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W. TAMM

3,363,533

METHOD FOR SCREENING AIR PASSAGES

Original Filed Aug. 26, 1964

6 Sheets-Sheet 1

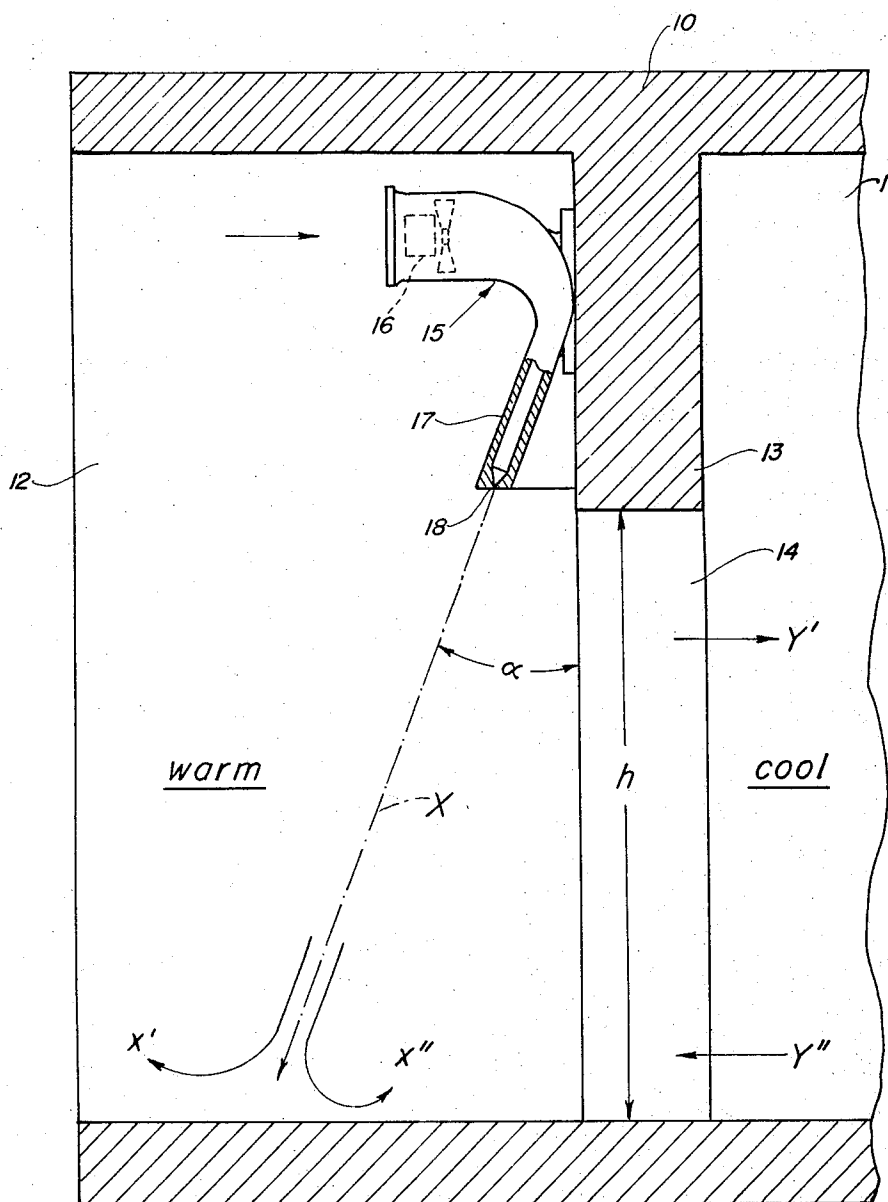


Fig. 1

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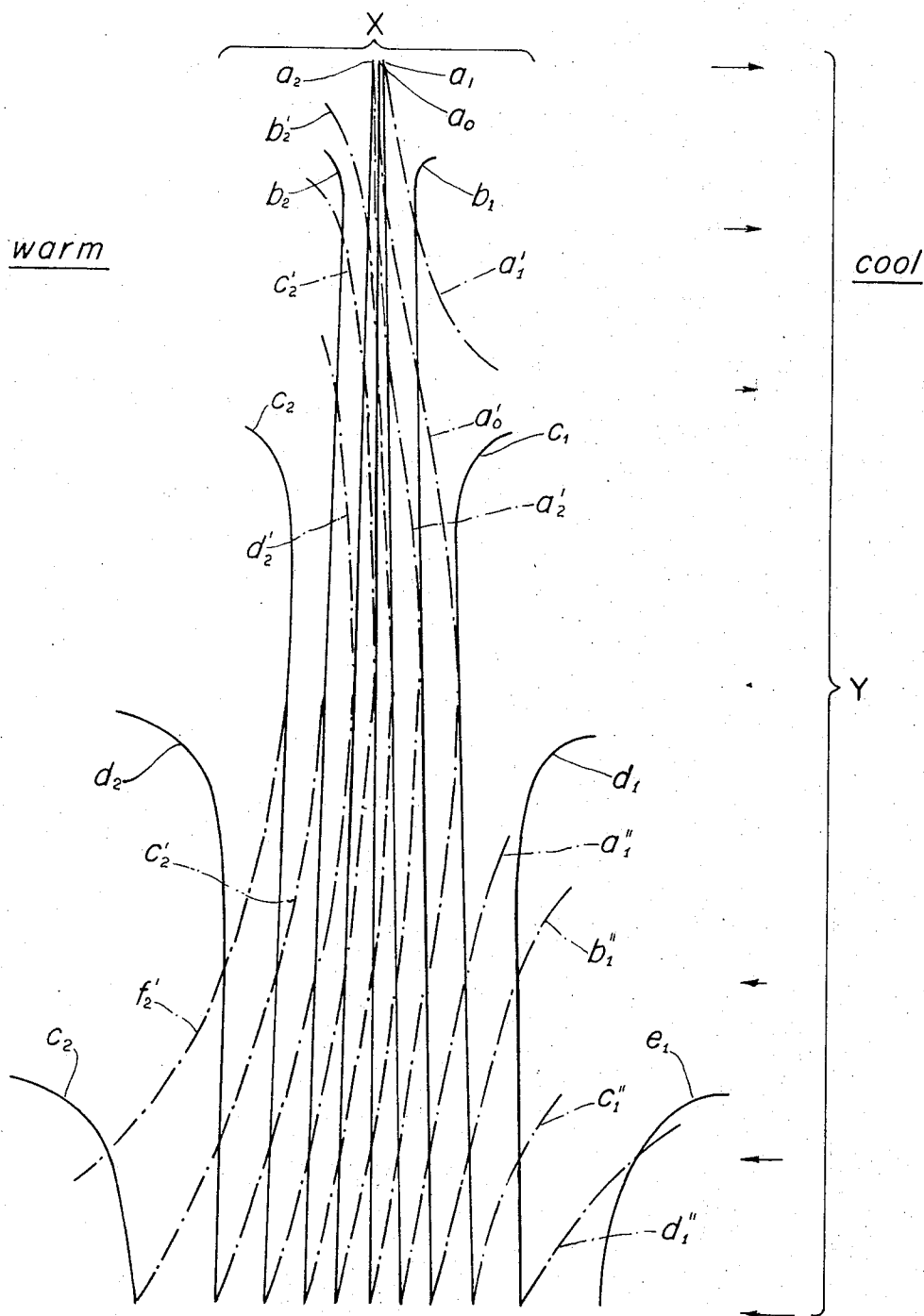


Fig. 2

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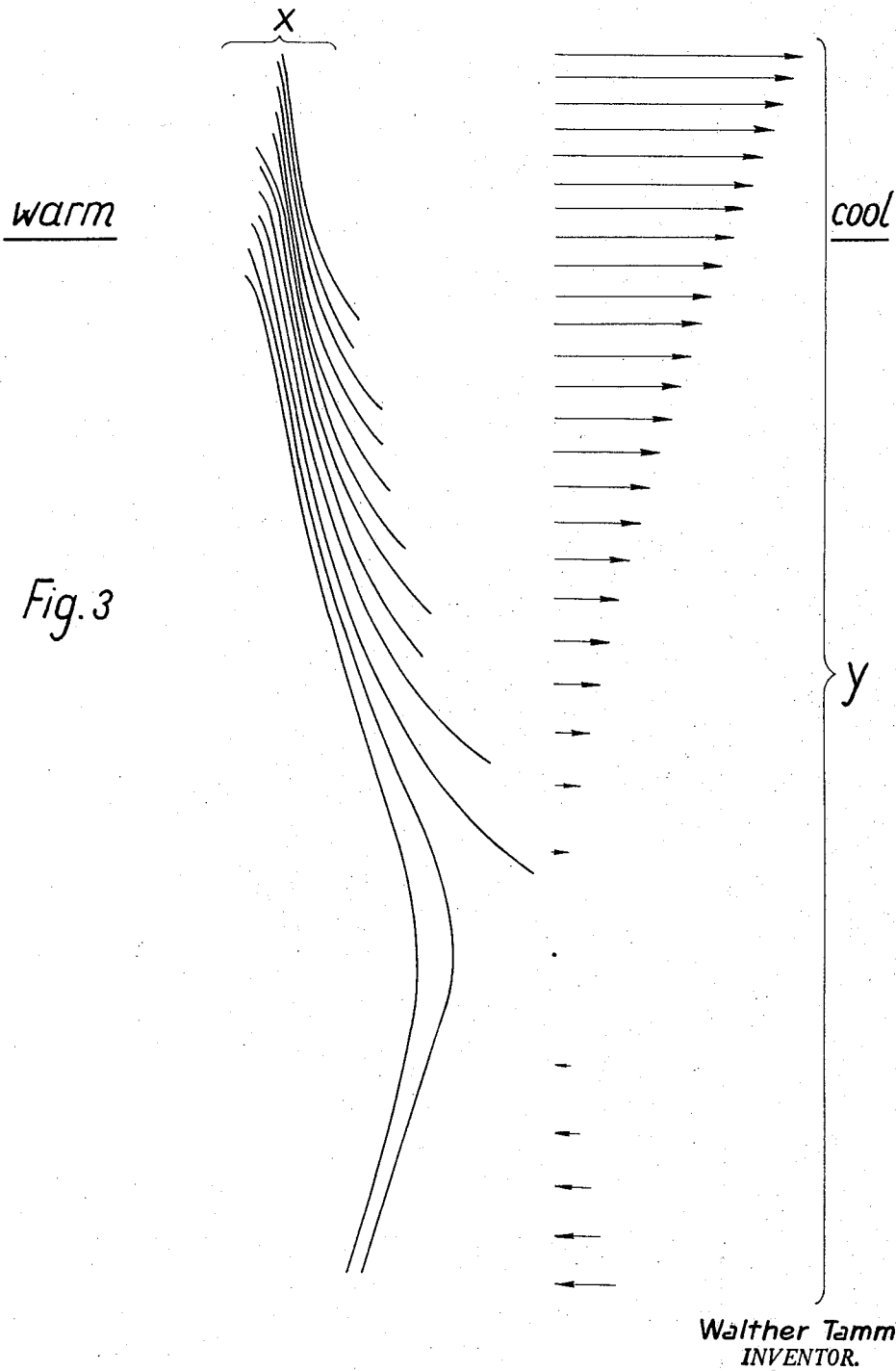
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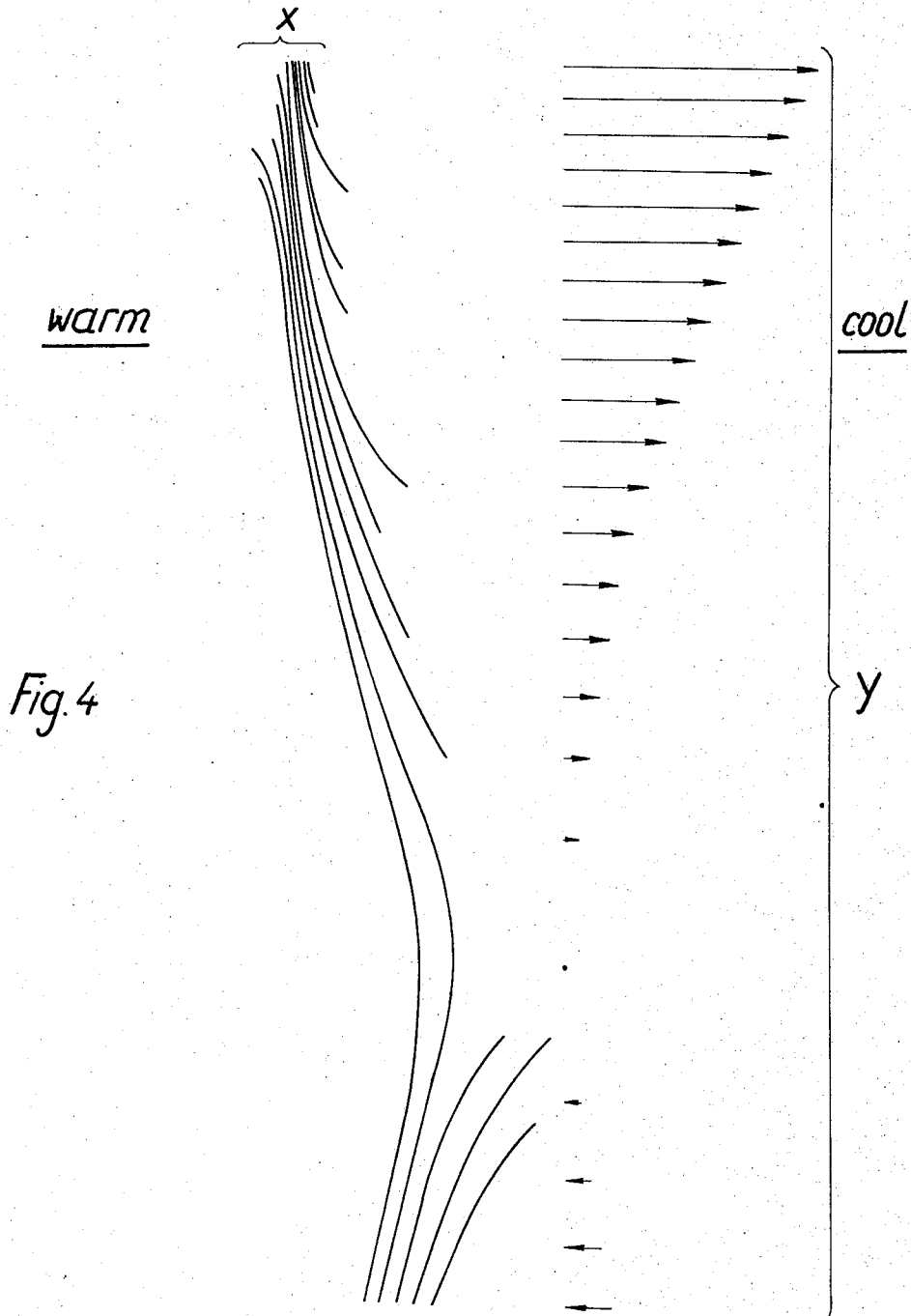
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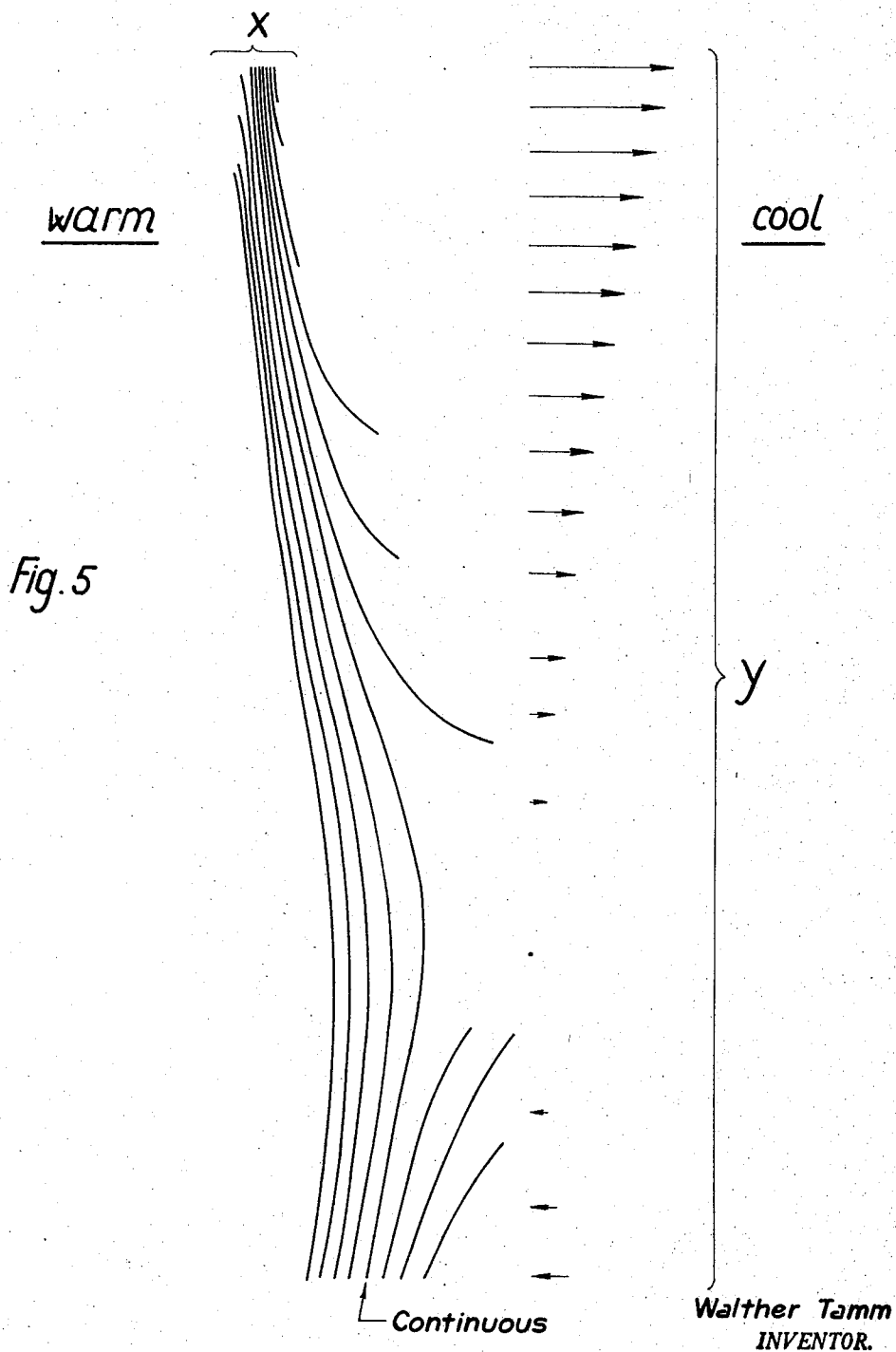
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METHOD FOR SCREENING AIR PASSAGES

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6 Sheets-Sheet 5



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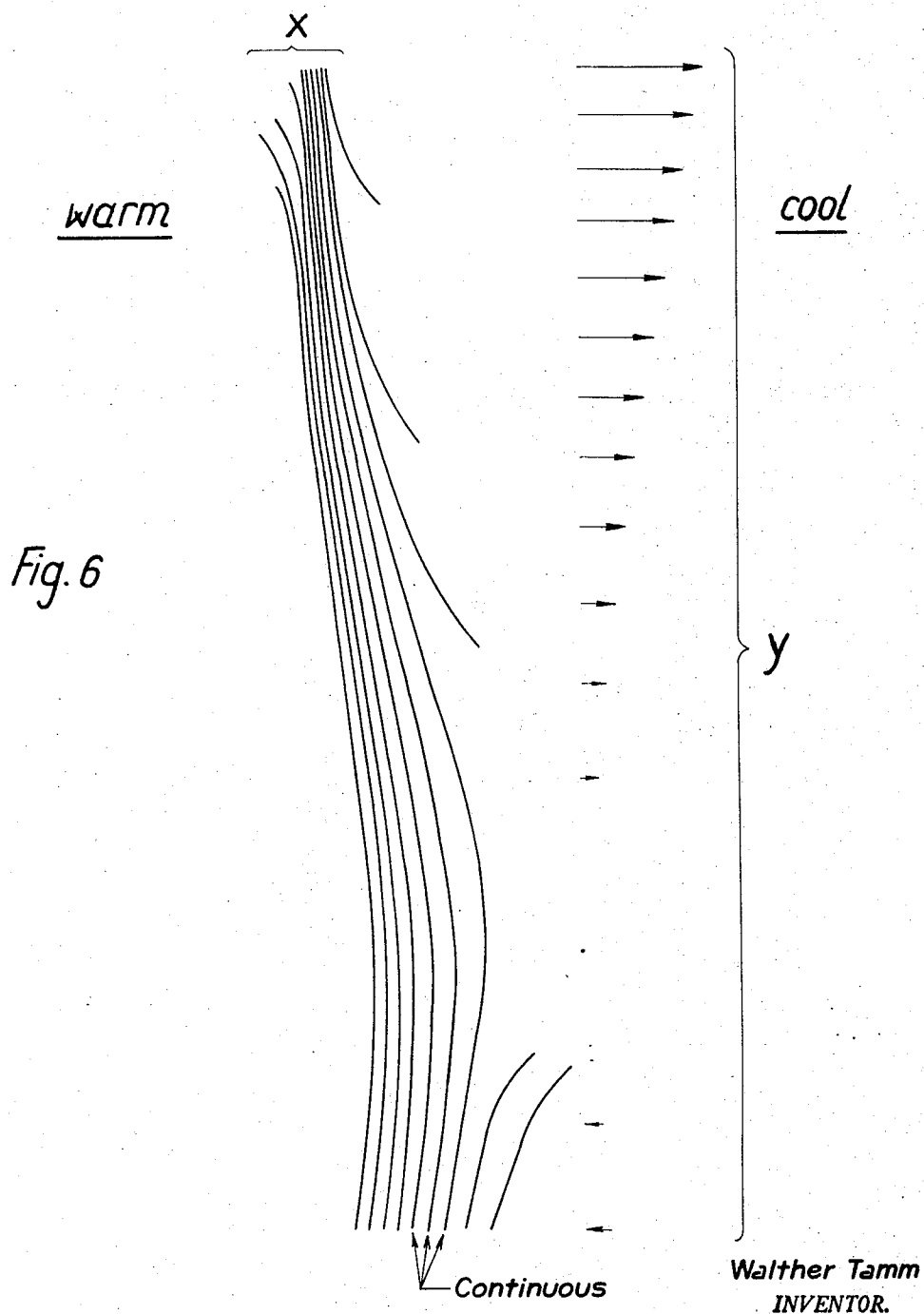
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METHOD FOR SCREENING AIR PASSAGES

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6 Sheets-Sheet 6



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3,363,533

METHOD FOR SCREENING AIR PASSAGES

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Continuation of application Ser. No. 392,341, Aug. 26, 1964. This application Nov. 14, 1966, Ser. No. 594,257

Claims priority, application Germany, Aug. 27, 1963, St. 21,021

3 Claims. (Cl. 98—36)

ABSTRACT OF THE DISCLOSURE

Method of screening an opening, such as a door, by a downwardly directed air flow to maintain a temperature differential between adjoining air spaces, the intensity of this air flow being held between a lower limit of one-third (preferably two-fifths) and an upper limit of about one-half the rate of air interchange which would occur through the opening in the absence of the screening air flow.

This application is a continuation of application Ser. No. 392,341 filed Aug. 26, 1964, and now abandoned.

My present invention relates to a method of and an apparatus for the screening of air passages, such as door and window openings, between the cooler air of a refrigeration chamber and the warmer air of the outer atmosphere.

In commonly assigned U.S. patent application Ser. No. 128,592, filed by me jointly with Werner Knapp on Aug. 1, 1961, there has been disclosed an apparatus for screening such openings by means of an air curtain, i.e. a sheet-like flow of air directed downwardly from the top of the opening across its full width. Such air curtains have proved highly useful in practice not only for mutually insulating adjoining regions of different temperature but also for preventing the passage of insects, dust particles and so on.

When such an air curtain is used to bar the entrance of warmer air into a cooler region, it has been found advantageous—as likewise disclosed in the aforementioned application—to train the air flow toward the bottom of the opening not exactly vertically but at a small angle toward the warmer region, preferably between about 15° and 25°, the purpose of this inclination being to split the air flow into two unequal horizontal currents, i.e. a major current directed toward the warmer region and a minor current directed toward the colder region, upon its rebounding from the floor. The preferred ratio of these two air currents, according to the teachings of the prior application, is approximately 2:1 with the usual temperature differences of, say, 20° to 50° C. This ratio will be an optimum, however, only under conditions not always realized in practice, such as the absence of strong winds creating an additional pressure differential across the opening; other hitherto unpredictable complications arise when the apparatus for producing the air curtain is mounted on a fast-moving vehicle, such as a refrigerated truck or railroad car.

It is, therefore, the general object of my present invention to provide a method of effectively utilizing such air curtains under a wide variety of conditions, as well as an apparatus for implementing this method.

A more particular object of my invention is to provide a method of and means for producing an air current of substantially 100% effectiveness with the greatest possible economy of energy.

I have found, pursuant to this invention, that there exists a definite relationship between the flow rate of the air curtain and the flow rate of the convection current across

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the opening, i.e. the rate at which air is interchanged between the cooler and warmer regions in the absence of an air screen, which must be observed if these convection currents are to be completely suppressed. More particularly, I have determined that the minimum ratio of screening flow to normal convection current lies in the neighborhood of 1:3 for suppressing air interchange under idealized conditions, i.e. in the absence of atmospheric disturbances, and that in practice a minimum ratio of about 0.4:1 ought to be maintained to this end. I have further determined that a ratio of about 1:2 provides a satisfactory safety margin for operation even under adverse conditions and that, accordingly, a higher rate of screening flow merely increases the cost of operation without any compensating advantages. It should be noted that this relationship holds true for both vertical and inclined air currents, up to a maximum angle of inclination of approximately 25° as mentioned above, but that the outward and downward inclination of the screening flow will in many instances enable a reduction of the flow rate well below the aforesaid maximum ratio of substantially 1:2.

The normal rate of air interchange by convection currents can always be determined quite readily by practical tests. In first approximation, in a manner satisfactory for the purposes of this invention, this rate can also be calculated mathematically for rectangular openings (neglecting friction) from the relationship (disregarding the gravity factor)

$$V=A\sqrt{h(1-R)}$$

where V is the volume of the convection flow in m.³ per second, A is the area of the opening in m.², h is its height in meters and R is the ratio of the specific gravities of the relatively light warmer air and the relatively heavy colder air on opposite sides of the opening; the application of this formula presupposes that the temperature difference is substantially unaffected by the convection currents, as will be the case if the cooler space is served by a refrigeration unit of sufficient capacity. Thus, I specifically propose to operate an air-curtain-producing apparatus at a rate substantially given by the expression

$$kA\sqrt{h(1-R)}m.^3/sec.$$

with k an arbitrary constant selected to fall between about 0.4 and 0.5.

The invention will be described in greater detail with reference to the accompanying drawing in which:

FIG. 1 is an elevational view, partly in section, of an air-screen-producing apparatus, generally similar to that disclosed in the copending application referred to, adapted to be operated in accordance with the teachings of my invention;

FIG. 2 is a diagrammatic illustration of the flow conditions existing in the region of an opening screened by an air curtain; and

FIGS. 3–6 are diagrams of the type shown in FIG. 2, relating to systems with different ratios of screening flow to normal convection currents.

In FIG. 1 I have shown a wall structure 10, which may be that of a building or a vehicle, wherein a chamber 11 filled with cooler air is separated from a space 12 of warmer air, communicating with the outer atmosphere, by a partition 13 having a rectangular door opening of height h. A source of air current 15, comprising a blower 16 working into a plenum chamber 17, draws atmospheric air from the region 12 and discharges it through a nozzle 18 which forms an elongated slot along the entire upper edge of the opening 14. The apparatus 15 is so disposed that the issuing air stream is inclined at an angle with reference to the vertical, this air stream upon reflection at the floor dividing into two components x', x'' of which

the outwardly directed first component x' may be several times as large as the inwardly directed second component x'' .

Normally, i.e. in the absence of the screening air current x , convection currents traverse the opening 14 in both directions, i.e. inwardly at y' in the upper half and outwardly at y'' in the lower half of the opening. At medium level $h/2$ the convection current is substantially zero. It is apparent that the rate of inflow at y' must balance the rate of outflow at y'' (it being assumed that the space 11 does not have any other air openings), both rates equaling the value V substantially as expressed in the formula given above.

In FIG. 2 I have shown at x the flow of screening air (here vertical) and at y the convection currents existing in the absence of such flow, the relative lengths of the horizontal arrows indicating the flow velocity at different elevations. The vertical screening flow x is arbitrarily represented by a central layer a_0 of maximum intensity and two outer layers a_1, a_2 of reduced intensity at opposite sides thereof, these layers spreading apart and diminishing in velocity with increasing distance from the nozzle 18 (FIG. 1). Other layers, drawn from the ambient air, are entrained by this flow as illustrated at $b_1, b_2; c_1, c_2; d_1, d_2$; and e_1, e_2 ; the layers a_0, a_1-e_1 and a_2-e_2 have been shown in their undisturbed state, i.e. as they would appear if no temperature and pressure differences existed across the flow.

At $a_0', a_1', a_2', b_1', b_2'$ etc. I have shown the manner in which these layers are distorted by the intercepted convection currents y . It will be noted that, in this particular diagram, the layers a_0' and a_2' are continuous from the nozzle to the floor of the compartment 12 (FIG. 1) but that the remaining layers are disrupted so as to be substantially without screening effect. The presence of even a single continuous layer, however, is theoretically sufficient to prevent the interchange of cool and warm air between the spaces 11 and 12.

In FIGS. 3-6 I have shown the relationship of the two flows x, y under four different conditions of operation. The ratio of vertical to horizontal flow increases progressively from FIG. 3 through FIG. 6, as indicated graphically by the decreasing density of horizontal arrows in these figures. More particularly, the ratio $x:y$ amounts to 1:4 in FIG. 3, to 1:3 in FIG. 4, to 3:7 in FIG. 5 and to 1:2 in FIG. 6.

In the systems of FIGS. 3 and 4, all the illustrated layers of flow x are discontinuous, although the degree of continuity is somewhat greater in the latter system than in the former; the system of FIG. 4 has a screening efficiency of approximately 80%, compared with an efficiency of less than 60% in the system of FIG. 3. FIG. 5 shows several continuous layers, for a screening efficiency of 100%, the number of such layers increasing in FIG. 6 with no change in efficiency but with a less pronounced curving of the layers so that disruption by gusts or shocks is less likely. In general, the relationship illustrated in FIG. 6 represents approximately the maximum rate of screening flow that is economically justifiable.

It should be noted that the diagrams of FIGS. 3-6 are substantially independent of absolute values and specific dimensions, being equally applicable to smaller volumes of air with higher flow velocities and to larger volumes with lower velocities.

I claim:

1. A method of screening an opening between a first space filled with relatively warm air and a second space filled with relatively cool air, comprising the steps of measuring the rate of horizontal air interchange through said opening in the absence of a transverse air flow therein and subsequently directing across said opening a downward air flow at a rate between one-third and substantially one-half of said rate of air interchange.

2. A method as defined in claim 1 wherein the intensity of said downward air flow is maintained in a range between substantially 0.4 and 0.5 times said rate of air interchange.

3. A method as defined in claim 1 wherein said air flow is directed past said opening on the side of said relatively warm air and is downwardly inclined toward said first space at an angle up to substantially 25° with reference to the vertical.

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