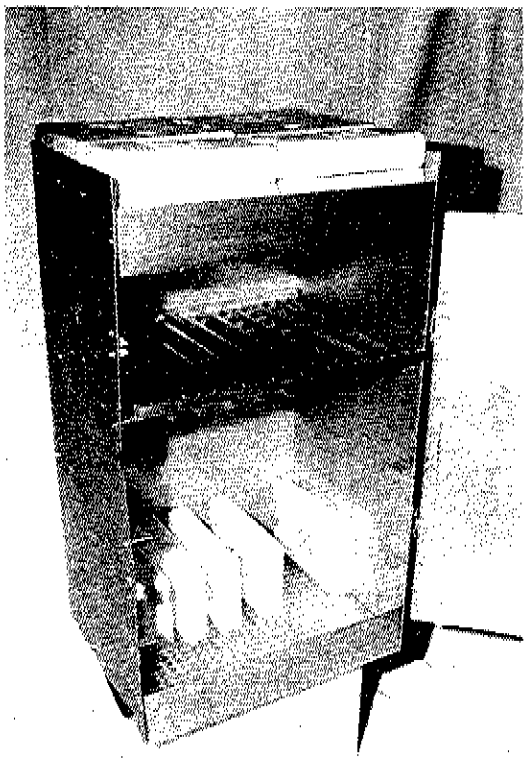


FIGURE 2b. The kit installed

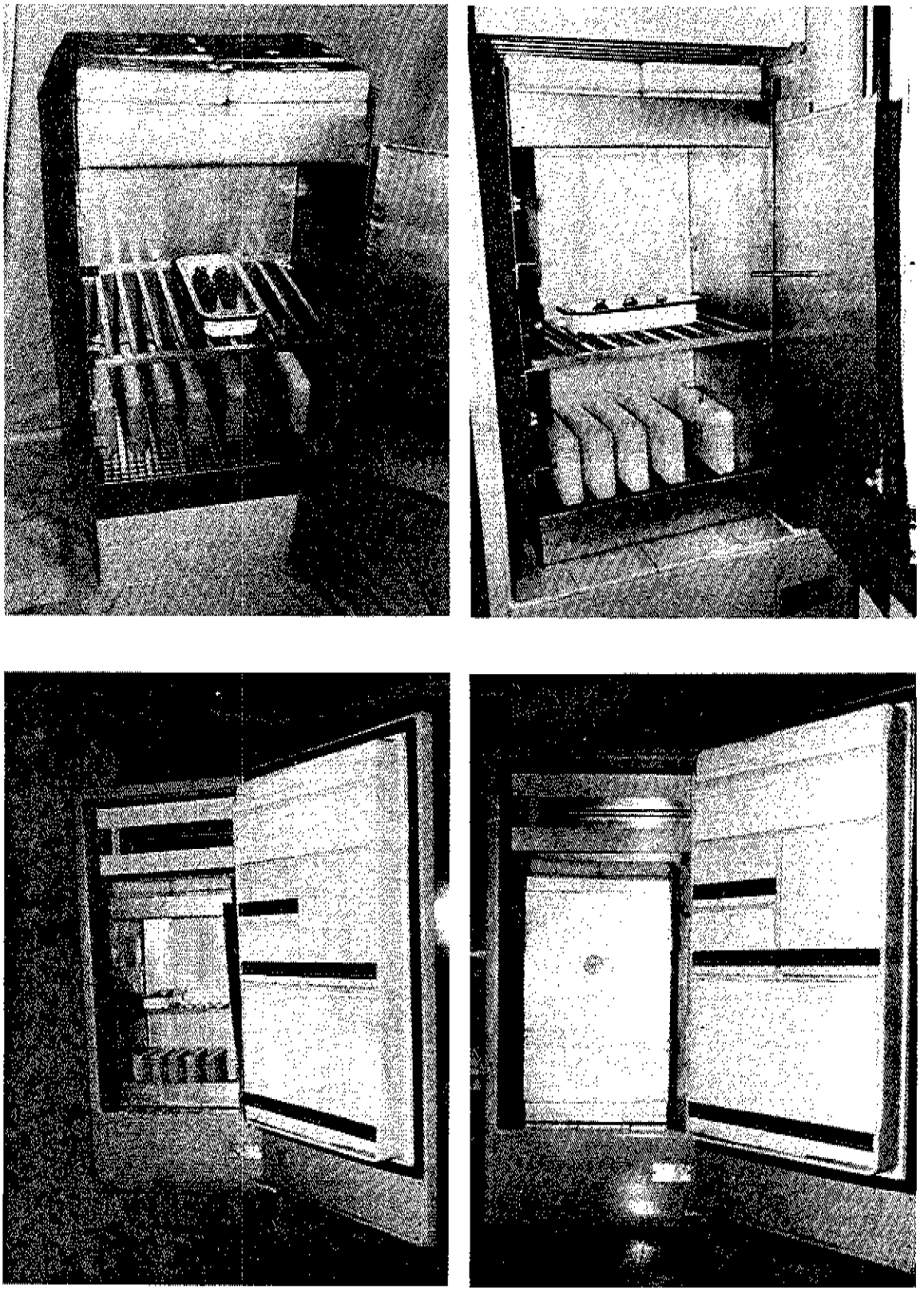


Figure 3: Heat transfer patterns

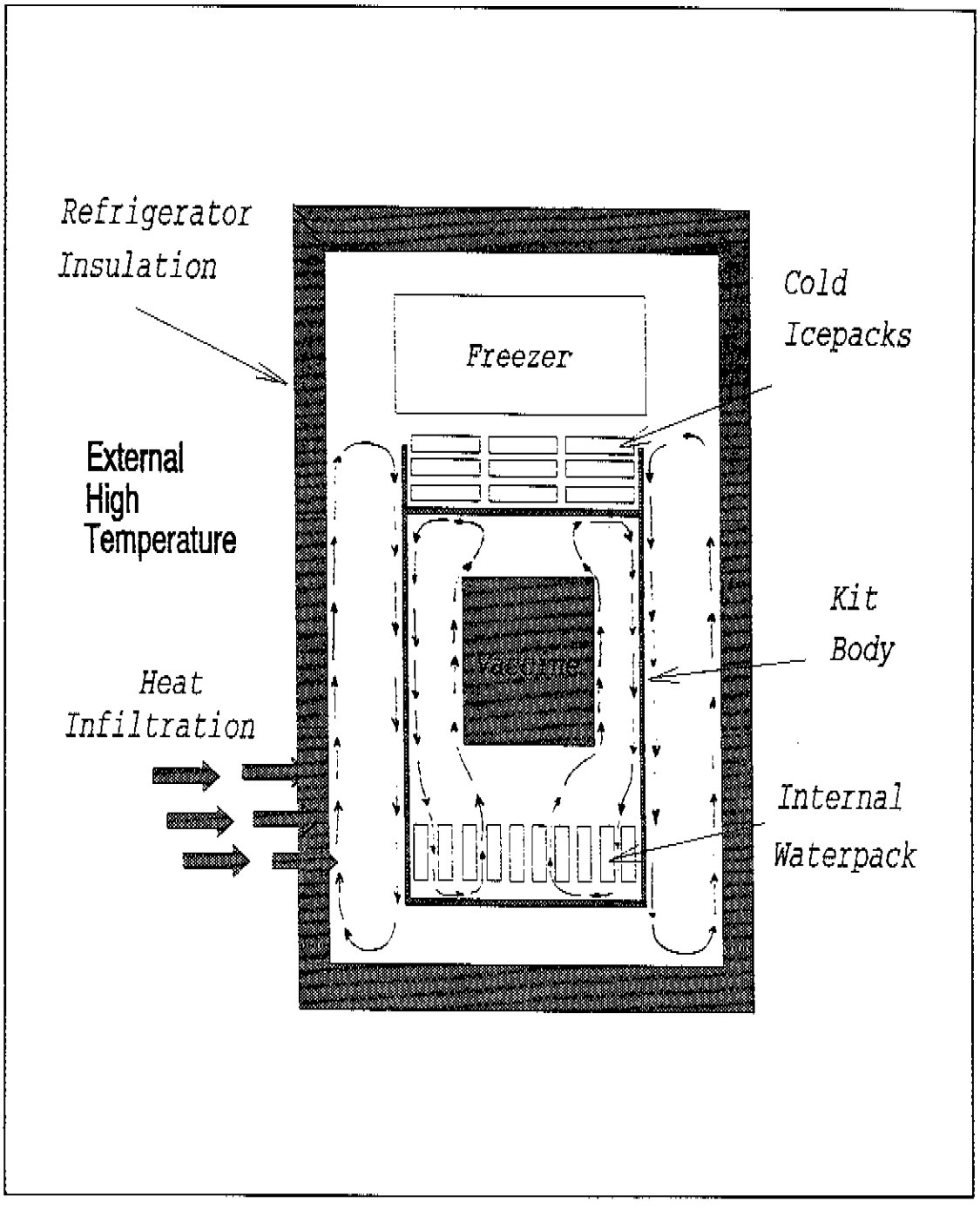


Figure 4: Location of sensors (Icasa refrigerator, code E3-2064)

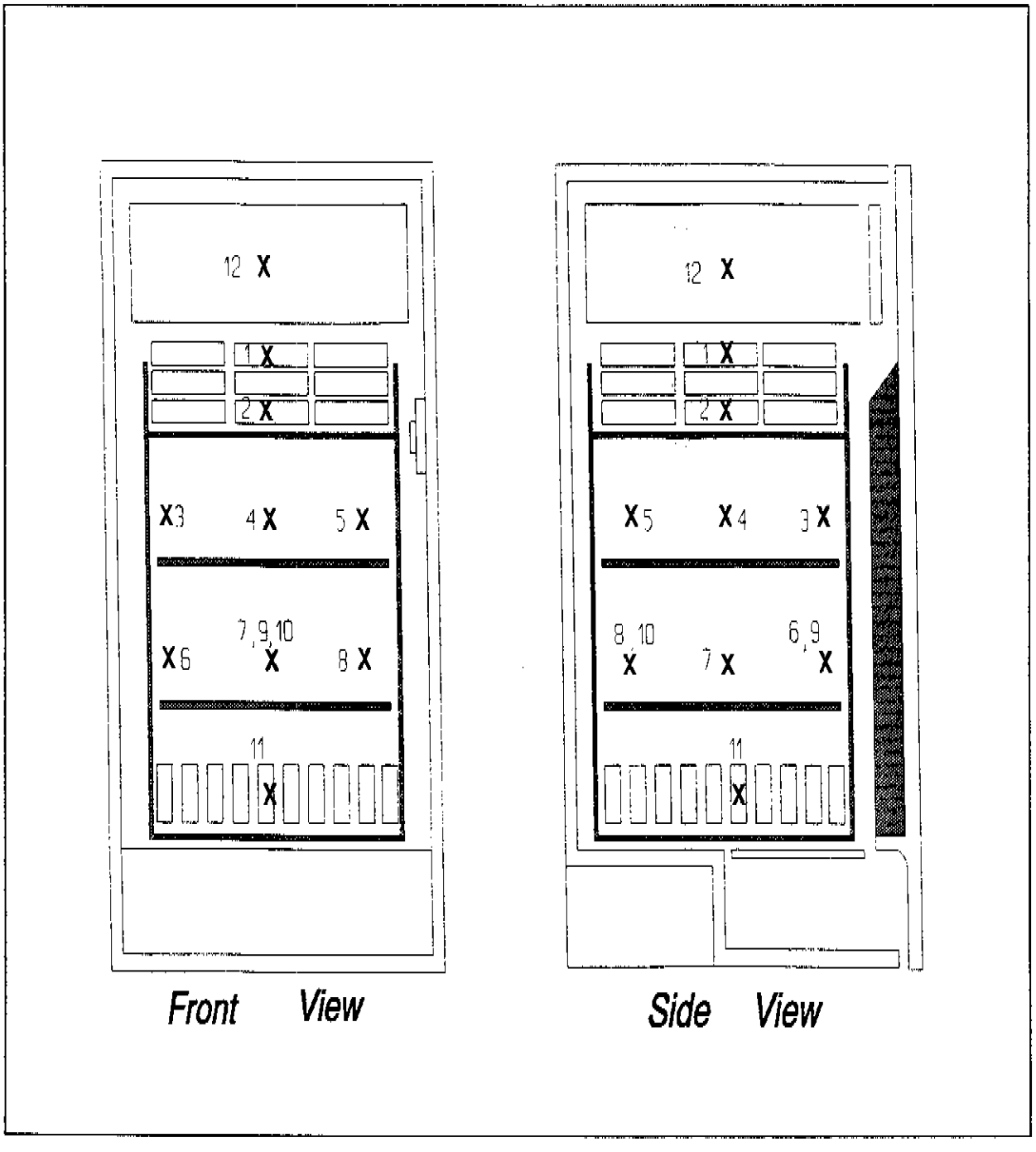


Figure 5: Location of sensors (Icasa refrigerator, code E3-2037)

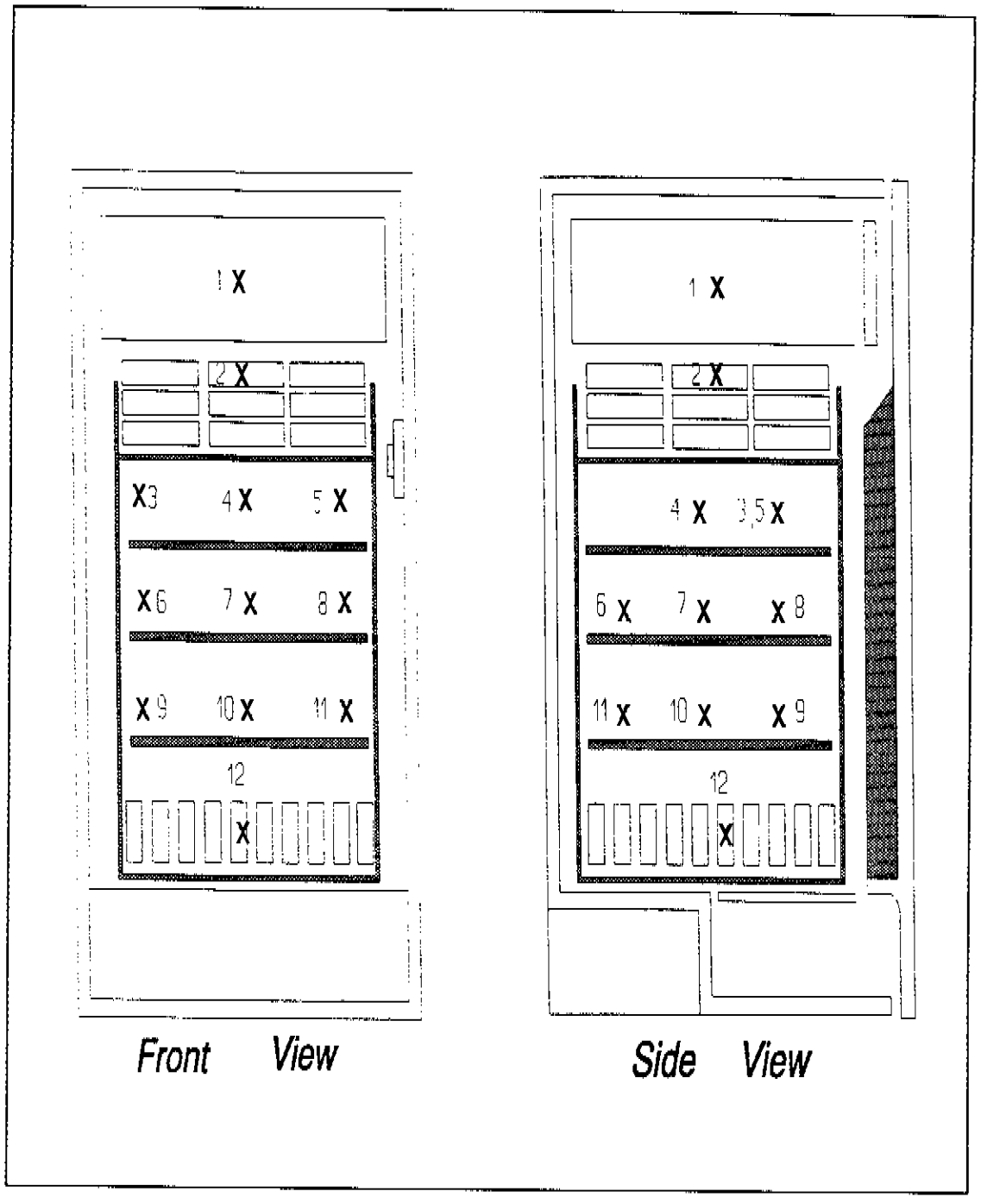
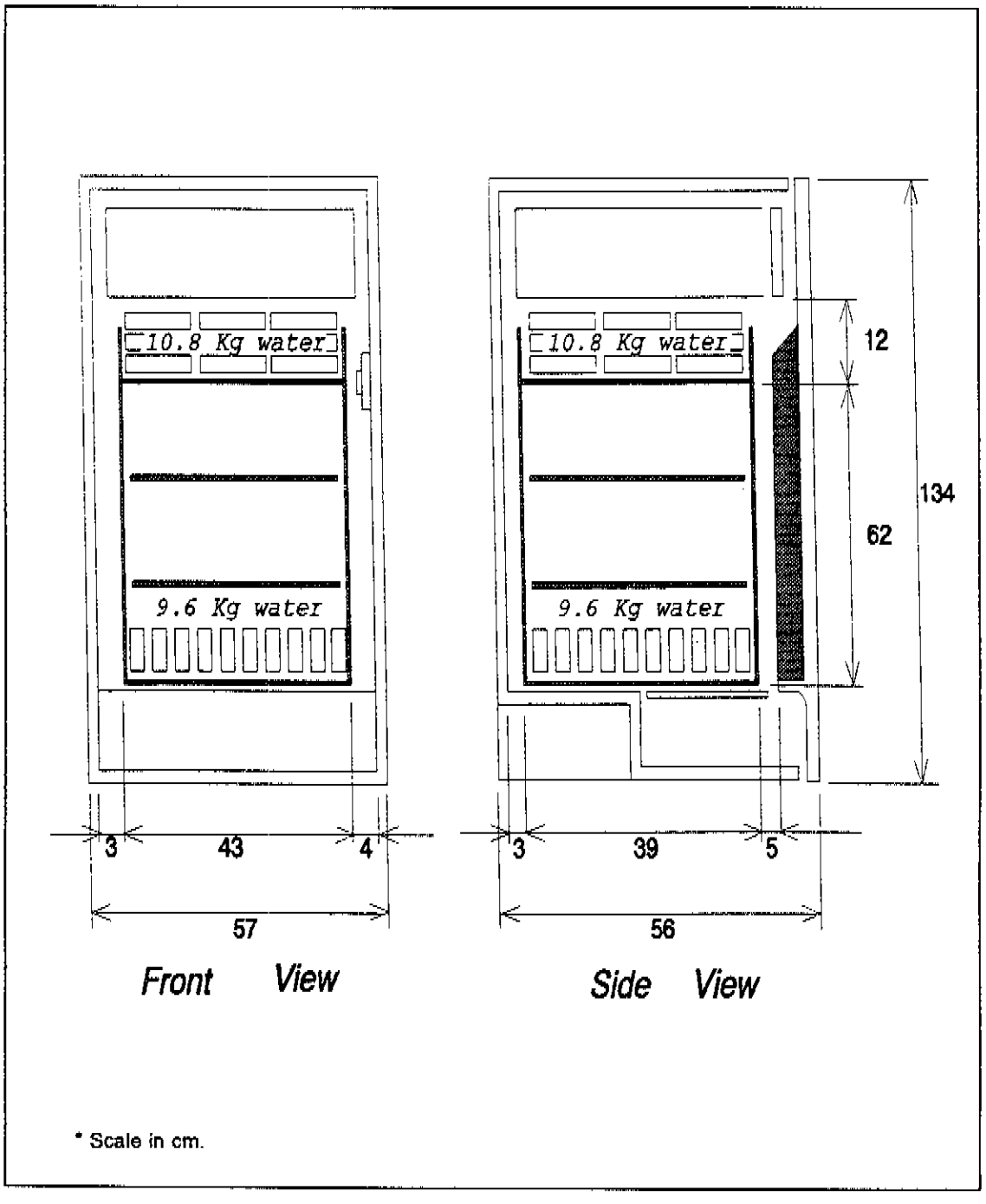
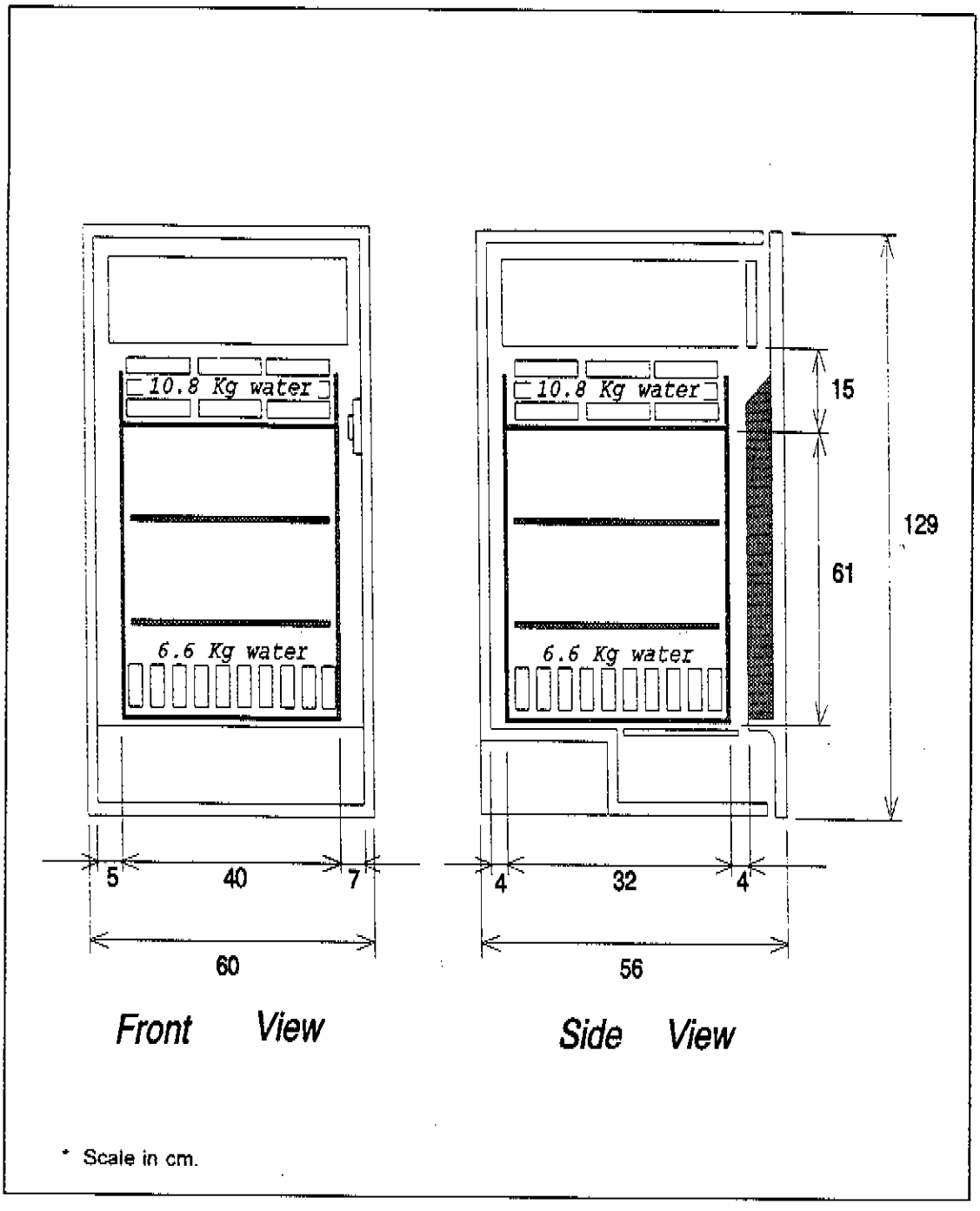


Figure 6: Dimensions and water load (Icasa refrigerator, code E3-2064)



* Scale in cm.

Figure 7: Dimensions and water load (Icasa refrigerator, code E3-2037)



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