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CONDUCTION COOLED RECTIFIERS

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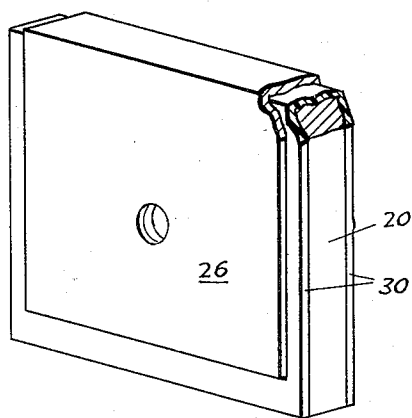
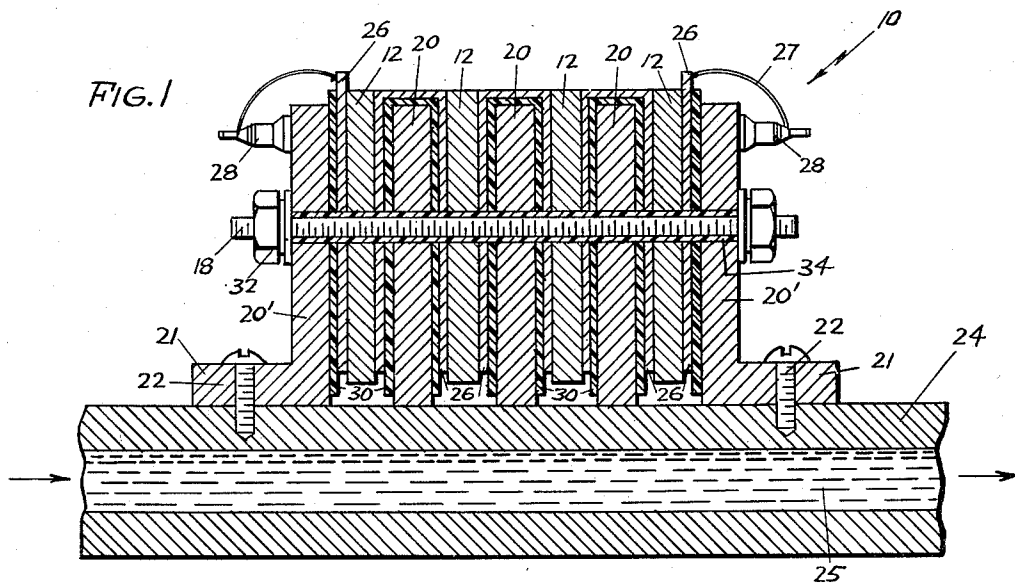


FIG. 3

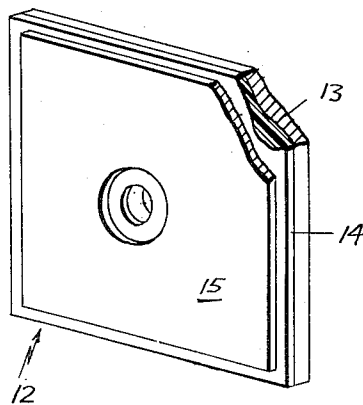


FIG. 2

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CONDUCTION COOLED RECTIFIERS

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This invention relates to a rectifier of the dry surface contact type and, more particularly, relates to means for readily dissipating heat generated in such a rectifier by conduction through several thermally-conductive members forming part of the rectifier assembly.

Rectifiers of the dry contact type have superseded vacuum tube and mechanical rectifiers in many electronic applications, not only because of the lack of moving parts and materials or elements requiring maintenance and renewal, but also because of the simplicity of design and light weight. The operation of such dry contact rectifiers is based upon the fact that certain combinations of thin contacting metallic films are capable of permitting electron flow more readily in one direction, often referred to as the forward direction, than in the other or reverse direction. Selenium and copper oxide are but two examples of rectifiers of the dry contact type now widely utilized in the electronics field. Junction diode rectifiers using semi-conductors, such as germanium or silicon, are also finding use in electronic equipment.

The practical dry contact rectifier comprises a stack of individual rectifier discs or elements, each constituting in itself an elemental rectifier. The number of discs used, as well as the disc size, depends upon the equipment rating. The power rating of such a rectifier is a function of the effective rectifying area, and is limited by the maximum permissible temperature rise within the rectifier.

Many of the dry contact rectifiers now used include a metallic layer, such as selenium, positioned between a rigid back electrode and an alloy serving as a front electrode. The metallic layer and alloy combine to form a rectifying device which permits current to flow freely from the metallic layer to the front electrode, but which offer a relatively high resistance to the flow of current in the opposite direction. Alloys which are suitable for use in rectifiers, however, are characterized by a relatively low melting point, thereby precluding the use of dry contact rectifiers of the usual construction in high current devices where operating temperature is correspondingly high. Dry contact rectifiers also undergo a deterioration in the form of a change in crystal structure of the metallic layer at elevated temperatures, and such deterioration increases very rapidly with temperature. For these reasons, therefore, it is essential that the operating temperature of the rectifier be kept reasonably low.

The present trend in electronic equipment design is towards increasingly smaller sized components, especially in airborne applications where space and weight must be kept to a minimum. In the present state of the art, it is necessary, in order to avoid overheating or burning out of dry contact rectifiers of large power rating, that they be made sufficiently large that the mass can transmit a substantial portion of the heat generated within the rectifier to an ambient region external thereto and so that the surface area of the component is sufficiently large to accomplish satisfactorily heat transfer by convection and radiation. Dry disc rectifiers are normally air-cooled de-

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vices in which heat transfer is accomplished by convection. Prior methods of cooling rectifiers, such as spacing of individual rectifier elements further apart by washers, or subjecting the rectifier to forced draft ventilation, are unsatisfactory for rectifiers which must satisfy the requirements of both high power rating and small size and weight, since these prior methods necessitate increasing the physical dimensions and weight of either the rectifier or its associated cooling equipment, or both.

In accordance with this invention, a dry contact rectifier of increased power output for a given size and weight is achieved by introducing highly conductive thermal paths into the rectifier so that the heat is transferred by conduction away from the portions of the rectifier where it is produced directly to a heat sink, such as a heat dissipative base structure of comparatively large surface area. This dissipative structure may, in turn, be cooled by a fluid coolant flowing in contact therewith. The temperature rises, for a conduction-cooled rectifier according to the invention, may be limited to approximately 10° Centigrade between the hottest spot in the rectifier and the temperature of heat dissipative structure.

One advantage of the conduction-cooled rectifier is that it can be used in equipments where there is insufficient cooled air for adequate convection cooling. This is often the condition in aircraft equipment where small size is essential and where the equipment must be sealed against foreign matter and moisture. In such cases it is necessary to remove the heat from the regions within and immediately surrounding the enclosure to avoid destruction of the equipment within the enclosure, as well as associated equipment located nearby. By means of a fluid cooled base structure, heat may be carried away to a region relatively remote from the heat source.

Referring to the drawing:

Fig. 1 is a central cross-sectional view of an embodiment of a conduction cooled dry contact rectifier with certain portions thereof exaggerated for the sake of clarity;

Fig. 2 is a view illustrating a typical construction of a rectifier element used in the device of Fig. 1; and

Fig. 3 is a view illustrating a wrapped cooling plate such as used in the device of Fig. 1.

The dry disc rectifier 10 of the subject invention includes a plurality of individual discoidal rectifier elements 12, each of which are capable of passing current in one direction much more readily than in the opposite direction. One type of rectifier element is shown in Fig. 2 and includes a backing plate 13 which may, for example, be constructed of iron or aluminum and which serves as a mechanically rigid back electrode. A semi-conductive layer 14 of material, such as selenium in the amorphous form, is deposited by any of several well known processes on one side of backing plate 13; this layer must be thin enough to provide minimum internal losses, but sufficiently thick to withstand reasonable inverse voltages. The selenium-coated plate is then subjected to suitable heat treatment to change the selenium layer from a relatively nonconductive state to a conductive crystalline form. A counterelectrode 15 having a low electrical resistance is then applied to the selenium surface, which may, for example, be an electrically conductive alloy of low melting point, such as an eutectic alloy containing tin. Such low melting point alloys have proven feasible for counterelectrode 15, since they may be deposited readily on the layer 14 without damaging the latter. Counterelectrode 15 preferably is of slightly smaller area than that of the selenium layer and back electrode so that the edges of the counterelectrode, including the annular edge adjacent the aperture, are spaced slightly from the edges of the selenium layer and back electrode. Certain lacquers may

be applied if desired to the selenium layer before application of the counterelectrode, thus obtaining an increased rectification ratio. The resultant rectifier element 12 is capable of passing current from back electrode 13 through the selenium coating 14 but offers high resistance to the flow of current through the selenium coating to the back electrode 13. The invention, however, is not limited to rectifiers including selenium; any rectifying element 12 may be used, such as copper oxide, or germanium junction.

The apertured rectifier elements 12 are stacked together by longitudinally extending supporting rod 18 and mounted between end cooling plates 20' provided with flanged portions 21 attached as by screws 22 to a heat dissipative base structure 24. The latter is a heat transfer medium of large surface area and made of a material, such as aluminum or copper, having a high thermal conductivity. As shown in Fig. 1, base structure 24 may be hollow in order to accommodate a circulating fluid coolant 25, thereby increasing the heat transfer capabilities of the structure over that of a solid structure not so cooled. Alternately, the structure 24 may be a solid plate of enlarged surface area to which fluid conduits are secured.

Cooling plates 20 of high thermal conductivity are inserted between adjacent rectifier elements 12 and, like the latter, are apertured to fit over supporting rod 18. Cooling plates 20 preferably are made of aluminum, which not only is of light weight, but also has a very high thermal conductivity.

The individual rectifier elements 12 are interconnected in series electrically by means of electrically-conductive sheets 26 positioned in direct contact with the major surfaces of the rectifier elements. Sheets 26 are preferably made of copper which, because of its high electrical conductivity, permits the use of relatively thin sheets even at high rectifier current ratings. The end sheets of copper foil 26 at opposite ends of rectifier assembly 10 are connected by short electrically-conductive leads 27 to output terminals 23 insulatedly mounted on the end cooling plates 20'. Conductive sheets 26 not located at the ends of the rectifier assembly are preferably of U-shaped configuration, which are fitted over a corresponding cooling plate 20 with a looped portion of said sheet wrapped over the top edge of the cooling plate, as shown clearly in Fig. 3. The ends of each sheet 26 are set back from the lower edge of cooling plate 20 so as to avoid a short circuit between rectifier elements 12 and dissipative base structure 24.

Since cooling plates 20 are excellent electrical conductors, as well as good conductors of heat energy, it is necessary to electrically insulate sheets 26 interconnecting the various rectifier elements and, hence, the rectifier elements themselves, from cooling plates 20 lest the rectifier discs become electrically shorted through the cooling plates and heat dissipative structure. This is accomplished by means of electrically insulating spacers 30 in the form of sheets inserted between electrically-conductive sheets 26 and cooling plates 20 and having the same general configuration as sheets 26 but of slightly larger area. The endmost spacers 30 are substantially rectangular, while the remaining spacers are preferably U-shaped and adapted to fit over the cooling plates in the same manner as sheets 26. Spacers 30 may be made of any sheet material having good electrically insulating and mechanical properties as well as a sufficiently large thermal conductivity. Materials reasonably satisfying these requirements include asbestos paper, polytetrafluorethylene, glass cloth impregnated with either silicon rubber or thermoplastic resins. Although the requirements of low electrical conductivity and high thermal conductivity are somewhat incompatible, the area of proximity of the rectifier elements and cooling plates is so large that effective heat transfer can be attained even though the insulating spacers may be of comparatively low thermal conductivity.

Because of the similarity in construction of the rectifier disc interconnecting means 26 and insulating spacers 30, it is not only feasible but preferable to use a laminated construction in which an electrically-conductive material, such as copper, is fixedly deposited on, or molded into, the surface of an electrically insulated layer of thermoplastic material by any one of several well known techniques, such as those employed in formation of printed circuits. The portion of the conductive material adjacent the edges of the insulating layer may be etched away in order to insure adequate electrical insulation between rectifier elements 12 and the thermally-conductive portions of rectifier assembly 10.

The entire assembly or stack of apertured elements, including rectifier plates 12, cooling members 20, rectifier disc interconnecting layers 26, and insulating layers 30, is clamped tightly together by means of nuts 32 threadedly engaging the ends of rod 18, thereby providing a high thermal conductivity between the rectifier discs and the cooling plates, and providing a compact unit which is comparatively insensitive to shock and vibration. The rectifier discs are electrically insulated from rod 18 by means of a sleeve 34 surrounding said rod, and made of fiber or other suitable insulating material.

An alternative method of constructing rectifier assembly 10 consists of anodizing the cooling members 20 so as to form thereon a mechanically strong, electrically insulating film. An electrically insulating coating, such as a thermosetting plastic or vitreous enamel, may also be applied directly to both sides of each cooling member 20 by any one of several available coating techniques. The means for interconnecting the individual rectifier elements may consist of a layer of electrically conductive material, such as copper, sprayed or otherwise applied to both sides of the insulatedly coated cooling member.

Furthermore, inasmuch as the back electrodes 13 of rectifiers of the selenium type serve only to provide a rigid supporting means during application of the rectifier layers and are of no practical value thereafter, it is possible to utilize the coated cooling member 20 as a back electrode for rectifier elements 12, that is, to apply the rectifier coating 14 and counterelectrode 15 directly to the coated cooling member 20. In this way, the entire rectifier stack may consist of a series of identical plates, each combining the properties and functions of a cooling member, an electrically insulating spacer, an electrically conductive rectifier interconnecting means and a rectifier element, and thereby facilitating construction and assembly of the conduction cooled rectifier stack.

Although the various elements of the rectifier assembly, as indicated in the drawing, are square, the rectifier is not necessarily limited to this configuration. For best utilization of a given space, rectangular or square rectifier plates are preferable to circular plates; furthermore, the cooling plates which contact the flat heat dissipative base structure should have squared edges at the point of contact with said base structure for adequate cooling.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. In combination, a plurality of electrically interconnected discoidal electronic rectifying elements, a heat dissipating structure having a single major mounting surface whose area and thermal conductivity are large as compared with the area and thermal conductivity, respectively, of said elements, a multiplicity of thermally conductive cooling members electrically insulated from and disposed between adjacent ones of said rectifying elements, all of said cooling members having a portion me-

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chanically contacting said single mounting surface of said structure, said cooling members further being in substantial thermally conductive relationship with said mounting surface and said rectifying elements for conducting heat from said rectifying elements to said heat dissipating structure.

2. In combination, a plurality of electronic rectifying elements, a multiplicity of thermally conductive cooling members of relatively high thermal conductivity compared with that of said rectifying elements disposed in heat conductive relationship with adjacent ones of said rectifying elements, electrically conductive means for electrically interconnecting said rectifying elements, electrically insulating means for electrically insulating said cooling members from said rectifying elements and said electrically conductive means, a thermally conductive heat dissipating structure, and means including the endmost cooling members for mounting said cooling members in substantial mechanical and thermal contact with said heat dissipating structure and for insulating said rectifying elements and electrically conductive means from said structure.

3. In combination, a plurality of electronic rectifying elements, a multiplicity of thermally conductive cooling members of relatively high thermal conductivity compared with that of said rectifying elements disposed in heat conductive relationship with adjacent ones of said rectifying elements, electrically conductive means for electrically interconnecting said rectifying elements, electrically insulating means for electrically insulating said cooling members from said rectifying elements and said electrically conductive means, a thermally conductive heat dissipating structure whose surface area is large as compared with that of said elements and members, and means for mounting said cooling members in substantial mechanical and thermal contact with said heat dissipating structure and for insulating said rectifying elements and electrically conductive means from said structure.

4. In combination, a plurality of electronic rectifying elements, a multiplicity of thermally conductive cooling members of relatively high thermal conductivity compared with that of said rectifying elements disposed in heat conductive relationship with adjacent ones of said rectifying elements, electrically conductive means for electrically interconnecting said rectifying elements, electrically insulating means for electrically insulating said cooling members from said rectifying elements and said electrically conductive means, said electrically conductive means and said electrically insulating means consisting of a unitary laminate, a thermally conductive heat dissipating structure whose surface area is large as compared with that of said elements and members, and means for mounting said cooling members in substantial mechanical and thermal contact with said heat dissipating structure and for insulating said rectifying elements and electrically conductive means from said structure.

5. In combination, a plurality of discoidal electronic rectifying elements, a multiplicity of thermally conductive cooling members of relatively high thermal conductivity compared with that of said rectifying elements inserted between adjacent ones of said rectifying elements, electrically conductive means for electrically interconnecting said rectifying elements, insulating means for electrically insulating said cooling members from said rectifying elements and said electrically conductive means, a thermally conductive heat dissipating structure whose surface area is large as compared with that of said

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elements and members, means for mounting said cooling members in substantial mechanical and thermal contact with said dissipating structure and for insulating said rectifying elements from said structure, said electrically conductive means and insulating means forming a thermally conductive path between said rectifying elements and said cooling members.

6. In combination, a plurality of electronic rectifying elements, a multiplicity of thermally conductive cooling members of relatively high thermal conductivity compared with that of said rectifying elements inserted between adjacent ones of said rectifying elements, electrically conductive means for electrically interconnecting said rectifying elements, insulating means for electrically insulating said cooling members from said rectifying elements and said electrically conductive means, said rectifying elements, cooling members, electrically conductive means and insulating means forming a continuous stack, a thermally conductive heat dissipating structure whose surface area is large as compared with that of said rectifying elements, said cooling members mechanically and thermally contacting said dissipating structure, said cooling members, electrically conductive means and insulating means forming a thermally conductive path between said rectifying elements and said heat dissipating structure for removal of heat from said elements.

7. In combination, a plurality of electronic rectifying elements, a multiplicity of thermally conductive cooling members of relatively high thermal conductivity compared with that of said rectifying elements disposed in heat conductive relationship with adjacent ones of said rectifying elements, electrically conductive means for electrically connecting said rectifying elements in series, means for electrically insulating said cooling members from said rectifying elements and said electrically conductive means, a thermally conductive heat dissipating structure whose surface area is large as compared with that of said elements and members, and mounting means for maintaining said elements, members, electrically conductive means and insulating means in mechanical contact under pressure, said cooling members being in substantial mechanical and thermal contact with said heat dissipating structure.

8. In combination, a plurality of electrically interconnected electronic rectifying elements, a heat dissipating structure having a single major mounting surface whose area and thermal conductivity are large compared with the area and thermal conductivity, respectively, of said elements, a multiplicity of thermally conductive cooling members electrically insulated from and disposed between adjacent ones of said rectifying elements, all of said cooling members having a portion mechanically contacting said single mounting surface of said structure, said cooling members further being in substantial thermally conductive relationship with respect to said mounting surface, and means including a supporting rod having an electrically insulated periphery and passing through said rectifying elements and said cooling member, said rectifying elements and said cooling members combining to form a compact assembly, said endmost cooling members of said assembly being secured to said structure.

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