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(71) Applicant : **SAFEWAY STORES, PLC.
P.O.Box 8, 6 Millington Road
Hayes, Middlesex UB3 4AY (GB)**

(72) Inventor : **Marriott, Douglas
New Forest Farm, New Forest Lane
Chilham, Kent CT4 8BG (GB)**

(74) Representative : **W.P. Thompson & Co.
Coopers Building, Church Street
Liverpool L1 3AB (GB)**

(54) **Refrigerated display units.**

(57) A refrigerated display unit has a base (12) and a storage compartment (29) located above the base. Access to the storage compartment is gained via a front access opening.

The unit is provided with a cooled air circulation system comprising a fan (14) and cooling means (16). Relatively warm air is drawn into the base (12) via an inlet opening (50) by means of the fan (14). The air is then cooled by the cooling means (16) and forced up a duct (22) behind the interior rear walls (17a to 17e) and roof (26).

The rear walls (17a to 17e) and/or the ceiling (26) are provided with a plurality of apertures, through which substantially all of the cooled air is discharged into the storage compartment (29) of the unit.

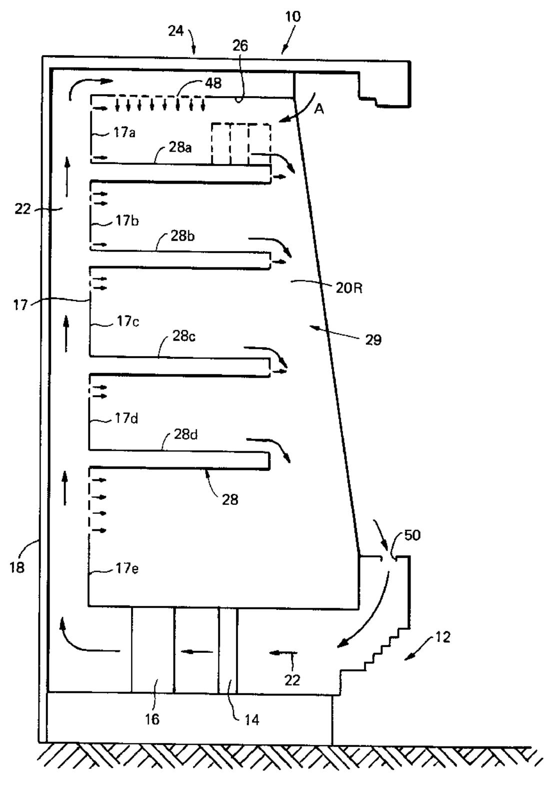

FIG. 1

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The present invention relates to refrigerated display units and more particularly, to open fronted refrigerated display units, which expression also includes display units for frozen goods.

Refrigerated display units of the open fronted type are used in supermarkets and are designed with the conflicting aims of refrigeration and display. The resulting compromise involves an inevitable loss of energy efficiency since the food must be stored at a cool temperature, but marketing considerations dictate that the customer is provided with a warm environment in which to shop, where food is attractively displayed and easily accessible.

One such design is an upright display unit in which products are displayed on shelves. The products may, for example, be dairy products in which case operating temperatures of from 0°C to 2°C must be maintained, fresh meat in which case operating temperatures of from -1°C to +1°C are maintained, or frozen products such as, for example, ice cream where temperatures of -20°C or lower may be maintained. Whatever the products, the way the unit is stacked plays a critical part on temperature maintenance.

A major problem with refrigerated display units is their high energy consumption, resulting from the fact that warm air is able to enter the open unit and cold air escapes from the unit. There is also a lesser problem in that cold air spilling from the unit has to be heated to warm the shopping environment.

Traditionally the display unit temperature is maintained by means of cooled air. A proportion of cooled air, usually around 45%, is blown through apertures in a back panel of the refrigerator unit into the interior of the unit, and around 55% of the cooled air is blown vertically downwards from a front downwardly directed port in a roof of the unit, in order to form a downwardly moving cold air curtain across the open front of the unit.

Such a refrigerated display unit is typified by that described in GB 2092730.

In GB 2092730 an attempt has been made to reduce the problem of significant temperature rise within the display unit, with consequential energy savings, by fitting a physical curtain across the opening during non-business hours when ready access is not required.

These open-front type refrigerated display units all have an air exhaust port in the roof portion from which cooled air is exhausted downwards, thereby forming a downwardly moving cold air curtain across the opening. The formation of a cool air curtain reduces the penetration of warm air into the case and thereby keeps the temperature low within the case.

In GB 2123938 a guide plate having a short vertical length is provided and projects downwardly immediately beneath the exhaust port. This guide plate is located within the depthwise dimensions of the exhaust port so that air issuing from the exhaust port comes into contact with the plate whereby the flow of the air curtain is rectified. This document also discloses an air inlet port extending along the lower edge of the front opening. Air is drawn into the inlet port by means of a fan within the apparatus and passed over cooling means, after which it is circulated through the apparatus to cool its interior. By locating the inlet port generally below the exhaust port, some cooled air from the exhaust port is drawn into the inlet port. This reduces the energy consumption of the apparatus, since the air to be cooled is already at a lower temperature than the ambient room temperature. However, much energy is still used because the inlet also introduces warmer room temperature air.

As well as having an air curtain the prior art refrigerator units include a perforated rear wall panel, see for example GB 2126697, through which part of the cooled air is directed into the unit's storage space. Baffles are provided to deflect the airflow upwards and outwards towards the air curtain.

A typical prior art unit is the Safeway Dairy case CHV supplied by Carter Refrigeration Display Limited, Birmingham and modified accordingly by Safeway. The unit is provided with an exhaust aperture at the bottom leading edge of the roof through which cooled air is forced to form an air curtain. It has fans situated in the base which draw air into the case through an inlet port situated at the lower front edge of the base across an evaporator arrangement where it is cooled and up a duct behind the back panel. This back panel is perforated so as to force a proportion (usually around 45%) of the air through the panel and over the shelves of the case. The remainder (around 55%) of the flow is channelled to the top of the case and is discharged as an air curtain vertically downwards across the open front face of the case.

The balance between the back panel flow and the air curtain flow is mainly determined by the design of the ducting and the size of holes in the back panel but also depends on the way products are stacked on the shelves. Shelves which are heavily loaded with non-porous products provide greater resistance to the back panel flow, forcing a greater proportion of air (up to 80%) into the air curtain.

The air entering the case through the inlet port at the lower front edge of the base is made up of the following components.

i) cold air from the back panel,

ii) cold air from the air curtain, and

iii) warm air from the store environment entrained by the air curtain and mixed with it.

The warm air from the store raises the temperature of the air drawn into the inlet port, which must then be re-cooled before it is recirculated.

An object of the present invention is to reduce energy loss whilst maintaining the temperature regime and allowing accessibility.

In accordance with the present invention a refrigerated display unit comprises a base, a storage compartment situated above the base, an access opening to said storage compartment, an air inlet, and a cooled air circulation system, wherein the cooled air is discharged substantially entirely into the storage compartment.

With the above arrangement, it has been found possible to dispense with the downwardly-directed vent in the roof of the apparatus, which formed an air curtain, while at the same time providing the necessary cooling and reducing energy costs.

Preferably, the storage compartment is at least partially defined by internal walls comprising a rear wall and a roof portion, one or more of the internal walls comprising a plurality of apertures for discharging cooled air into the storage compartment.

In one embodiment the rear wall and optionally the roof communicate with an air duct through which cooled air is circulated.

Preferably, the internal walls will also comprise two side walls.

In one embodiment the duct behind the rear wall is closed at its upper end.

In another embodiment the duct extends from behind the rear wall into the roof portion of the unit, where it helps keep the roof portion cold. It is not, however, exhausted from the front end thereof in the form of a curtain, as in the prior art, but can only leave via the apertures in the rear wall and/or roof.

The roof portion may be substantially sealed, in which case substantially all of the cooled air is discharged into the storage compartment through apertures in the rear wall. Alternatively, the roof portion may also be provided with exhaust apertures (but not so as to produce an air curtain) such that the cooled air is discharged through apertures in the rear wall and in the roof portion.

In the present invention cooled air, being more dense than the ambient air, moves downwardly "under its own weight" when it meets the ambient air, and it is this downwardly moving air which helps to reduce the ingress of warm air into the housing.

In the context of the present invention cooled air is air which has a lower temperature than the desired air temperature of the supermarket environment, which is typically 20°C ± 5°C.

As well as directing all of the cooled air into the storage compartment, other measures can be taken to further improve energy savings.
These include:

i) Maintaining low air velocities;

ii) reducing the overall unit ventilation rate;

iii) introducing fairings or deflectors, preferably with an aerodynamic profile, towards the leading front edge of the roof portion of the unit, preferably at the innermost edge of a lighting well (if present); and

iv)providing air passages, linking any lighting wells to the top of the unit to allow venting of warm air away from the cooled space.

Specific embodiments of the present invention will now be described by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic cross-sectional side elevation of a first embodiment of open fronted refrigerated display unit according to the invention;

Fig. 2 is a front elevational view of one side of the unit of Fig. 1; and

Fig. 3 is a schematic cross-sectional side elevation of a second embodiment of open fronted refrigerated display unit in accordance with the invention.

Referring to Figs. 1 and 2, an open fronted refrigerated display unit 10 comprises a base 12 which houses a fan 14 and air cooling means in the form of an evaporator 16. A substantially planar outer rear wall 18, an inner rear wall formed by a plurality of perforated panels 17a to 17e, arranged coplanar with each other and parallel with the rear wall 18, and left and right side walls 20L, 20R extend upwardly and substantially perpendicularly from the base 12 and define a rear air duct 22. A hollow roof 24 having an optionally perforated roof panel 26 extends substantially perpendicularly to the upper end of the outer rear wall 18. The air duct 20 communicates with the interior of the hollow roof 24. Four hollow shelves 28a to 28d which communicate with the air duct 20 extend substantially perpendicularly to the perforated panels 17a to 17e.

The perforated panels 17a to 17e define the rear of the interior of the storage compartment 29 of the refrigerated unit and are illustrated in more detail in Fig. 2. Only the left-hand half of the unit is illustrated in Fig. 2, but it should be noted that the right-hand half is a mirror image of the left-hand half about the centre line CL. The uppermost panel 17a is provided with a single horizontal row of apertures 30 of 7.4mm diameter towards the upper edge of the panel 17a and a single horizontal row of apertures 32 of 4.5mm diameter spaced 18mm apart just above the upper surface of the uppermost shelf 28a. Each of panels 17b, 17c and 17d is provided with two horizontal, parallel rows of apertures 34 of 4.5mm diameter with adjacent apertures in each row spaced apart by 18mm, towards the upper edge of the panels. The second highest panel 17b is additionally provided with a single horizontal row of apertures 36 of 4.5mm diameter and spaced 18mm apart, just above shelf 28b. The rows of apertures 30,32,34,36 actually extend across the whole width of the panels, but only a portion of the rows has been shown in the drawings, for clarity.

It will also be noted that at each lateral end of each of the panels 17a to 17d, two parallel vertical columns of apertures 40 of 4.5mm diameter are provided, adjacent to the left and right-hand walls 20L, 20R. Additionally, the lowermost panel 17e is provided with a plurality of apertures. The apertures comprise eight parallel vertical columns of apertures 42 of 11.5mm diameter and two parallel horizontal rows of apertures 44 of 9.0mm diameter, the apertures 44 in the two rows being offset or staggered with respect to one another.

It should also be noted that the distal end faces of three of the shelves 28a, 28b, 28c are each optionally provided with a single row of apertures 46 of 4.5mm diameter and spaced apart by 18mm, although the apertures 46 may be omitted if desired. The roof panel 26 may also be perforated with a plurality of parallel rows of apertures 48 aligned with the longitudinal direction of the unit as shown in Fig. 1, but this is an optional feature, and the apertures may be omitted if desired.

In use, ambient air is drawn by the fan 13 into the base 12 of the unit via an air inlet 50 at the lower front edge of the base 12. The air is passed over the evaporator 15 whereupon it is cooled, and it then passes up the duct 20. As the cooled air passes up the duct 20 it spills through the apertures in the panels 17a to 17e. (If apertures 46 are provided in the ends of the shelves 28a,b,c cooled air also spills through these apertures). The cooled air passing through the apertures in the panels 17a to 17e flows over the shelves 28 and the goods stacked thereon, thereby cooling the products on the shelves.

If the roof panel 26 is also provided with apertures 48 additional cooled air also spills onto the products through the roof panel 26, helping to keep those products cool more reliably. This may be necessary if, for example, lighting units generating a significant amount of heat are located on or adjacent to the roof 24 in a lighting well 54. If apertures 48 are provided in the roof panel 26, typically 60% to 80% of the cooled air spills out through the roof apertures 48, and through the apertures 46 in the ends of the shelves 28 with the remaining cooled air spilling out substantially equally through each of the five perforated panels 17a to 17e. However, by adjusting the number, size, location and arrangement of the apertures the cooled air spillage distribution can be adjusted to suit particular circumstances and requirements.

The dense cold air travels across the products on the shelves, and then moves downwardly under its own weight (in contrast to the prior art in which it is propelled downwardly to form an air curtain across the front of the unit) forming a "waterfall" effect of cold air which eventually enters the inlet 50 together with warmer air from the store.

By varying the internal shape of the ducting and the size, number and spacing of the apertures in the rear panels and the roof portion the proportion of air leaving the panels and/or the roof portion at any particular point can be controlled.

Thus, the overall ventilation flow rate, the distribution of ventilation flow and the flow geometry can all be controlled by modifying the ducting as necessary.

The Applicant's invention is based on the unexpected discovery that in the prior art apparatus the upper part of the air curtain, where velocities and entrainment were greatest, dominated in terms of net heat gain.

By looking at the effect of the air curtain velocity on entrainment it was noted that an increased inflow velocity resulted in a consequential net heat gain and it was surmised that this was probably due to more warm air mixing with the air curtain.

A comparative example is represented by a fully packed food unit, the Safeway Dairy Case CHV, with product at the bottom of the case being stacked to the front edge of the case. The flow rate for the perforated back panel and the air curtain were deduced from instore measurement and from this data temperature contours and heat fluxes were obtained.

These temperature contours and heat fluxes were attained for a case operating with approximately 55% of the cooled air being discharged in the form of an air curtain and 45% of the cooled air being discharged through apertures in the rear panel of the unit, the unit being maintained at a temperature of approximately 2°C.

The main features to be noted from were a spreading of the air curtain and an extensive zone of cold air in front of the case. The result of the turbulent mixing on heat flux results in an estimated net heat flux into the case of 1345 W/m.

In contrast, with the present invention where all of the cooled air is discharged through apertures in the internal walls and none of the cooled air is discharged downwardly to form an air curtain, the estimated net heat flux into the case was reduced from around 1345 W/m to around 1000 W/m. This equates to a reduction of energy consumption to around 75% of the origional providing a saving of around £15,000 per year on electricity bills for a typical supermarket of 2754m^2 (30,000 ft^2).

The reduction in net heat inflow is thought to be due to the lower air velocity causing less mixing. The results indicate that significant energy savings can be made by reducing the air velocity by passing most or all of the air through the back panel (and optionally also the roof portion) as opposed to vertically down as an air curtain.

In a first modification of the Fig. 1 embodiment, the mass flow rate in inflow velocity of the cooled air were significantly reduced (by about 45% in each case). It was that because less air was discharged from the back panel, the warm air would penetrate further into the case which would in turn affect the condition of the product on the top shelf. However, the heat fluxes were reduced even further so that the net heat flux into the case was only about 1000 W/m.

Whilst the removal of the air curtain clearly leads to a significant reduction in net heat gain by the unit, it is believed that there may be a problem with the ingress of warm air (arrow A) to the product (illustrated in dotted lines) on the top shelf, resulting particularly from the proximity to the lighting. In the prior art this problem does not exist because the moving cold air curtain reduced heat ingress.

The second embodiment of the invention, illustrated in Fig. 3, is intended to overcome the aforementioned problems. The construction of the Fig. 3 embodiment is identical to that of Fig. 1, with the exception that a fairing 52 is located on the innermost edge of a lighting well 54 of the refrigerator unit. The fairing comprising an elongate member which is a trapezium in cross-section with its longer parallel side facing outwards and having a maximum height of 63mm and a maximum width of 66mm. The fairing is intended to provide a solid barrier against warm air ingress and a clearly defined turning point for flow from the back panel. As with the Fig. 1 embodiment, exhaust apertures 48 may also optionally be provided in the roof panel 26.

The temperature contours and heat fluxes under these conditions are similar to those of the first embodiment, but the flow above the top shelf, near the lighting well, has been improved quite effectively. The heat gain to the case is higher than that in the first embodiment, but this may prove acceptable if colder temperatures are desired close to the product. Whilst a large fairing was chosen in this example a smaller fairing should give rise to reduced velocities, mixing and net heat gain to the case, while still helping to prevent warm air ingress to the top shelf region.

In a second modification to the embodiment of Fig. 1, the flow distribution at the back panel was altered.

The modification affected only the back panel behind the top shelf space, and comprised a bottom section (75% of the shelf height) with low porosity and ventilation rate (10% of the shelf flow) and an upper section (25% of the shelf height) with high porosity and ventilation rate (90% of the shelf flow). It was hoped that such an arrangement would be less affected by variations in product loading on the shelf, since most of the flow would pass above the product.

The temperature contours and heat fluxes for this Example were generally very similar to those of the second embodiment. The main difference was above the top shelf where warm air had advanced a little closer to the shelf space.

In a third modification, of the Fig. 1 embodiment, the total mass flow rate and the inflow velocity were increased. The results were similar to those for the first embodiment. However, the warm air region was pushed further away from the shelves by the increased flow of cold air.

Finally, a fourth modification to the Fig. 1 embodiment, was made to consider the effect of split flow across the whole back panel.

The arrangement used for the top shelf of the second modification to the Fig. 1 embodiment was applied to the back panel section behind all the shelves. Thus, the back panel behind each shelf comprised a bottom section (75% of the shelf height) with low porosity and ventilation rate (10% of the shelf flow) and an upper section (25% of the shelf height) with high porosity and ventilation rate (90% of the shelf flow).

The input data was the same as for the top shelf in the second modification and the results were very similar to those for the second modification. This was not surprising since the ventilation arrangement on the top shelf was the same for both cases, whilst lower down the mixing zone was more spread out and further from the shelves, and therefore less affected by changes in the back panel flow distribution.

However, it will be appreciated that with frozen food temperature, significant advantages will also be achieved and the foregoing examples are used merely to exemplify the invention and should not be construed to limit the invention to any particular temperature range. In particular, it is envisaged that the present invention is suitable for displaying frozen foods.

Claims

1. A refrigerated display unit comprising a base (12), a storage compartment (29) situated above the base, an access opening to said storage compartment, an air inlet (50), and a cooled air circulation system (14,16,22), characterised in that, in use, the cooled air is discharged substantially entirely into the storage compartment (29).

2. A refrigerated display unit as claimed in claim 1, wherein the storage compartment (29) is at least partially defined by internal walls comprising a rear wall (17) and a roof portion (26), one or more of the internal walls being provided with exhaust apertures (30, 32, 34, 36, 44) through which the cooled air is discharged.

3. A refrigerated display unit as claimed in claim 2, wherein the internal walls further comprise side walls (20L, 20R).

4. A refrigerated display unit as claimed in claim 2 or claim 3, wherein the cooled air circulation system comprises an air duct (22) located behind the rear wall (17).

5. A refrigerated display unit as claimed in claim 4, wherein the air duct (22) extends above the roof portion (26).

6. A refrigerated display unit as claimed in any of claims 2 to 5, wherein the rear wall (17) is provided with a plurality of exhaust apertures (30, 32, 34, 36, 44) for discharging cooled air into the storage compartment (29).

7. A refrigerated display unit as claimed in claim 6, wherein the cooled air is discharged substantially entirely through exhaust apertures in the rear wall (17).

8. A refrigerated display unit as claimed in any of claims 2 to 6, wherein the roof portion (26) is provided with a plurality of exhaust apertures (48) for discharging cooled air into the storage compartment (29).

9. A refrigerated display unit as claimed in any of claims 2 to 8, wherein the rear wall (17) comprises a plurality of panels (17a to 17e), each panel being provided with a plurality of exhaust apertures.

10. A refrigerated display unit as claimed in claim 9, wherein at least one panel (17a, 17b, 17c, 17d) is provided with a row of apertures (30, 34) adjacent to an upper edge of the panel, through which apertures, in use, cooled air is discharged.

11. A refrigerated display unit as claimed in claim 9 or claim 10, wherein at least one panel (17a, 17b) is provided with a plurality of discharge apertures (32, 36) located adjacent to a lower edge of the panel, through which apertures, in use, cooled air is discharged.

12. A refrigerated display unit as claimed in any of claims 9 to 11, wherein at least one panel (17a, 17b, 17c, 17d, 17e) is provided with a vertical row of exhaust apertures (40, 42) through which, in use, cooled air is discharged.

13. A refrigerated display unit as claimed in claim 12, wherein at least one panel (17a, 17b, 17c, 17d, 17e) is provided with a vertical row of exhaust apertures (40, 42) adjacent a lateral edge of the panel.

14. A refrigerated display unit as claimed in any of the preceding claims, further comprising at least one shelf (28a, 28b, 28c), the shelf being hollow and having a plurality of exhaust apertures (46) for discharging cooled air into the storage compartment (29) of the unit.

15. A refrigerated display unit as claimed in claim 14, comprising a plurality of said shelves.

16. A refrigerated display unit as claimed in claim 14 or claim 15, when appendant to any of claims 9 to 13, wherein the or each shelf (28) is located between panels (17a to 17e) forming the rear wall (17).

17. A refrigerated display unit as claimed in any of the preceding claims, wherein the cooled air is introduced into the unit with a substantially zero vertical velocity.

18. A refrigerated display unit as claimed in any of the preceding claims, comprising a substantially vertical rear wall (17), a plurality of substantially horizontal shelves (28) projecting from said rear wall and a front access opening.

19. A refrigerated display unit as claimed in any of the preceding claims, comprising a deflector (52) for deflecting external air away from the storage compartment (29).

20. A refrigerated display unit as claimed in claim 19, wherein a deflector (29) is located at the uppermost periphery of the access opening.

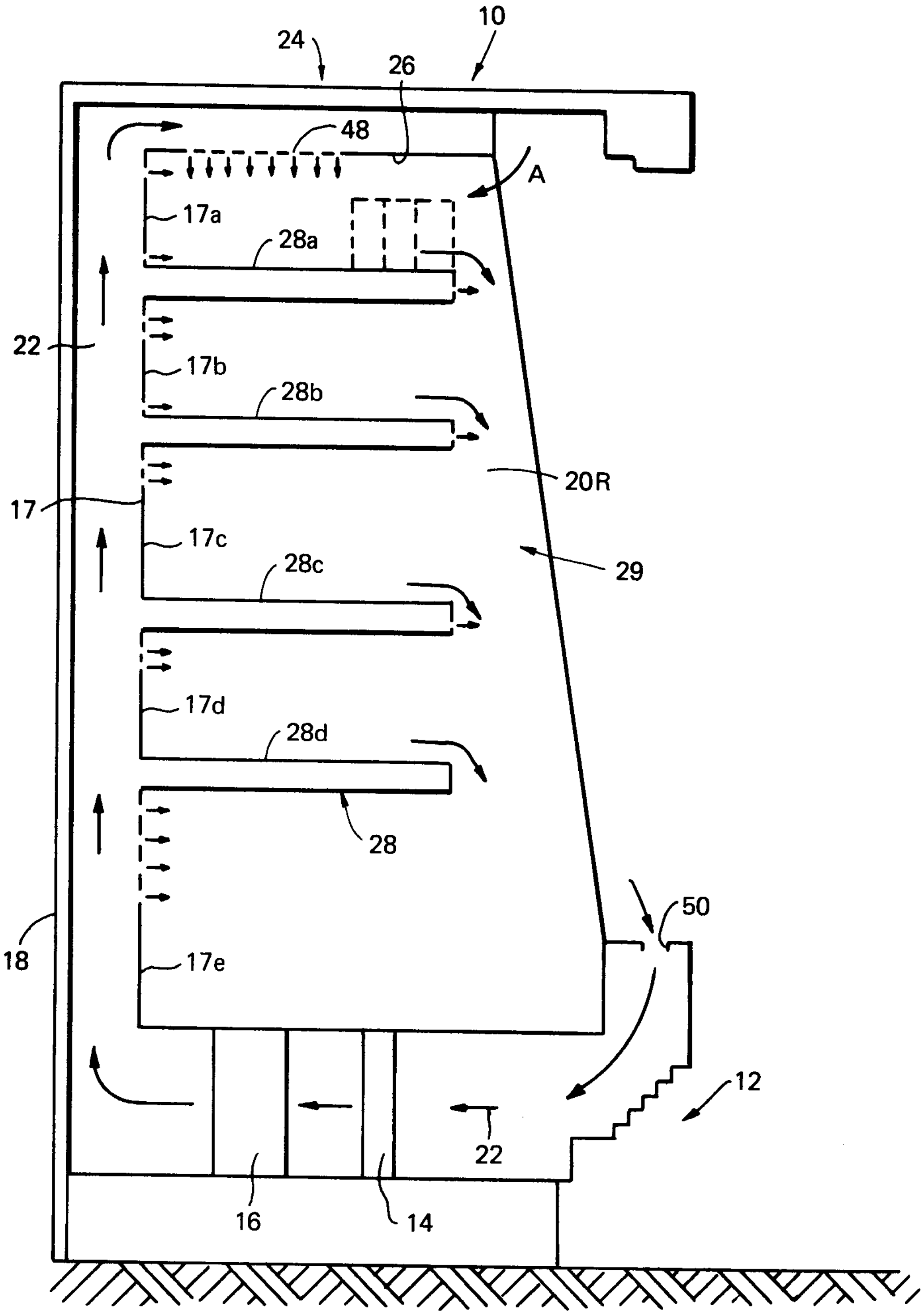
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FIG. 1

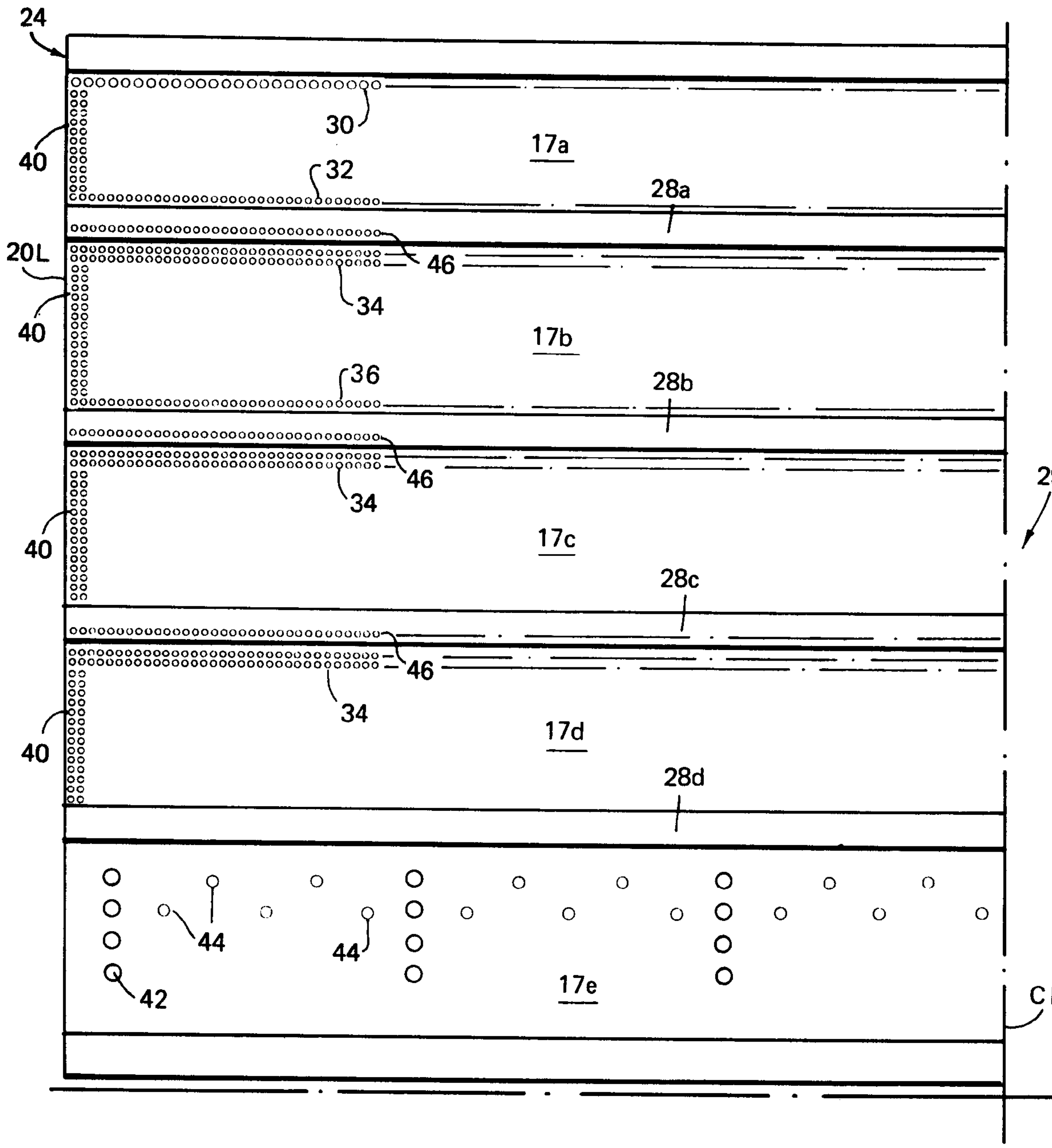
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FIG. 2

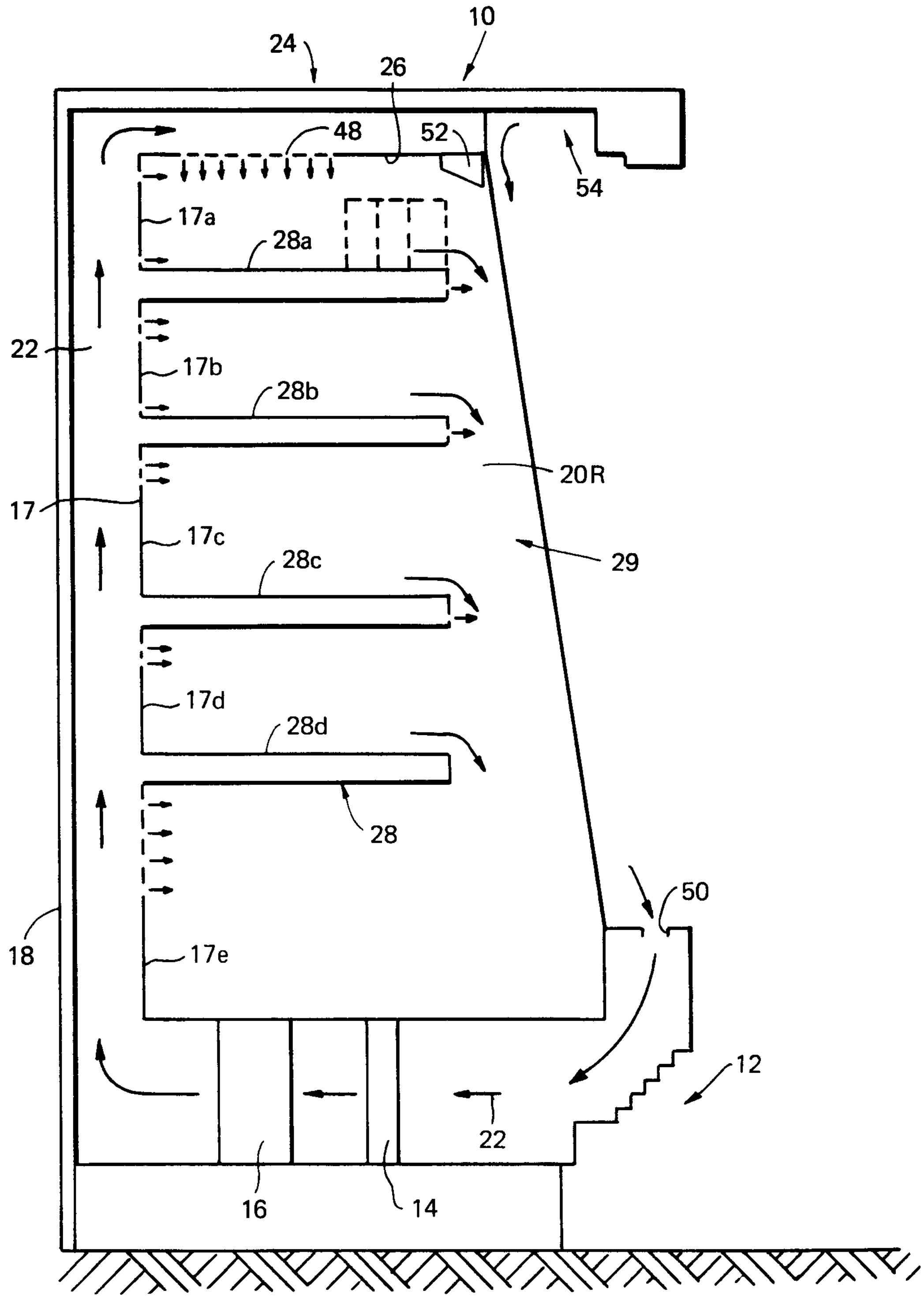
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FIG. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 30 7987

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	US-A-3 125 864 (URAL)	1-6,8, 14,15,18	A47F3/04
Y	* claim 1; figures 1,4 * * column 2, line 61 - column 3, line 51 * ---	7,9	
Y	DE-A-22 01 676 (BROWN BOVERI & CIE AG) * claim 1; figure 1 * ---	7	
Y	US-A-4 953 363 (PRIMOZIC) * column 4, line 13 - line 37; figure 2 * ---	9	
A	US-A-3 584 467 (BARROERO) * abstract; figures 1-3 * ---	9-13	
A	FR-A-1 316 616 (HOUPLAIN) * page 2, column 1, paragraph 5; figure 2 * -----		

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

A47F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14 January 1994	JONES, C

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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