HERMETICALLY SEALED RECTIFIER

Filed May 27, 1957

3 Sheets-Sheet 1

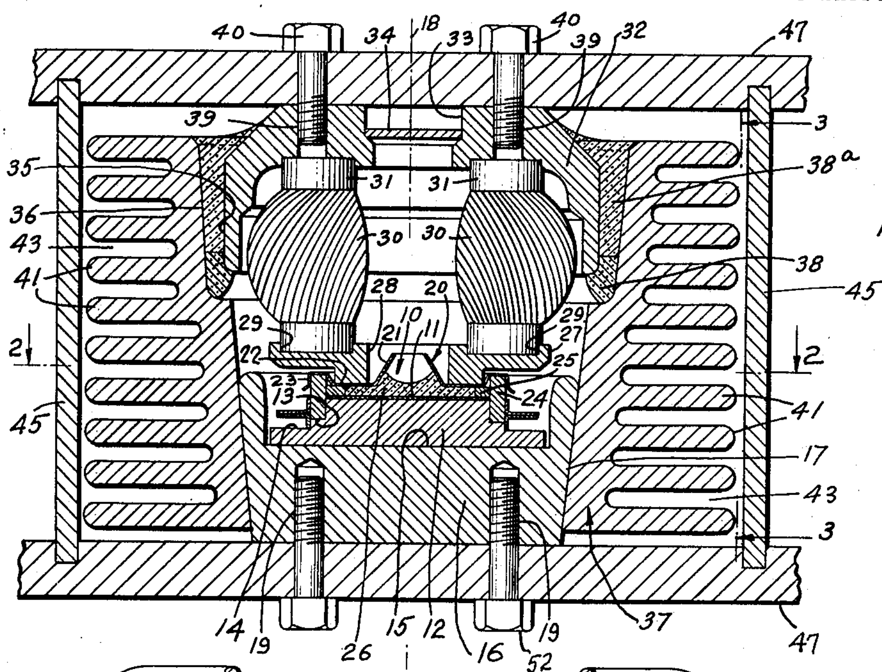

FIG. 1.

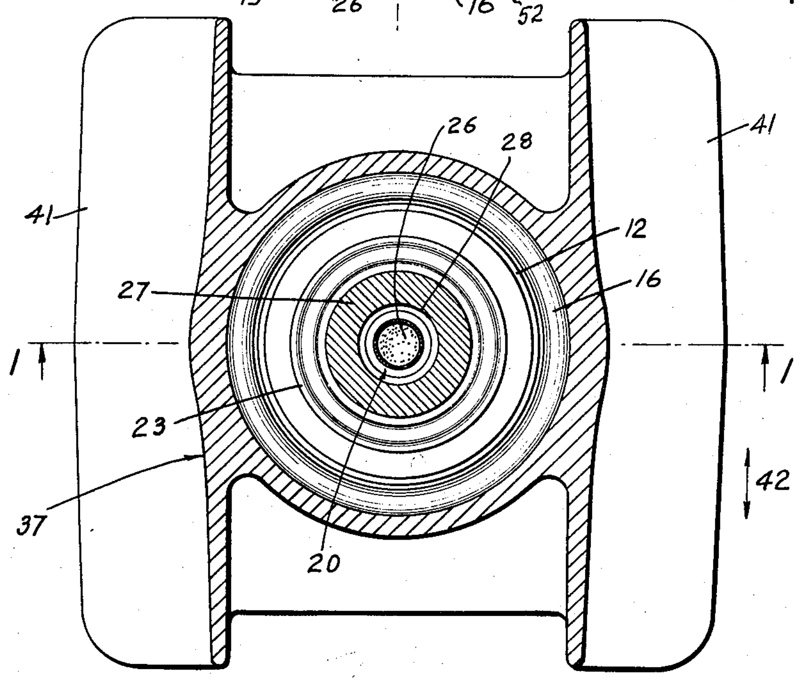

FIG. 2.

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Oct. 20, 1959 E. J. DIEBOLD 2,909,714

HERMETICALLY SEALED RECTIFIER

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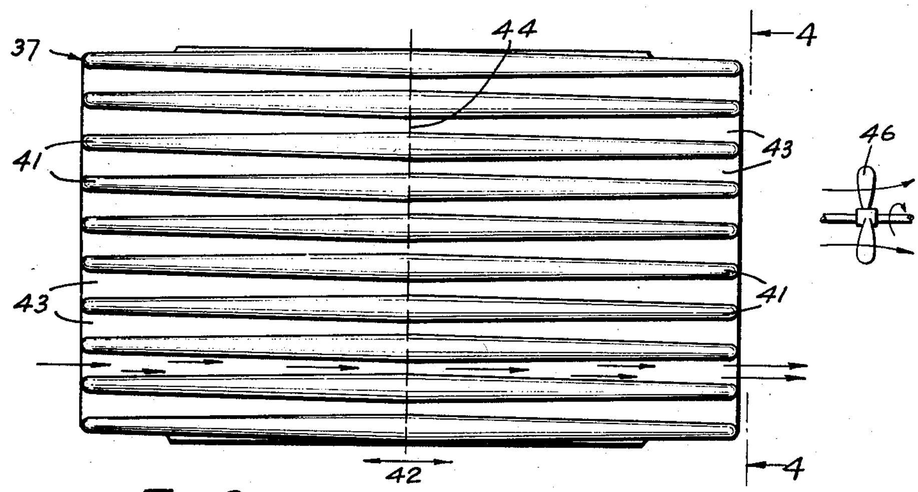

FIG. 3.

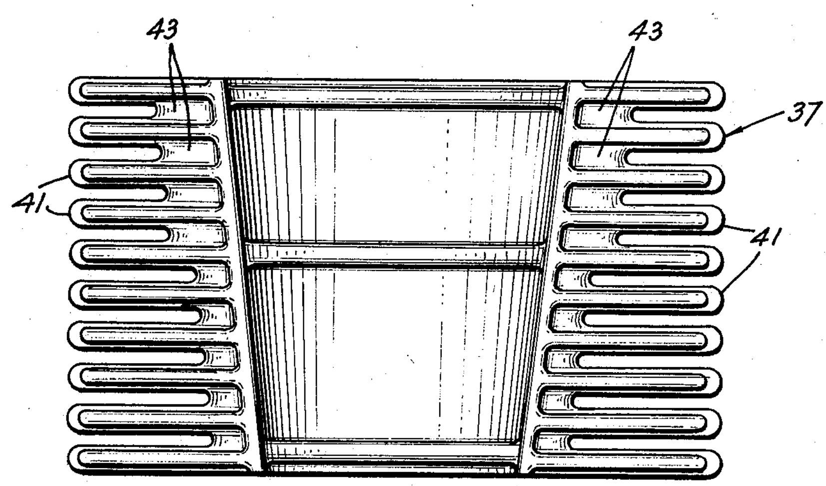

FIG. 4.

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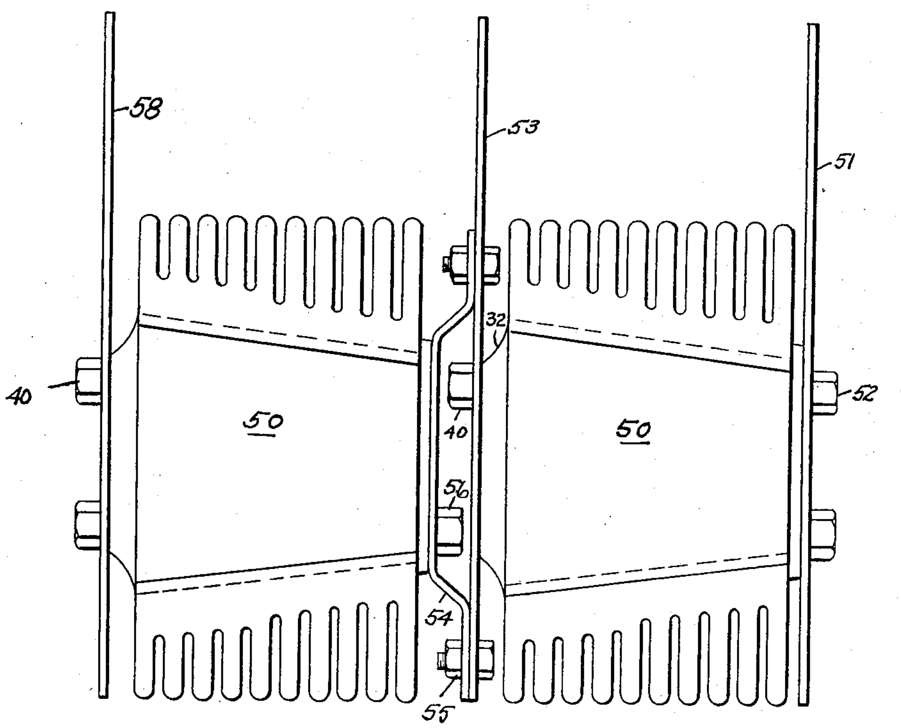
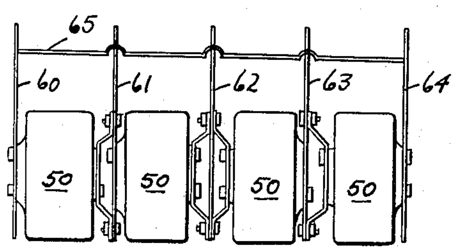


FIG. 5.

FIG. 6.



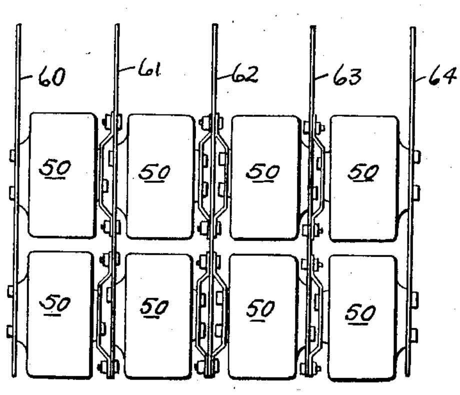


FIG. 7.

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HERMETICALLY SEALED RECTIFIER

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Application May 27, 1957, Serial No. 661,872

16 Claims. (Cl. 317—234)

This invention relates to electrical current rectifiers and to means for mounting and cooling the same.

An object of this invention is to provide a rugged but simple structure for mounting the rectifier which can also serve as means for cooling the rectifier and also for carrying electrical current.

A related object is to provide fin means on a housing for said rectifier wherein an optimum coolant fluid flow is created so as to provide efficient cooling of the aforesaid rectifier by heat transfer to the fluid.

According to one embodiment of this invention, a rectifier is mounted to a tapered base plug, which base plug is force-fitted into a housing whereby heat generated by the operation of the rectifier is conducted through the plug to the said housing for dissipation.

According to a preferred but optional form of this invention, a housing for such a rectifier is provided with fins for transferring the heat from the rectifier to a flowing coolant fluid such as air or some other gas. Adjacent fins on the housing create venturi sections by virtue of an initial inclination toward each other, and a subsequent divergence from each other, thereby creating a flow section for the coolant fluid which initially decreases and later increases in cross-section.

The above and other features of this invention will be fully understood from the following detailed description and the accompanying drawings, of which:

Fig. 1 is a side view, partly in cut-away cross-section, taken at line 1—1 of Fig. 2 of a rectifier assembly according to this invention;

Fig. 2 is a cross-section taken at line 2—2 of Fig. 1;

Fig. 3 is a cross-section taken at line 3—3 of Fig. 1;

Fig. 4 is a side view taken at line 4—4 of Fig. 3;

Fig. 5 is an elevation of a pair of rectifier assemblies connected to form part of a full-wave rectifier;

Fig. 6 is an abbreviated elevation of four rectifier assemblies connected to form a full-wave bridge rectifier; and

Fig. 7 is an abbreviated elevation of two bridges of the type shown in Fig. 6, connected in parallel.

In Fig. 1 there is shown a rectifier **10** having a wafer **11** of semi-conductive material such as a crystal of germanium or silicon which is soldered or otherwise conductively attached to a base plate **12**. This base plate has a pair of shoulders **13, 14** and a flat bottom that is conductively attached by soldering or other means to the bottom of a dished surface **15** in a base plug **16**. The base plug has a tapered outer wall **17** which taper is about 6 degrees to the central axis **18** of the plug; that is, a 12 degree conical angle. It is fitted by a press-fit into a centrally located interior opening or cavity of a housing **37** having a corresponding tapered conical interior wall. This base plug has threaded attachment holes **19** therein.

A mold **20** which is preferably made of a conductive nickel-iron alloy has a frusto-conical section **21** that is open at the top and a circular flange **22** which extends outwardly to form a hook section **23** which fits over an annular ring **24** that is made of ceramic or other insulating material. The annular ring **24** is seated on shoulder **13**. An annular washer **25** fits beneath the flange **22** and abuts tightly against the annular ring **24**. It will be seen that a mold space is provided inside the mold **20** and the annular ring **24**, above the wafer **11**. This mold space is filled with an activating material **26** such as indium, which activating material abuts against the wafer **11** to form a rectifying junction. As is evident from the drawing the mold is filled by pouring the indium into the mold until it rises into the frusto-conical section **21** so that there is a conductive connection between the wafer **11**, through the activating material **26** to the mold **20**.

An anode contact **27** has a central hole **28** therein for accommodating the frusto-conical section **21** so that the anode contact fits around the same, and bears down atop the flange **22**. This anode contact may conveniently be a ring having seats **29** for receiving the ferruled ends of flexible conductive cables **30**.

These flexible conductive cables **30** comprise a weak link in this structure, and have their second ferruled ends **31** attached to a terminal **32**. This terminal may conveniently be ring-shaped and have a central hole **33** therein which can be closed with a washer **34** when the construction of the assembly is completed. The terminal **32** has an outer wall **35** which projects downward into a cavity **36** inside the housing **37**, and is held in the housing by an insulating spacer comprising an insulating ring such as caulking compound **38** and an epoxy resin **38*a*** which are poured into the space between said housing and said terminal. The terminal is provided with threaded holes **39** for receiving mounting bolts **40**.

The housing **37** will now be described in further detail. As will be seen from Figs. 3 and 4, exterior fins **41** are provided on two opposite sides of the housing. These fins extend in a direction **42** which direction is parallel to the plane of Fig. 3 and perpendicular to the plane of Fig. 4. This housing is preferably cast from a high-conductivity aluminum alloy such as alloy F–4110 (SAE 303). The fins **41** have a length extending in the flow direction as indicated by arrow **42**, and the fins **41** are generally parallel to each other. They are also spaced from each other so as to leave a flow section **43** therebetween. This flow section varies in width from end to end along the length of the fins, having its greatest width at its ends, and its narrowest width at the center or medial position. It narrows down toward the center, and then broadens out on the other side. In addition, the flow section has a depth which varies from a greater depth at the left hand and right hand ends as seen in Fig. 3, to a minimum depth near the midpoint where the fins most closely approach each other. It will thereby be seen that at a plane **44**, there is a minimum flow section, the section increasing in both directions therefrom. Baffles **45** are installed adjacent to and in contact with the fins so as to close the flow sections. A fan **46** draws a coolant fluid such as air through the flow sections. End plates **47** complete the enclosure. If baffles **45** are made of insulating material, end plates **47** can be used for bus bars. The rectifier can be put into circuit by connecting the respective bus bars **47** into the circuit; for the terminal **32**, the cable **30**, the anode contact **27**, and activating material **26**, the semi-conducting material **11**, the base plate **12** and the base plug **16** are all serially electrically connected in the order named. Thus, the terminal **32** and the base plug **16** comprise contact means for connecting the electrical circuit through the rectifier. Since the upper bus bar **47** is connected with terminal **32** by bolts **40** and the lower bus bar **47** is connected to base plug **16** by volts **52**, it is apparent that the two bus bars **47** constitute the means for connecting the rectifier in the circuit.

Figs. 5, 6 and 7 show means for utilizing the rectifier assembly of Fig. 1. In uses of this type, the baffles **45** and end plates **47** can be dispensed with as shown, and a rectifier assembly **50** comprising the housing **37** and its contents is used. Suitable baffling can be devised and provided for the individual installations.

In Fig. 5, a first bus bar **51** is fastened by bolts **52** to the base plug **16** of a first rectifier assembly **50**. A second bus bar **53** is fastened to the terminal **32** by bolts **40**. An electrically conductive adapter **54** is held by fasteners **55** to bus bar **53**. The adapter is relieved at the center to clear the heads of bolts **40** and bolts **56**, which latter fasten a rectifier assembly **50** to the adapter. Bolts **40** attach a third bus bar **58** to terminal **32** of the second rectifier assembly.

Fig. 6 shows four rectifier assemblies **50** connected by adapter **59** to five bus bars **60–64**. Bus bars **61** and **63** may be appropriately connected to any desired A.C. source, and bus bars **60**, **62** and **64** provide D.C. terminals. Bus bars **60** and **64** are interconnected by a jump lead **65**.

Fig. 7 shows two rectifier bridges according to Fig. 6 connected in parallel by joining four additional rectifier assemblies **50** to bus bars **60–64**.

It will be seen that in the various embodiments shown above, the fins and baffles create a number of venturi sections on both sides of the housing. This arrangement provides for an optimum heat transfer to the coolant, utilizing blower power efficiently with only a modest pressure drop. In addition, the cooling system is rugged, and has few places where leakage could develop.

Air entering the flow sections **43** may have an initial low velocity. As the air progresses toward the midpoint **44**, it is speeded up, and after it passes by midpoint **44**, it slows down. However, at any point significantly removed from the ends of the flow sections, the air velocity is higher than its initial velocity. Inasmuch as the cooling effect of a fluid is proportional to the ¾ power of its velocity, this increase in velocity improves the cooling effect provided by a coolant under a given total pressure drop.

Furthermore, in this aerodynamically clean flow section, any net pressure drop is largely due to friction losses, and not to turbulence. Loss of pressure by friction results in optimum cooling. It will thus be appreciated that the fins shown provide an efficient use of blower power, and optimum heat transfer to a coolant fluid.

In addition, the mounting structure shown has other distinct advantages. A crystal-junction rectifier utilizing a germanium or silicon wafer is ordinarily quite small, often of the order of 0.75 in.^{2}. A considerable amount of heat is generated at this area, which, because of its relatively small size, has a high heat density. The operation of the rectifier is adversely affected by this heat unless it is dissipated fast enough to keep the rectifier from heating up.

In order to remove the heat from the germanium wafer as quickly as possible, a metal of high thermal conductivity, such as copper is used for the base plate **12** and base plug **16**. A metal such as copper quickly and effectively conducts the heat away from the germanium wafer. Even the solder attachment between the base plate and the wafer aids in dispersing the heat quickly.

The aluminum used in the housing is not as effective a heat conductor as copper, but it will be observed that the joint between the base plug and the housing has an area which is considerably greater than the area of the germanium. Furthermore, the area of this joint is less than the area of the fins. The area of the joint might conveniently be of the order of ten times greater than that of the wafer, and the fin area may be of the order of ten times the joint area so that there is sufficient joint area to handle the heat effectively even though the aluminum is a somewhat poorer conductor of heat than copper. This permits the housing to be made of the easily casted aluminum which is cheap and light and which is not corroded by anodic oxidation. Furthermore, aluminum has better heat transfer efficiency to coolant fluids such as air than copper does. The aluminum housing can therefore handle, and effectively transfer to the coolant fluid, the heat brought to it by the copper plug. This combination of metals gives a better ultimate heat transfer efficiency than a similar construction made only of copper or of aluminum.

The tapered press fit between the base plug and the housing has additional advantages, both in economy of assembly, and in the efficiency of heat transfer from the copper base plug to the aluminum housing. Previously known joints of this general type wherein two metals have been joined for heat conductivity have not ordinarily been successful, at least those which could be produced at a reasonable cost. Soldered joints for example do not work particularly well. A press fit of two carefully machined elements, while reasonably effective, is an expensive expedient.

In the device of this invention, the soft copper base plug need be machined to only a moderately smooth tapered surface. The aluminum housing can be die cast. Then the two can be pressed together in a hydraulic press or arbor, almost to the bursting point of the housing. This results in a plastic flow of copper into any surface irregularities of the aluminum, so that the copper assumes the shape of the aluminum cavity **36**. A joint results wherein a full metal-to-metal contact is made over the entire surface thereof.

This full metallic contact which is attained by pressing a soft metal into a hard metal is of considerable importance. Air gaps have heat conductivity of the order of only about $\frac{1}{10,000}$ that of metals. Such air gaps are substantially useless for heat dissipation, inasmuch as only a minuscule amount of heat can be conducted across them. If the joint between the plug and the housing has such gaps, however small, the over-all efficiency of the rectifier assembly will be adversely affected. The press-fit shown above which utilizes a soft and a harder metal, wherein there is some plastic flow of the softer metal into any irregularities in the harder metal, effectively eliminates any such air gaps.

This device also minimizes, almost to the point of elimination, any mechanical forces on the wafer **11** and its electrical connection. From a stress standpoint, the device comprises a substantially rigid link from the copper base plate through the copper plug, housing, insulating materials **38**, **38*a***, and terminal **32**. The connection to the upper side of the rectifier wafer is through the flexible cables **30**. Any movement of terminal **32** relative to the base plug will be quite slight, and would be occasioned by warping of the housing, or strong forces thereon, or perhaps by strong vibration. Many of these forces would be absorbed by the insulating material **38**, **38*a***. Such small movements as might occur will simply bend the flexible cable. The cable thus forms a "weak link" in the structure. Therefore the actual rectifying element in this device is substantially isolated from destructive mechanical forces.

The result of the above features is a rugged, self-contained, easily cooled rectifier of inexpensive construction. Furthermore, the rectifier is hermetically sealed.

In addition, this rectifier construction is amenable to a wide range of physical arrangements. Figs. 5–7 show three ways in which simple adapter plates can be utilized to join rectifier assemblies to create built-up circuit units. Stacks of this type fit compactly into small spaces, and permit the draft from one fan to cool many rectifiers simultaneously.

This invention is not to be limited by the embodiments shown in the drawings and described in the description, which are given by way of example and not of limitation, but only in accordance with the scope of the appended claims.

I claim:

1. A housing for mounting and cooling a current rectifier with forced fluid flow, said housing having a cavity for receiving said rectifier in thermal contact with said housing, said housing having protruding from it a plurality of exterior parallel cooling fins, said fins being separated into two groups, each group being spaced from the other on opposite sides of said housing, and comprising a plurality of said cooling fins, said fins extending lengthwise in substantially the same direction as the fluid flow, said fins being spaced from each other, the said spacing being lesser between adjacent fins at a medial position thereof than at the ends thereof along the length of the fins, whereby a fluid flow passage is formed between adjacent fins in the shape of a venturi section.

2. A rectifier assembly comprising a finned housing having a tapered cavity therein, a tapered base plug press-fitted into said cavity, a base plate mounted to said base plug, a rectifier comprising a wafer of semi-conducting metal applied to said base plate, a layer of activating material applied to said layer of semi-conducting material, an anode contact in conductive connection with said activating material, a terminal, an insulating spacer between said housing and said terminal for mounting said terminal in said cavity, a flexible conducting cable between said anode contact and said terminal, the terminal, cable, anode contact, activating material, semi-conducting material, base plate and base plug being serially electrically connected in the order named, whereby the terminal and the base plug comprise contact means for an electrical circuit through the rectifier.

3. Apparatus according to claim 2 in which the terminal, insulating spacer, and plug close the cavity.

4. Apparatus according to claim 2 in which an annular insulating washer is disposed atop the semi-conducting material and around the activating material, and the base plate has a shoulder, an annular insulating ring resting on said shoulder and surrounding said annular washer.

5. Apparatus according to claim 4 in which a conductive frusto-conical member having a flange on its larger end is disposed atop and in contact with the activating material, said flange being hooked over the said annular insulating ring, the anode block being in contact with said flange.

6. Apparatus according to claim 5 in which the plug is made of a softer metal than the housing.

7. A rectifier assembly comprising: a housing having a tapered cavity therein; a tapered plug force fitted into said cavity; a plurality of exterior parallel cooling fins on said housing which are spaced from each other, the said spacing being lesser between adjacent fins at a medial position thereof than at the ends thereof, whereby a coolant passage is formed between adjacent fins in the shape of a venturi section; a rectifier comprising a wafer of semi-conducting metal thermally and electrically conductively connected to said base plug; a layer of activating material applied to said wafer on its side opposite the base plug; an anode contact conductively connected to said activating material; an insulating spacer; a terminal supported by said spacer; the spacer being located between the housing and the terminal; and a flexible conductive cable interconnecting said anode contact and said terminal.

8. A circuit unit comprising a plurality of rectifier assemblies according to claim 7, an electrically conductive adapter physically and electrically interconnecting two of said rectifier assemblies, and bus bars disposed adjacent to and in conductive connection with the terminals and base plugs of said rectifier assemblies.

9. In combination, a rectifier, a housing for mounting and cooling said rectifier, said housing having a cavity for receiving said rectifier in thermal contact therewith, said housing having a plurality of exterior parallel cooling fins, said fins being spaced from each other, the said spacing being lesser between adjacent fins at a medial position thereof than at the ends thereof, whereby a coolant passage is formed between adjacent fins in the shape of a venturi section, said rectifier being fastened to a tapered plug, and said cavity having a matching taper, the plug being pressed into the cavity, whereby the rectifier, plug, and housing are in tight, thermally conductive connection so that heat from the rectifier is transferred to the fins.

10. Apparatus according to claim 9 in which the plug is made of softer metal than the housing.

11. Apparatus according to claim 9 in which the plug is made of copper and the housing is made of aluminum, the copper being softer than the aluminum.

12. A housing for mounting and cooling a current rectifier with forced fluid flow, said housing having a plurality of exterior parallel cooling fins, said fins being separated into two groups, each group being spaced from the other on opposite sides of said housing, and comprising a plurality of said cooling fins, said fins terminating at their tips, said fins extending lengthwise in substantially the same direction as the fluid flow, said housing being enclosed on each of said sides by a baffle plate, said baffle plates being adjacent to the tips of said cooling fins and mutually perpendicular to said fins and extending lengthwise in substantially the same direction as the fluid flow.

13. A housing in accordance with claim 12 wherein said baffle plates are made of insulating material.

14. A housing in accordance with claim 12 wherein said baffle plates are attached to two end plates, said end plates being parallel to each other and mutually perpendicular to said baffle plates, and extending in substantially the same direction as the fluid flow.

15. A rectifier assembly in accordance with claim 2 wherein an end plate is attached to said base plug and another end plate is attached to said terminal.

16. A housing in accordance with claim 13 wherein each of said baffle plates is in contact with said tips of fins whereby a maximum venturi effect results.

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