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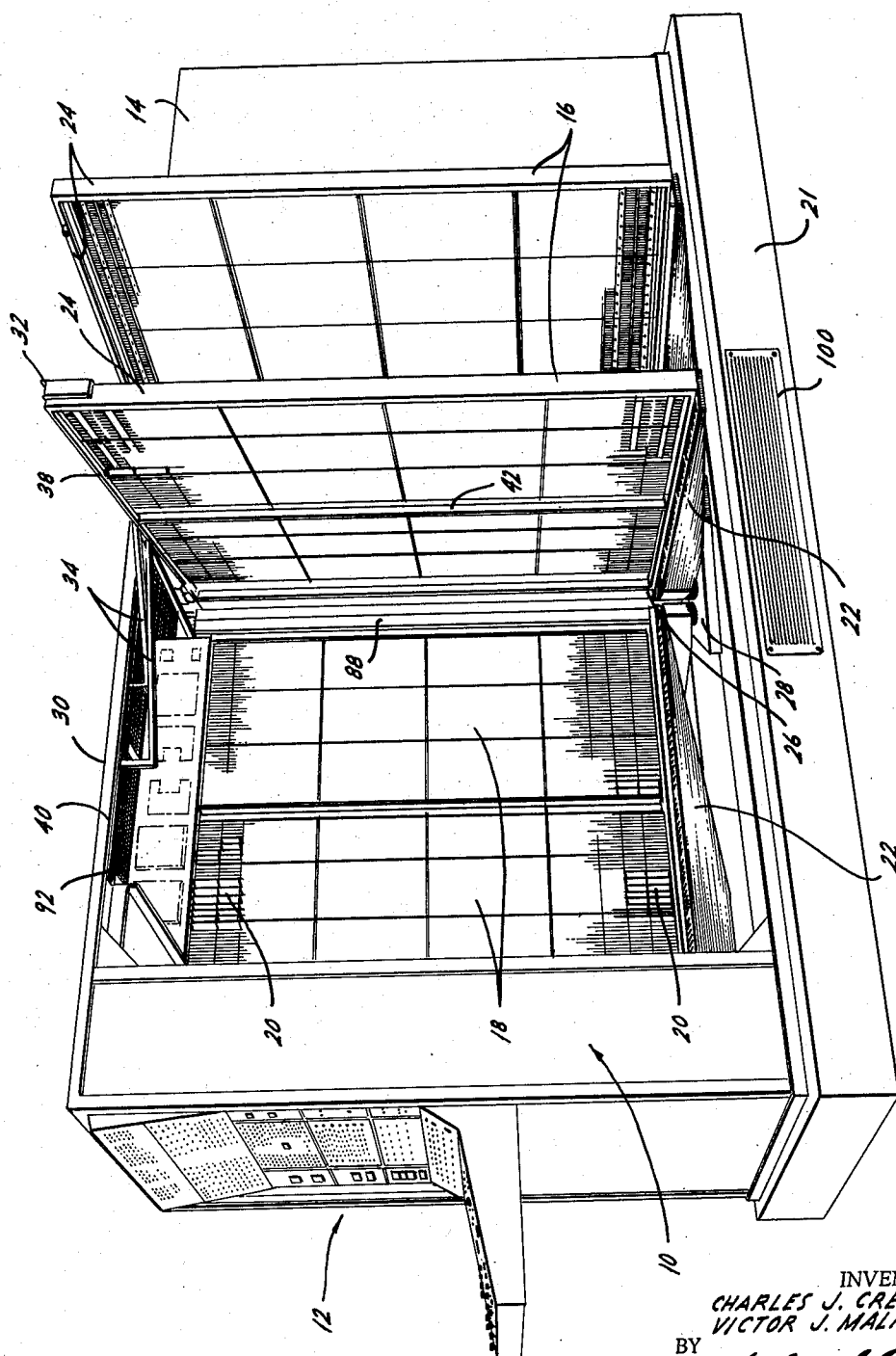
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3,147,403

COOLING SYSTEM FOR ELECTRONIC APPARATUS

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2 Sheets-Sheet 1



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2 Sheets-Sheet 2

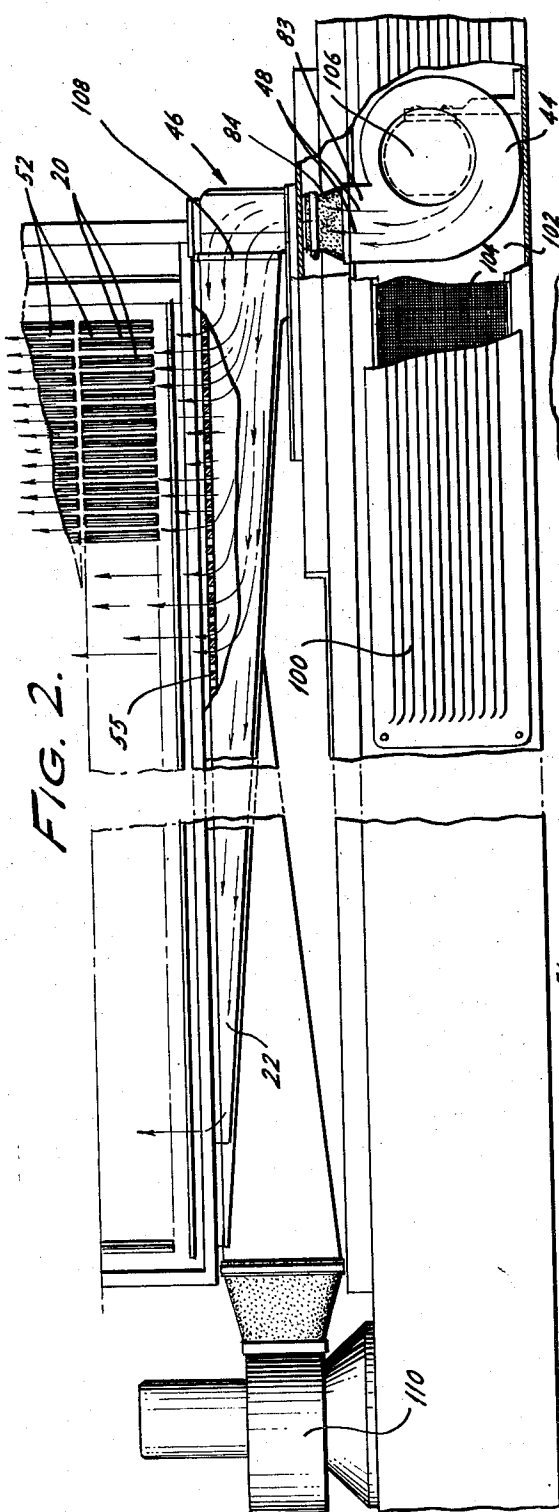


FIG. 2.

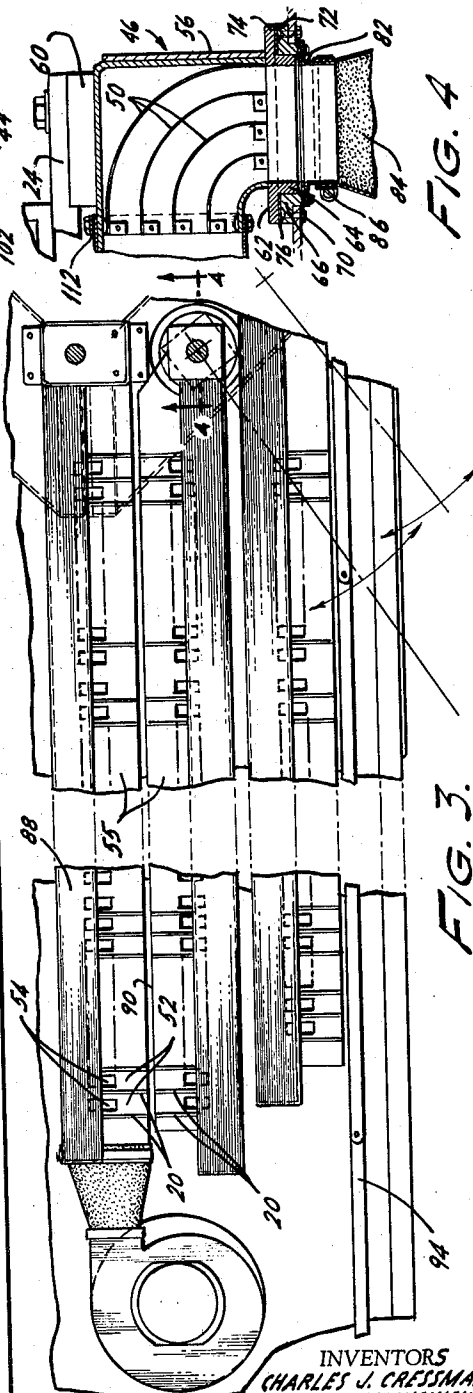


FIG. 4

FIG. 3.

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3,147,403 COOLING SYSTEM FOR ELECTRONIC APPARATUS

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This invention relates generally to forced-air cooling systems and more particularly to improved means for cooling pivotally supported electronic apparatus.

While of broader applicability the invention will be illustrated and described in connection with its use in the computer field.

With the widening demand both militarily and commercially for computers capable of handling increasingly greater amounts of information at higher rates of speed the need for high density electronic packaging has become of paramount importance. A concomitant of this trend is the need for improved means for removing the heat generated within such compact assemblies in order to maintain system stability.

To achieve optimum use of available space while at the same time providing for ease of access to the unit to facilitate system servicing and maintenance use has been made of pivotally mounted electronic apparatus. One such arrangement is to use a paginated system wherein pluralities of modular assemblies are mounted on frames or "pages" foldable into a closed or tightly compacted operating position. When servicing is required the pages can be opened permitting easy access to component parts of the system.

Because of the high density packaging made possible by this constructional arrangement there is a considerable problem of heat removal. This problem is further complicated by the desirability of cooling the pages when moved into their open position in order to permit servicing or maintenance procedures to be carried out under normal operating conditions.

Prior art apparatus directed to the problem of cooling equipment of this type has generally taken the form of providing a pressure plenum in which the air-outlet means is sufficiently restrictive of the air flow to permit a static pressure buildup within the plenum to insure a uniform air distribution over the area serviced.

This approach has the disadvantages of requiring the employment of high capacity, large size blowers in addition to requiring the use of enlarged, hermetically sealed plenums, factors which increase both the size of the unit and its constructional cost. Moreover, the prior art approach has been to use a fixed air distributing system which is only effectual in cooling the page when in its normally closed operating position.

It is accordingly a general object of the present invention to provide a system for cooling electronic apparatus of the type described which eliminates the aforementioned difficulties of the prior art.

It is another object of the invention to provide a blower system uniquely adapted to achieve uniform cooling of paginated electronic assemblies.

It is a further and more particularized object of the invention to provide a cooling system which has optimum compactness, is capable of cooling paginated electronic assemblies in either their closed or open position and provides selective cooling of the multiplicity of components comprising the assembly.

These and other objects and features of the invention will become apparent by reference to the following detailed description and drawings in which:

FIGURE 1 is a perspective showing of a central processing unit of a digital computer embodying the present

invention, the electronic "pages" of the processor being shown in both their open and stored or packaged positions;

FIGURE 2 is a partially sectionalized side elevation of the page and cooling apparatus showing constructional details of the assembly;

FIGURE 3 is a fragmentary plan view of the processor showing pages in their closed position; and

FIGURE 4 is a sectional elevational view taken along the cutting plane 4-4 seen in FIGURE 3 showing details of the bearing duct construction.

In achievement of the aforementioned as well as other objectives, a preferred embodiment of the invention contemplates the provision of a unique air-distributing system which is transportable with the electronic page assembly and is capable of selectively and continuously cooling the page assembly over its entire surface and throughout its range of motion.

Referring to FIGURE 1, there is shown a central processing unit 10 of a digital computer, the unit comprising a control and maintenance console 12, a self-contained power supply 14 and a plurality of pages 16 each consisting of four pairs of horizontally disposed, serially connected pans 18 each containing over 200 printed circuit modules, a few of which have been illustrated at 20. The base 21 of the unit is provided with a fully enclosed chamber which contains a blower system designed for selective and individual cooling of each of the page assemblies, air being supplied to each page through a uniquely constructed page bearing and tapered air distributing duct or plenum 22 secured to the page for movement therewith.

Certain of the pages are shown in their open position to facilitate explanation of their construction. Each page is defined by a metal frame 24 hinged along its inner edge 26 to the cabinet structure 28. The pages are held in closed position within the cabinet 30 by conventional latch means 32 and are limited in their outward movement by links 34 which are pivotally secured at one end to the upper surface of the frame cross member 38. The opposite end of the link terminates in an upwardly presented leg portion retained within track means 40 for sliding movement therein. To facilitate securing of pans 18 to the page there is provided a recessed, vertically extending ledge along frame portions of the page which in cooperation with a medially disposed channel member 42 forms a support for opposite vertical edge portions of each pan.

Constructional details of the pan assemblies and their electrical interconnection are fully set forth in copending application Serial No. 193,963, filed May 11, 1962 and assigned to the assignee of the present invention. Since that aspect of the computer construction forms no part of the present invention no further elaboration is believed necessary.

In the illustrated example the electronic network of the central processor is contained on seven pages each containing over 1600 printed wiring modules requiring individualized cooling. In fulfilling this requirement each page is serviced by its own independent cooling system. The elements comprising each of the cooling systems are shown in sectional elevation in FIGURE 2 and consist of a centrifugal blower 44, an air distributing plenum 22 removably secured to the bottom edge of the page, and an interposed transitional bearing duct 46 interconnecting the plenum and blower in fluid flow communication.

To minimize turbulence in the translation of the air stream from the vertically directed output passage 48 of the blower 44 to the horizontally disposed cooling plenum 22 the bearing duct 46 is equipped with a series of arcuately shaped guide vanes 50. The air flow path is diagrammatically shown by arrows in FIGURE 2 and is

kept as smooth as possible to prevent eddy currents and to reduce frictional drag on the air stream. By reducing the static pressure buildup within the system the size of the air-moving equipment necessary to meet the system's cooling requirements can be kept at a minimum.

To cool the page effectively requires the air being delivered by the blower to be divided into a plurality of discrete streams individual ones of which are directed through the vertical running channels 52 (FIGURE 2) formed by the vertically aligned columns of modules 20. To accomplish this the duct 22 is provided with a number of rectangularly shaped air discharge ports 54, along its page confronting surface 55, equal in number to that of the module-formed channels 52. This construction is seen most clearly in FIGURES 2 and 3. To provide for the equal distribution of air in such a system the cooling plenum is configured to accommodate the reduced quantity of air which flows within the duct at the downstream side of each outlet. By reducing the duct's cross sectional area the velocity of the air stream within the duct remains substantially constant. The ports are of equal size to equalize their outlet flow rates.

To achieve a balanced-flow system, herein defined as a system which is not dependent on the development of a static pressure head to insure uniform air distribution, the aggregate area of the outlet vents 54 is made substantially equal to that of the air intake area. To compensate for the reduced quantity of flow resulting from loss of air through successive, upstream vents, the plenum is tapered. This construction provides for movement of air through the plenum at constant velocity as previously mentioned. Since the outlets are of equal area the quantity of flow through each of the vents is identical.

By this arrangement the need for a static pressure plenum is eliminated and there is provided a balanced, air-distributing system of extreme compactness and one capable of achieving uniform air distribution.

To permit cooling of the page in both its closed and opened position, the page is supported on a rotary L-shaped casing 56 journaled in the floor of the unit. Constructional details of this arrangement are shown in FIGURE 4.

As seen in that figure the page frame 24 is bolted to a circular plate 60 welded to the casing 56, for rotation therewith. The lower portion of the casing terminates in a flanged collar 62 provided with a depending journal member 64. A bronze support bearing 66 is positioned within an opening provided in the floor of the unit and is secured thereto by bolt means 70. Positioned between flanges 72 and 74 of the bearing and journal members respectively, is a bronze thrust washer 76 designed rotatively to carry the full weight of the page assembly. Interposed in a connection between the fitting 82, secured to the bearing 66, and the outlet scroll 83 of blower 44, is a flexible duct 84 desirably made of low-temperature resistant neoprene on fiberglass fabric. The ends of the flexible duct are secured to the fitting 82 and blower 44 by means of a worm-gear clamp 86, only the upper connection being shown. By this arrangement cooling of the page can be carried out using a blower fixedly secured within chamber 21 without adversely affecting the compactness of the paginated electronic packaging.

To provide a more rigid unit the frame 88 of the central page of the processor, see FIGURE 3, is fixedly secured to the cabinet structure. This page remains fully accessible since the flanking pages are pivotally mounted in the manner above described.

FIGURE 3 is a plan view of the computer assembly showing pages in their closed position. The page immediately adjacent the fixed frame 88 is pivotable into a position which places the leading edge 90 of its cooling plenum 22 in contiguous relation to the plenum carried by the fixed frame 88. The air cooling systems of the two pages act selectively and cooperably to direct streams of air upwardly through the columns 52 formed by the tiers

of modular printed wiring assemblies 20. The PW assemblies have only been shown in selected locations for clarity of illustration. To permit venting of the heat-laden air in its movement upward over the page the top of the unit is provided with an open metal grid work 92.

The outermost page, as seen in FIGURE 3, acts in cooperation with the foldable front cover 94 to form a series of partially sealed channels. In those assemblies employing an even number of pages the face-to-face arrangement previously described can be employed while in arrangements using uneven numbers of pages the alternative construction of using the unit covers provides an equally satisfactory arrangement for sealed operation.

As seen in FIGURES 1 and 2 air is drawn into the unit by way of the louvered opening 100 provided in the front face of the base chamber 102 through an air filter 104. Air passes through this filter into the eye 106 of the blower 44 and is expelled from the blower scroll 83 through the flexible duct 84 and vaned casing 56 into the tapered duct 22. The pattern of air distribution achieved by this arrangement is diagrammatically shown by arrows in FIGURE 2. As previously explained the quantity of air coming from each of the discharge vents 54 is identical and results in uniform cooling of the page assembly. Furthermore, by resort to this constructional arrangement, cooling may be maintained regardless of page position. When the page is in the open position, such for example, as the position of the two foremost pages shown in FIGURE 1, the air washes out about midway up the page. This mode of operation however is effective in preventing overheating of the page as a result of the turbulence created by spillage of air from and over lower surfaces of the page. Since the heat generated in the lower half of the page is removed without rising over the components positioned at higher elevations, satisfactory operation in the open position can be maintained in an ambient atmosphere as high as 80° F.

To provide a better understanding of the cooling system comprising the present invention, each page of electronic apparatus shown in FIGURE 1 is approximately 4 ft. x 4 ft. in area and contains as stated over 1600 printed wiring panels. The panels in the illustrated example are substantially identical both in construction and in their heat generating capabilities, each printed wiring module generating about .2 of a watt, or in the aggregate producing a heat load of over 400 watts per page inclusive of the heat introduced into the system by the blower itself. To facilitate cooling, the panels 20 are arranged in tiers of vertical oriented columns to provide for unobstructed movement of air through panel-formed channels 52.

Given a temperature range which is not to be exceeded, such for example as an 8° C. rise over the temperature of the ambient atmosphere, and assuming an operating ambient temperature of 27° C. (80° F.), the quantity of air required, based on an 80% operating efficiency, can be readily computed. Based on the above conditions the air required to cool a page of electronic equipment of the type described is approximately 120 c.f.m. By resort to the unique constructional features described, the static pressure of the air distributing system can be kept below about .45 inches of water. Given these desired performance characteristics a centrifugal blower of something less than 10 inch diameter capable of delivering 150 c.f.m. at a static pressure of 0" of water and 100 c.f.m. at a static pressure of 1" of water operating on a 60 cycle single phase 115 volt A.C. system was found to provide satisfactory operation.

To keep noise at a minimum, and to stay within the practical limits of fan power, a main duct velocity of 2000 ft./min. was selected.

The packaging arrangement shown results in the formation of 84 channels through which air is to be selectively directed. To provide for a uniform distribution of air through these channels the duct is tapered in the manner

previously described, and provided with 84 air vents of equal area along its length. To handle a flow rate of 130 c.f.m. at a velocity not in excess of 2000 feet per minute requires each air vent to have an outlet area of about .117 inches². To provide for most effective cooling each air vent is centered between adjacent panels and is of a width not exceeding panel spacing. This arrangement is best seen in FIGURE 3. To comply with these requirements the outlet size was made $\frac{3}{16}$ " wide by $\frac{5}{8}$ " long. As mentioned before to maintain a balanced flow and to prevent restriction of the air stream, the inlet and outlet areas are made substantially equal. Given an inside height dimension of 4" and a width of $2\frac{1}{2}$ " at the inlet side 108 of the duct, the duct is uniformly tapered throughout its length of 34 inches to a height of about $\frac{1}{2}$ " in the tip area. The minimal height of the duct in the tip area must be something less than a feather edge to avoid excessive frictional losses in the downstream end of the duct. There is a critical ratio of duct perimeter surface to cross-sectional area below which it is not desirable to go if losses are to be kept at a minimum. This critical ratio is empirically determined and in the illustrated example was found to occur in ducts having a rectangular cross section of a dimension less than approximately $\frac{1}{2}$ inch by $2\frac{1}{2}$ inches.

A unit employing the air cooling system described, when in the completely sealed condition experiences a temperature rise of something less than 7° C. which is well within the assumed design requirements.

The central fixed page of the unit, which carries the memory-control circuits, has a heat output which is three times greater than that of the other pages. Because of the fixed nature of this page it is serviced by a rigidly mounted blower 110 which is of substantially greater size than those needed for cooling the other pages. The balance of the air distributing system which serves this page is the same as that already described with the exception that no transitional bearing duct is required. To aid in disassembling the system and in repairing the duct it is detachably secured to the page by metal screws not shown and to the rotary casing by means of duct clamps 112.

In summary, there is provided an air distributing system of extreme compactness and one which is particularly adapted for use with paginated electronic apparatus and which is effective in providing a uniform distribution of air over the entire surface undergoing treatment. Moreover, this uniform distribution of air is achieved without resort to previously required high-pressure plenums and their attendant disadvantages—such as providing an air-tight duct—and by a unique combination of features is made available to pivotable electronic assemblies using fixed, air-moving equipment.

Although the invention has been described with particular reference to specific practice and embodiments, it will be understood by those skilled in the art that the apparatus of the invention may be changed and modified without materially affecting the invention as defined in the appended claims.

We claim:

1. A forced-air cooling system for use with a pivotable page of electronic apparatus of the type described, comprising: air-moving means; an air discharge plenum constructed and arranged for pivotal movement with said page; and apertured bearing means supportive of said page assembly and interposed in a connection permitting pivotal movement between said air-moving means and plenum and providing an air communicating passageway therebetween.

2. A forced-air cooling system for use with a pivotable page of electronic apparatus of the type described, comprising: air-moving means; an elongate discharge plenum mounted for movement with said page and containing a series of discharge vents along a surface thereof and said plenum having a configuration producing a substantially uniform discharge of air from each of said vents; and

means interposed in a connection between said air-moving means and said plenum permitting their relative movement and providing an air-communicating passageway therebetween.

3. A forced-air cooling system for use with a pivotable page of electronic apparatus of the type described, comprising: fixed air-moving means; a multiported air-discharge plenum mounted for pivotal movement with said page; and apertured bearing means supportive of said page assembly interconnected in air-conducting relation between said air-moving means and plenum and constructed and arranged to permit relative movement therebetween.

4. A forced-air cooling system for use with a pivotable page of electronic apparatus of the type described, comprising: air moving means; an air-discharge plenum mounted for pivotal movement with said page and having a plurality of air discharge vents of equal size provided along its length adapted to direct individual streams of air over said apparatus, and said plenum being configured to provide a uniform distribution of air from each of said vents; and apertured bearing means supportive of said page assembly interposed in a connection permitting pivotal movement between said air-moving means and plenum and providing an air-communicating passageway therebetween.

5. Forced-air cooling apparatus for use with a pivotable electronic page assembly of the type described, comprising: air-moving means; an air discharge plenum mounted for pivotal movement with said page assembly and having a plurality of discharge vents of substantially equal size along one surface thereof adapted to deliver streams of air over said page assembly, and said plenum being tapered in the direction of air flow to provide uniform discharge of air from each of said vents; and bearing means supportive of said page assembly and interposed in pivotal connection between said air-moving means and duct and constructed to provide an air communicating passageway therebetween.

6. The combination comprising: a pivotable page of components arranged in channel-forming tiers; air-moving means; duct means secured to said page for pivotal movement therewith having a plurality of equal-size vents disposed along a page-confronting surface thereof adapted to deliver individual streams of air through said tier-formed channels; and means supportive of said page assembly pivotally interconnecting said air-moving means and duct means in air flow communication.

7. A forced-air cooling system for use with a pivotable page of electronic apparatus of the type described, comprising: air-moving means; an elongate discharge duct movable with said page and containing a series of discharge vents adapted to deliver individual streams of air over said apparatus and said duct having a tapered configuration producing a substantially uniform discharge of air from each of said vents; and means interposed in connection between said air-moving means and said duct permitting their relative movement and providing an air-communicating passageway therebetween.

8. The combination comprising: a pair of pages of electronic apparatus, of the type described, at least one of which is pivotable into substantially closed, confronting relation with the other of said pages, each containing components arranged in aligned channel-forming tiers; elongate duct means secured to an edge portion of each of said pages for movement therewith and said duct means having a plurality of substantially equal-size vents disposed along a surface thereof adapted to deliver individual streams of air over its associated page assembly and said ducts having a configuration providing for substantially uniform discharge of air from each of said vents; air-moving means associated with said duct means; apertured bearing means supportive of said pivotable page assembly interposed in a connection permitting pivotal movement between said air-moving means and duct and

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providing an air-communicating passageway therebetween; and said pages when in closed position forming, through cooperative alignment of confronting components on each of said pages, a plurality of discrete channels, and said ducts abutting to form a composite air-discharge system of aligned pairs of air vents for delivery of confluent streams of air through individual ones of said channels.

9. The combination comprising: a pair of page assemblies of electronic apparatus, of the type described, at least one of which is pivotable into substantially closed confronting relation with the other of said page assemblies, and each containing components arranged vertically aligned; elongate duct means mounted for movement with each of said page assemblies and having a plurality of substantially equal-size vents disposed along its length for delivery of individual streams of air over its associated page assembly, said duct means further hav-

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ing a tapered configuration providing for substantially uniform discharge of air from each of said vents; air-moving means associated with said duct means; means interposed in a connection between said air-moving means and duct means permitting their relative movement and providing an air-communicating passageway therebetween; and said page assemblies in closed position forming, through cooperative alignment of confronting components on each of said pages, a plurality of discrete, vertically-running channels and said ducts forming a composite air-discharge system of aligned pairs of air vents for delivery of confluent streams of air through individual ones of said channels.

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