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REFRIGERATED CABINET WITH CIRCULATING AIR PANELS

Sterling Beckwith, Lake Forest, and Robert E. Vogel, Deerfield, Ill., assignors to Dual Jet Refrigeration Company, Chicago, Ill., a corporation of Illinois
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This invention relates to an improved refrigeration system which is characterized by a unique arrangement for efficiently maintaining refrigeration. The invention is particularly directed to devices of the type which are capable of maintaining a refrigerated state within an enclosed space while still providing an opening for access to the contents.

In an application of Hagen et al., Serial No. 54,077, filed September 6, 1960, now Patent No. 3,134,243, granted May 26, 1964 and in the issued Simons Patent No. 2,862,369, there are described refrigerated display cabinets which are provided with access openings exposed to the atmosphere while still being capable of maintaining the contents in a refrigerated state. Loss of refrigeration from the enclosed space through the access opening is reduced in a highly effective manner in these constructions by the use of a gaseous, preferably air, curtain which is continuously advanced across the open side from one edge of the opening to the opposite edge. The air curtain in these constructions is adapted to be formed of adjacent panels of air, with the innermost panel comprising a refrigerated cold air panel, and with one or more outer panels having temperatures approaching the ambient temperature. It has been found that it is desirable to recirculate the inner cold air panel and to provide means for circulating the adjacent guard panels, to conserve the refrigeration and to maintain the enclosed space in a satisfactory refrigerated state.

In these constructions there are described assemblies which include nozzles extending across the bottom edge of the access opening to direct the air panels upwardly across the opening towards inlets which extend across the top side of the access opening. As an alternative, the nozzles are located across the upper edge for projecting the air panels downwardly toward inlets arranged across the bottom edge. It is also contemplated that the air nozzles be located across one of the lateral edges of the opening for directing the corresponding air panels across the opening toward inlets in the opposite edge. Because of the more desirable effect of gravity on the higher density cold air, it has been found preferable to provide the air curtain with a downward movement from nozzles across the top to inlets across the bottom. The following description will refer to this preferred construction, although it will be understood that the concepts to be described are also applicable to other directions of flow.

In the use of cabinets of the type described, it is, of course, desirable to provide maximum efficiency insofar as the amount of power consumed is concerned. In refrigeration systems of this type, the consumption of power is primarily due to the refrigeration of the moving air streams which pass over the access opening for the cabinet. To a somewhat lesser degree, power is consumed during defrosting cycles and due to the driving of fans for circulation of the streams. As far as the refrigeration of the streams is concerned, a major factor contributing to the amount of power consumption is the loss of refrigeration (or intake of heat) through the access opening.

It is an object of this invention to provide a refrigerated cabinet construction which is provided with means for

decreasing the power consumption necessary for maintaining a desired level of refrigeration.

It is a more particular object of this invention to provide a refrigerated cabinet which is provided with means for decreasing the loss of refrigeration or intake of heat through the access opening of the cabinet.

It is an additional object of this invention to provide a method for controlling the characteristics of the air streams passing across the access opening whereby loss of refrigeration is avoided and a decrease in power consumption is realized.

These and other objects of this invention will appear hereinafter, and for purposes of illustration, but not of limitation, specific embodiments of this invention are shown in the accompanying drawings in which:

FIGURE 1 is a schematic elevation in section of a refrigerated enclosure characterized by the features of this invention; and

FIGURES 2 and 3 illustrate schematically alternative passage and nozzle constructions characterized by the features of this invention.

As indicated, the improvements of this invention are directed to refrigerated enclosures of the type which define an access opening in one wall, which is provided for communication with the otherwise enclosed space. The enclosures are provided with a plurality of nozzles arranged in side-by-side relationship across one edge of an access opening, and corresponding inlets are located across an opposite edge of the access opening. The inner nozzles and inlets are provided for the passage of refrigerated streams across the access opening, while the outer nozzles and inlets circulate progressively warmer air panels. The inner refrigerated streams are circulated through passages having refrigeration coils or the like situated therein, and one or more of the outer streams may also be refrigerated.

In accordance with this invention, it has been found that if means are provided for controlling circulation of the air panels in a certain manner, then a greater degree of efficiency, insofar as loss of refrigeration is concerned, can be obtained. Specifically, it has been found that by providing for control of the speed of circulation of the air streams, whereby the inner streams move at a higher speed than adjacent outer streams, the desired results can be accomplished.

In one aspect of this invention, one or more of the inner streams of air are powered as by circulating fans located in the cabinet passages. An outer stream of air is adapted to circulate through an outer passage. However, circulating fans are not provided for powering this stream. This outer stream is adapted to circulate by means of contact with an adjacent powered stream as the air panels formed by the streams pass across the access opening of the cabinet. Since the outer panel is effectively "dragged along" through frictional contact with the adjacent panel of the powered stream, the outer stream will inherently move at a slower average speed.

In a further aspect of this invention, adjacent streams are powered so that they move at different speeds to accomplish the desired effect. Specifically, this form of the invention provides for a greater speed in the innermost of two adjacent streams, with progressively decreasing speeds prevailing in panels formed by outer streams.

Various combinations of powered and non-powered air streams and different cabinet designs having two or more air passages are contemplated. Thus, a cabinet having a pair of inner powered streams with an outer stream circulated through contact with an adjacent powered stream represents one possible combination of the above described concepts. On the other hand, cabinets having two passages adapted to circulate a faster inner

stream and an adjacent slower stream can be provided with two circulating fans or a single fan for the inner stream. Obviously, the provision of a circulating fan for each passage in a cabinet, including three or more passages, also falls within the scope of this invention.

The accompanying drawing illustrates a refrigerated cabinet 10 which is characterized by means for practicing the invention. The cabinet includes a top wall 12, bottom wall 14, back wall 16 and a front wall 18. The structure defined by these walls is located on a support 20. The front wall 18 defines an opening 22 which provides access to an enclosed refrigerated space 24. The inner wall 26 defines the extent of the refrigerated space.

A pair of partitions 28 and 30 are located intermediate the inner and outer walls and define with these walls passages 32, 34, and 36. These passages confine air streams which are adapted to be circulated through the cabinet. The streams in the embodiment illustrated form laminar panels 38, 40, and 42 which pass across the access opening. Screens 48 can be provided over inlet openings 46 for the passages in order to prevent entry of insects or other foreign material.

Nozzles 44 are provided at the ends of each of the passages, and the air streams pass through these nozzles toward inlets 46 which communicate with the passages at the opposite end of the access opening. The nozzles 44 preferably comprise constructions of the type disclosed in co-pending application Ser. No. 91,875 entitled Refrigerated Display Case and Elements Thereof. Such nozzles may comprise a plurality of parallel, longitudinally spaced vanes or members which subdivide the nozzle into a number of closely separated parallel passages. The nozzles form a continuation of the passages which confine the streams circulating through the cabinet housing.

In the preferred practice of the invention, the nozzle sections are formed of honeycomb which may be manufactured of sheet aluminum. The most satisfactory honeycomb sections have a depth greater than $\frac{1}{2}$ inch and preferably greater than one to two inches so that streams of air issuing from the honey comb will be guides in laminar flow across the access opening in the front wall of the cabinet.

In the cabinet illustrated, the inner passage 36 is provided with a circulating fan 50 and a refrigeration means 52. The air panel formed in this passage is adapted to be circulated by means of the fan into contact with the refrigeration means and then passes out through the innermost nozzle 44 as the refrigerated panel 42. The innermost stream is thus the coldest stream, while the streams 40 and 38 are progressively warmer. As above explained, this arrangement permits access through the front opening of the cabinet while still providing an effective refrigerating operation.

A circulating fan 54 is provided for the intermediate passage 34. In accordance with the concepts of this invention, the fan 54 is adapted to operate at lower speed so that the panel 40 will move more slowly than the panel 42.

There is no circulating means provided in the passage 32 which confines the outermost stream of air. However, the outer stream form a panel 38 which contacts panel 40 as these panels cross the access opening. This arrangement of the panels causes the panel 38 to be dragged by the panel 40 so that the outer panel circulates, although at a lower speed.

As previously indicated, various alternatives are available insofar as the arrangement of the panels and design of the panel are concerned. Thus, the outer passage 32 could be eliminated, providing either two passages each having a circulating fan, or two passages with only the fan 54. If three passages are retained, a low capacity circulating fan could be provided for the outer stream.

It is also contemplated that the feature of a non-powered stream could be employed in combination with two or more inner streams which operate at the same speed. Thus, there are advantages in employing the differential operation of the outer stream, even if the same speeds prevail in the two inner streams. On the other hand, a fast moving innermost stream could be utilized in combination with two or more outer streams moving at the same speed. These alternatives, although providing in some instances less advantageous results, have utility, particularly where equipment for providing complete differentials in the air panels is not available.

Although it is not the applicants' intention to limit the invention to any particularly theory, it is believed that the advantageous results arise due to an interaction between the respective moving panels as they cross the access opening. Specifically, it is believed that the faces of moving panels are subject to mixing with respect to the adjacent still air and that the amount of mixing determines the amount of heat loss from the panels. It has also been observed that the mixing is a function of the velocity of the panels, and that, therefore, the amount of heat loss is dependent on the velocities.

The mixing or turbulence is believed to result in the heat loss because of a "whipping" action to set up in the streams. Thus, air turbulence occurs at the interface between adjacent streams, and there is then a tendency for the streams to be displaced from a direct path across the access opening. This displacement, which occurs most readily near the end of travel of the streams across the opening, takes the form of back and forth movement, and, it will be appreciated that substantial amounts of the cold air in the streams will be displaced toward the outside of the cabinet as a result of this whipping action. It will also be appreciated that the occurrence of turbulence necessarily results in the mixing of colder air with the adjacent outer air whereby the colder air is moved out of the innermost streams.

It has been found that operation of the intermediate stream 40 at a lower speed than the stream 42 can be carried out without resulting in significant turbulence or mixing at the interface 58 between the streams 42 and 40. If the respective speeds are properly regulated, these streams slip by one another and, therefore, the laminar character of the respective streams is maintained. The maintenance of this laminar character substantially preserves the temperature differential between the inner refrigerated stream and the adjacent guard stream.

It is well-known that laminar flow of fluids can be maintained even though a differential exists in the speed of different portions of the fluid. If the differential exceeds a certain value, it is also well-known that turbulence will result and laminar flow will not be possible. Thus, the relative speeds of the panels must be maintained within the limits which enable substantial laminar flow.

A barrier to the inflow of warm air results at the outer face 60 of the stream 40 in the illustrated cabinet. Thus it has been determined that a laminar character also exists at this interface since the streams 40 and 38 can be caused to slip with respect to each other.

The outermost stream 38 will create a minimum of turbulence with the ambient air at the face 62 of this stream. This is the case since the average velocity of this stream is low, and since the outermost portions of this stream will necessarily have a below average velocity. Accordingly, the small turbulence created does not cause inflow of warm air to any great extent.

It has been observed that higher temperatures are recorded in the lower part of cabinets when a pair of streams comprising a refrigerated stream and a guard stream are moved at the same speed across the access opening. The use of a third stream whether or not it is powered, did not totally avoid this situation. However, when the speed of the inner stream was increased,

this detrimental condition was effectively avoided and substantially uniform temperature conditions were recorded. The improved operation was attributed to a reduction in whipping caused by the greater throw created by the higher velocity of the inner stream. With the whipping reduced, laminar flow was maintained for a longer distance and a reduction in heat loss realized. To illustrate, if the inner air panel is at -25° F. when at the top of the cabinet, the further it travels without significant mixing with the adjacent stream, the lower the temperature will be at the intake nozzle. If a temperature of about -15° F. is preserved at this point, then the burden on the refrigerating coils is not extreme. Furthermore, a maximum temperature of -15° F. within the enclosure is assured.

In a typical operation, the speed of the inner refrigerated stream is maintained at about 400 ft. per minute, while the adjacent guard panel is moved at about 275 ft. per minute. Where an outer panel is employed, it is pulled along at an average speed between 50 and 75 ft. per minute. As previously suggested however, the relative speeds are determined with a view toward maintaining laminar flow and eliminating turbulence. It will be understood that many combinations of speed are available for use.

It will be appreciated that the various speed values can be changed to suit different conditions such as the desired temperature within the cabinet, the prevailing ambient temperature and similar conditions. It has been found that speeds in the inner panel in excess of 300 ft. per minute provide the results of this invention, while the adjacent guard panel can be maintained at speeds between 200 and 300 ft. per minute. The true limiting factor on the values, however, is related to the effect of the speeds on the turbulence in the various planes made up by the faces and interfaces of the streams. Thus, the speed of the adjacent guard panel is maintained at a sufficiently high level to provide slippage between these laminar streams thereby avoiding turbulence at the interface of these streams. If an outer panel is employed, the speed is preferably maintained below about 100 ft. per minute, or at a level which minimizes creation of turbulence between the stationary ambient air and the slow moving guard panel.

It is also contemplated in accordance with this invention to provide means for producing variable speeds across individual panels in the apparatus. Specifically, the invention is intended to cover the use of means adapted to control the movement of portions of a panel, such as the panel 40, whereby the innermost portions of the panel move faster than adjacent portions, with a progressive decrease in speed to the outer portions.

FIGURES 2 and 3 illustrate two examples of means capable of effecting this result. It will be appreciated from the following discussion that variations in the design of these means will produce substantially the same results and various other mechanisms for producing these results will be obvious to skilled observers.

The structure shown in FIGURE 2 comprises a passage 70 extending to an outlet opening 72. A honeycomb section 72 is fitted into the outlet in the manner previously described. A plurality of vanes 76 are positioned to extend across the passage upstream of the outlet and it will be noted that these vanes are equally spaced apart at their leading edges. The spacing between the vanes changes toward the trailing edges thereof in a manner such that a progressively increasing spacing toward the outside of the passage results at the exit ends of the vanes.

When a stream of air is circulating through the passage 70, the vanes 76 will divide the streams into equal portions. Since the same amount of air must pass through openings of a different volume, the speeds of the air will vary in a corresponding manner. By providing the pro-

gressively increasing openings toward the outside of the passage 70, the innermost stream will move faster than the adjacent stream and this adjacent stream will move faster than the next stream and so on. When these portions of the streams pass through the honeycomb section and across the access opening, they will move at different speeds, however, the speeds are regulated by the design of the vanes so that turbulence will not be set up by the adjacent portions of the stream. Accordingly, these portions will move as individual laminar panels across the access opening.

FIGURE 3 illustrates an alternative structure which includes a passage 80 provided with a honeycomb section 82. The passages in the honeycomb section are shorter in the innermost portions of this section and become progressively longer toward the outer portions of the honeycomb. With this arrangement, the air passing through the section will move faster through the inner portions thereof since there will be less drag in these portions. By providing progressively longer portions, the air panel passing out of the honeycomb section will comprise a plurality of individual sections moving progressively slower in a direction toward the outside of the cabinet.

The concepts above described are advantageously provided in the passage immediately adjacent the innermost refrigerated stream. This gradual decrease in velocity is highly effective in preserving the low temperature character of the innermost stream which is in turn responsible for preserving the temperature of the cold interior portions of the cabinet. By providing progressively slower portions in the stream adjacent the refrigerated stream, it is possible to virtually eliminate turbulence with respect to an outer stream or with respect to the ambient air.

There are many advantages to the system of this invention from the standpoint of efficiency of operation. Thus, the provision of the differential velocities in the moving streams preserves refrigeration and, at the same time, effects uniformity of temperature within the enclosure. The elimination of a circulating fan for the outer stream decreases the original cost of the apparatus and provides greater economy in its operation. The provision of the third circulating stream also acts as an additional buffer or barrier, preventing inflow of heat. Finally, the provision of a third circulating stream and its associated passage provides for catching of relatively cold air which would otherwise spill onto the floor outside the cabinet. By avoiding loss of this air, a maximum amount of refrigeration is preserved and, in addition, discomfort to those standing at the front of the cabinet is avoided. In this latter connection it was observed that an amount of very cold air spilled out from the second duct which could be annoying to one standing in front of the cabinet. By providing a third stream, the air spilled from the second duct is mixed with the warmer air of the third stream, and, therefore, any air spilling out of the cabinet will be at a warmer temperature.

It will be understood that various modifications may be made in the above described construction which provide the features of this invention without departing from the spirit thereof, particularly as defined in the following claims.

That which is claimed is:

1. In a refrigerated cabinet of the type which defines an access opening in one wall communicating an otherwise enclosed space with the ambient atmosphere, and which is provided with a plurality of air inlets and a plurality of air nozzles, said inlets and nozzles extending in side-by-side relationship across opposite edges of said access opening, passages communicating each of the corresponding inlets and nozzles, said passages being independent and being separately defined by the top, bottom and back walls of said cabinet whereby the passages are out of communication with each other and with said enclosed space except through said inlets and nozzles, and

refrigeration means disposed in at least one of said passages to refrigerate at least the innermost stream passing through said passages and across said access opening, the improvement comprising means for circulating the streams of air through said passages and across said access opening in the form of panels, said circulating means being located in each passage except in the passage containing the outermost stream, said outermost stream being circulated through contact of the panel formed thereby with the moving panel adjacent thereto as these panels cross said access opening.

2. A refrigerated cabinet in accordance with claim 1 wherein three passages and three circulating streams are provided in said cabinet and wherein refrigeration means are provided only for the innermost stream, said third stream comprising the outermost stream providing a buffer against the inflow of heat and serving to reduce the amount of cold air lost by spilling out of the cabinet and also serving to mix the air spilled from the intermediate passage with warmer air in the third passage thus raising the temperature of the spilled air to a point nearer ambient temperature.

3. A refrigerated cabinet in accordance with claim 1 wherein said circulating means comprise fans located upstream of said refrigeration means, and including means for operating the fan in the innermost passage at a higher rate than the fan in the adjacent passage whereby said innermost panel moves at a higher speed than the panel adjacent thereto.

4. In a refrigerated cabinet defining an access opening in one wall communicating the otherwise enclosed space with the ambient atmosphere, at least two passages defined in said cabinet each terminating at one end in an air inlet and at the other end in an air nozzle, said passages being independent and being separately defined by the top, bottom and back walls of said cabinet whereby the passages are out of communication with each other and with said enclosed space except through said inlets and nozzles, said inlets and nozzles being disposed in side-by-side relationship on opposite sides of said access opening, and refrigeration means located in at least one of said passages for refrigerating at least the stream of air passing through the innermost passage, the improvement comprising circulating means located in the passage confining said refrigerated stream and in the passage immediately adjacent thereto, and means for operating the circulating means in the passage confining the refrigerated stream at a higher rate than the circulating means in said adjacent passage whereby the innermost air panel formed by said refrigerated stream as it crosses said access opening is adapted to move at a greater speed than the adjacent panel, said circulating means being adapted to maintain the relative rates of speed of said panels within limits permitting slipping between the panels and avoiding significant turbulence between panels including a third passage located outwardly of the two other passages and having an air inlet and air nozzle at its ends, said third passage confining a stream of air which forms an air panel passing in contact with said adjacent panel, this contact providing for circulation of the stream in said third passage.

5. In a refrigerated cabinet of the type which defines an access opening in one wall communicating an otherwise enclosed space with the ambient atmosphere, pas-

sages comprising an inner passage, an intermediate passage and an outer passage, each of said passages terminating at one end in an air inlet and at the other end in an air nozzle, said passages being independent and being separately defined by the top, bottom and back walls of said cabinet whereby the passages are out of communication with each other and with said enclosed space except through said inlets and nozzles, said inlets and nozzles being disposed in side-by-side relationship on opposite sides of said access opening, and refrigeration means located in at least said inner passage, the improvement comprising means for circulating streams of air through said passages thereby forming three adjacent moving panels of air across said access opening, said circulating means comprising fans in each of said inner and intermediate passages, the fan in said inner passage being adapted to circulate the stream in the inner passage at a speed greater than the stream in the intermediate passage, the stream in said outer passage being circulated through contact of the outermost panel with the intermediate panel, said circulating means being adapted to maintain the relative rates of speed of said panels within limits permitting slipping between the panels and avoiding significant turbulence between panels.

6. In a refrigerated cabinet defining an access opening in one wall communicating the otherwise enclosed space with the outside atmosphere, at least two passages defined in said cabinet each terminating at one end in an air inlet and at the other end in an air nozzle, said passages being independent and being separately defined by the top, bottom and back walls of said cabinet whereby the passages are out of communication with each other and with said enclosed space except through said inlets and nozzles, said inlets and nozzles being disposed in side-by-side relationship on opposite sides of said access opening, and refrigeration means located in at least one of said passages for refrigeration of at least the streams of air passage through the innermost passage, the improvement comprising means providing for circulation of streams of air through said passages thereby producing adjacent moving panels of air across said opening, said circulating means including at least one fan located in the innermost passage, the streams in a passage adjacent said innermost passage being circulated through contact of the adjacent air panel with the panel corresponding to said innermost stream, said circulating means being adapted to maintain the relative rates of speed of said panels within limits permitting slipping between the panels and avoiding significant turbulence between panels.

References Cited by the Examiner

UNITED STATES PATENTS

1,298,655	4/1919	Briner	98—40
2,268,014	12/1941	Bridges	98—40
2,794,325	6/1957	Shearer	98—36
3,021,776	2/1962	Kennedy	98—115
3,063,252	11/1962	Lamb	62—256
3,091,942	6/1963	Dickson	62—256

WILLIAM J. WYE, *Primary Examiner*.

ROBERT A. O'LEARY, *Examiner*.