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(54) **EXPLOSION PROTECTED CIRCUIT BOARD ASSEMBLY**

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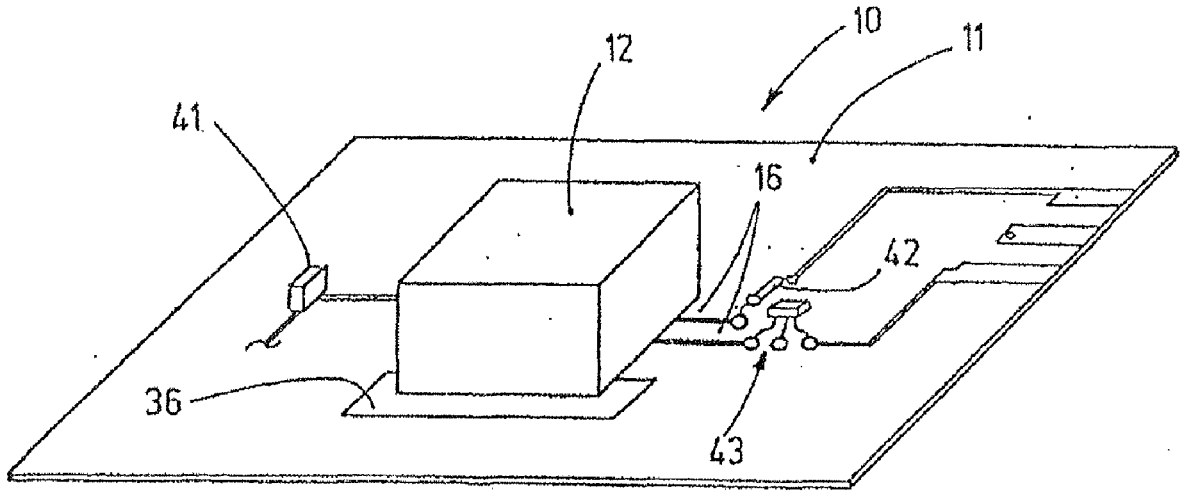
(57) **ABSTRACT**

An explosion protected circuit board assembly that includes a circuit board having a carrier plate with conductive strips and at least one electrical component thereon. The circuit board assembly includes a housing part that defines a hollow space encasing the electronic component in intrinsically safe fashion while preventing flame transmission from the electrical component to the outside environment. In an alternative embodiment, housing parts defining hollow electrical component receiving spaces are mounted on opposite sides of the circuit board, with the components being electrically interconnected.



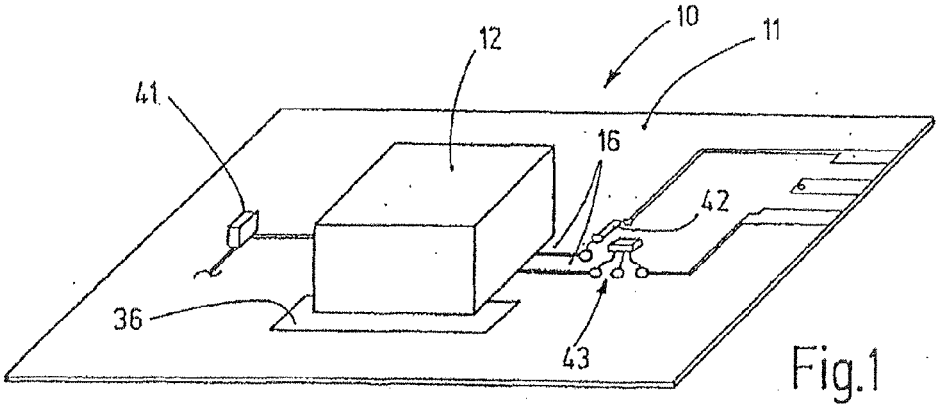


Fig.1

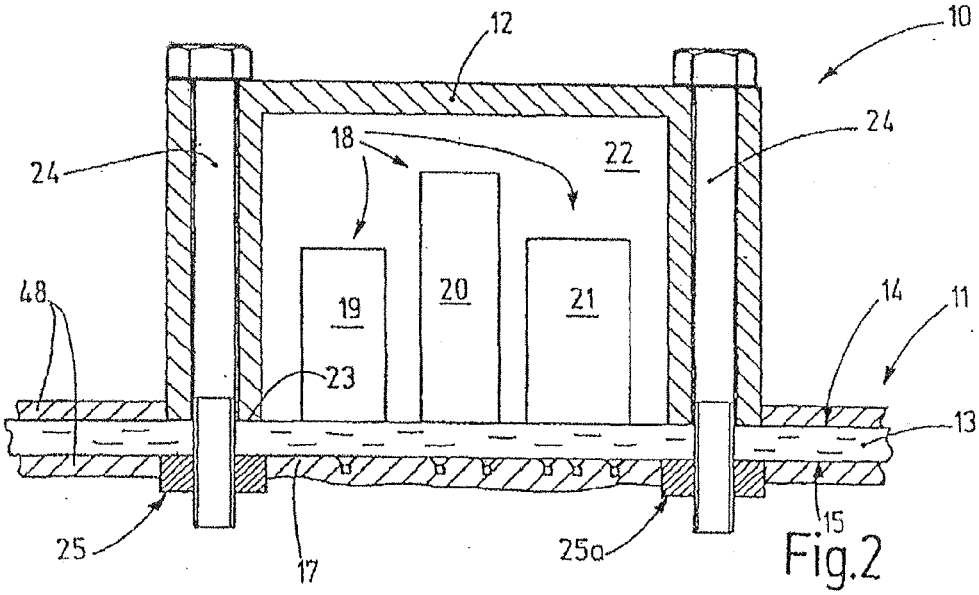


Fig.2

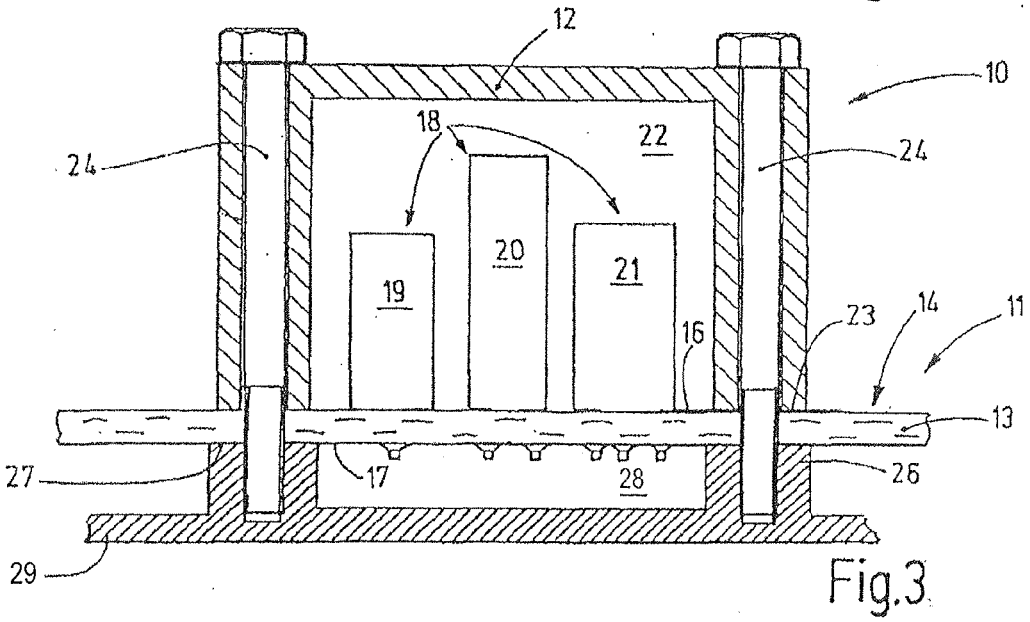


Fig.3

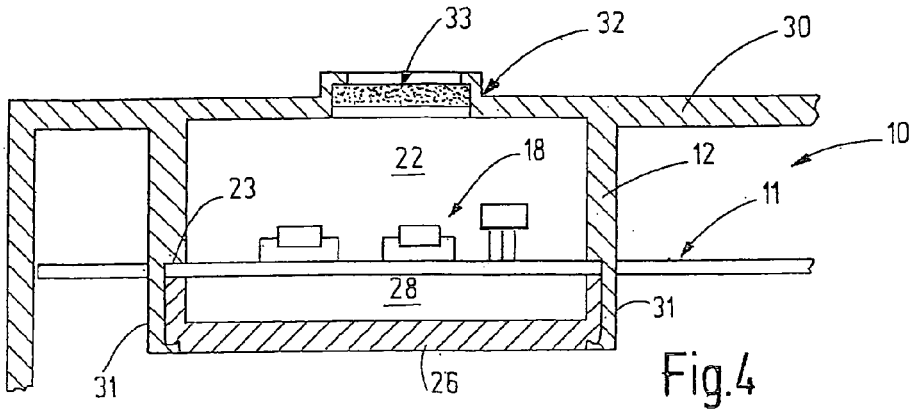


Fig.4

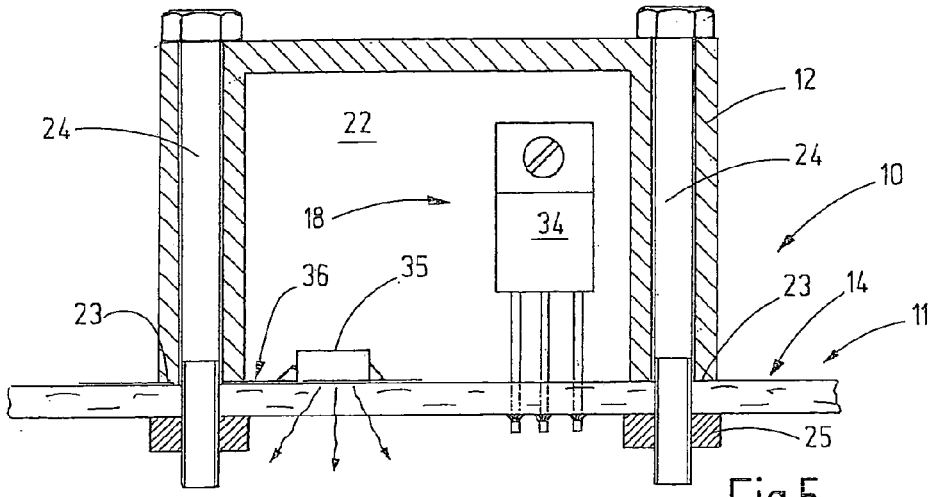


Fig.5

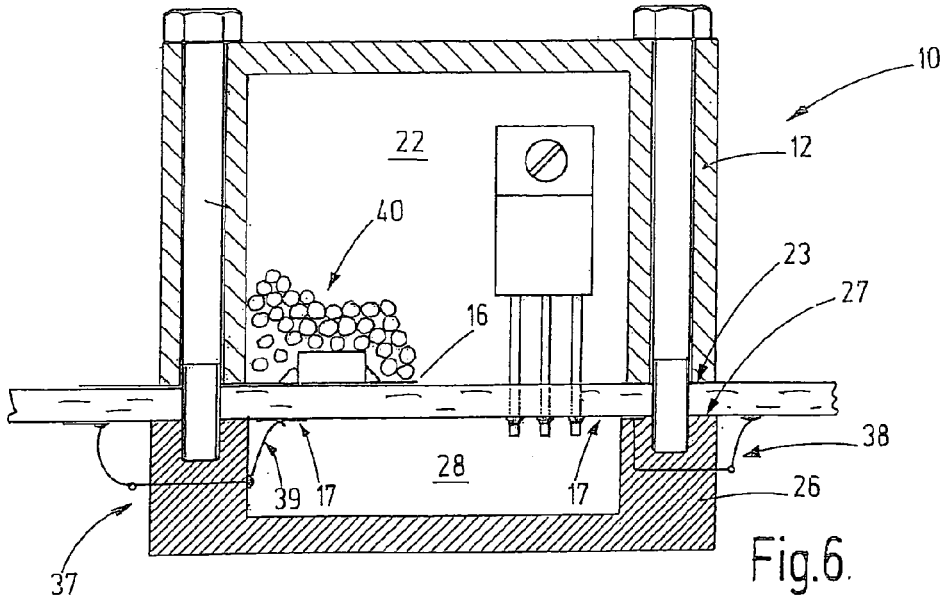


Fig.6.

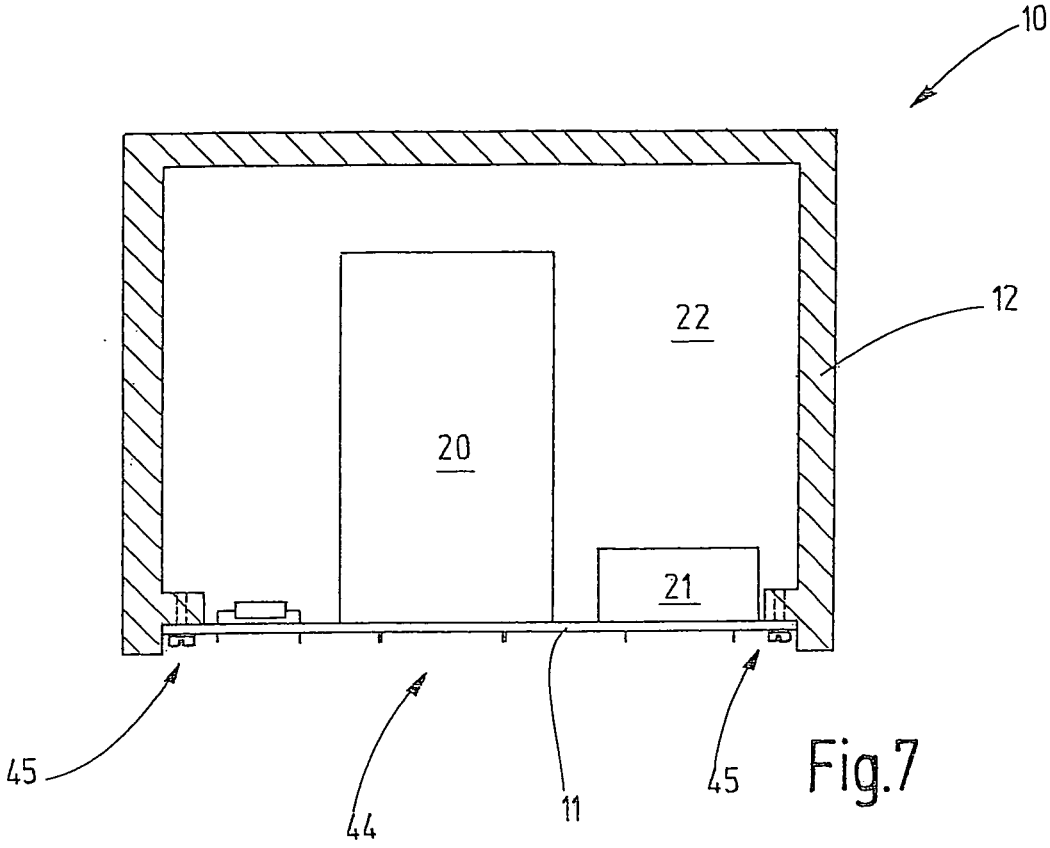


Fig.7

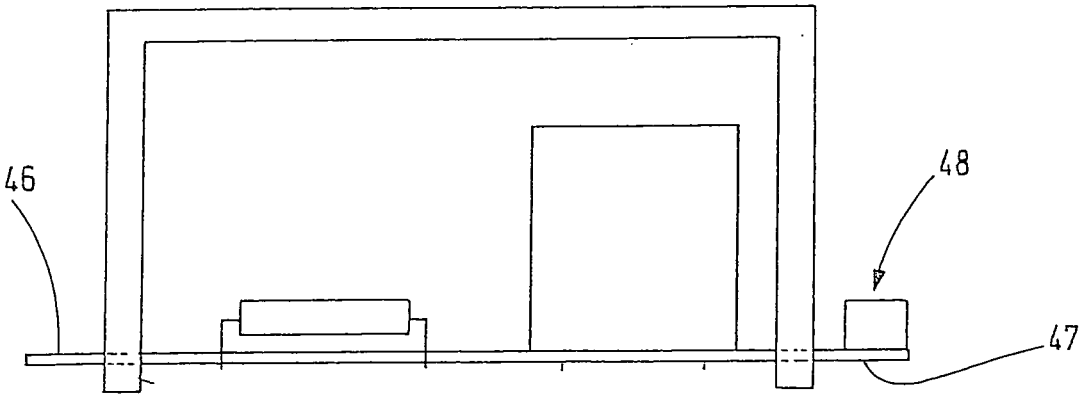


Fig.8

EXPLOSION PROTECTED CIRCUIT BOARD ASSEMBLY

FIELD OF THE INVENTION

[0001] The invention relates to a circuit board assembly that is protected against explosion.

BACKGROUND OF THE INVENTION

[0002] The invention relates to electronic assemblies that are suitable for installation in an environment in which an explosive atmosphere exists, at least occasionally or also frequently. In particular, the invention relates to a circuit board assembly comprising at least one non-intrinsically safe circuit, i.e., a circuit, wherein the occurring voltages and currents can lead to the ignition of a gas mixture that—at least in an error situation—is capable of exploding.

[0003] In order to protect electronic installations against explosion it has been known to accommodate them in a housing that, for example, communicates with the ambient air via a sintered metal disk. In that regard, publication DE 10 2005 050 914 B4 discloses a gas metering device comprising a detector cell. The detector cell contains a thin, helical platinum wire that is enclosed in a small ceramic bead having a catalytically active surface, in particular, of precious metals. The platinum wire is heated in a targeted manner. Explosive gases are catalytically combusted in a controlled manner on the heated detector element. The detector cell has its own housing that communicates with the ambient air via a sintered metal disk.

[0004] Furthermore, it has been known to accommodate electronic units in pressure-proof encapsulated housings. In that regard, publication DE 20 319 489 U1 discloses such a multi-component housing.

[0005] It further has been known from publication DE 10 024 427 A1 to accommodate electronic assemblies inside an electrical installation—such as, for example, a lamp—in a partial housing, and to pot them there. Such potting prevents the contact of the electronic components and the circuit board with ambient gases.

[0006] The potting of circuit boards and their electrical components has been found to be fundamentally effective. However, it also brings about problems. For example, such potting makes the repair of the electronic assembly difficult. If electromechanical components are present, they must have a closed design in order to prevent the casting compound from penetrating into the components, for example a relay. It is also possible for mechanical tensions to form between the casting compound and the conductor strips of the circuit board that can result in the malfunction of the assembly. Furthermore, the production of a casting compound represents an expensive and complex manufacturing process. In addition, for the potting compound to qualify qualitatively, extensive and time-consuming tests are required, thus slowing the development process.

OBJECTS AND SUMMARY OF THE INVENTION

[0007] It is an object of the present invention to provide a relatively simple and economical circuit board assembly that is adapted for reliable usage in explosive atmospheres.

[0008] The circuit board assembly in accordance with the invention comprises a circuit board to which is mounted at least one electrical, electromechanical or electronic component that is part of a non-intrinsically safe circuit. Arranged on the circuit board is a housing part that defines a hollow space that accommodates the element, encapsulating it in an explosion-proof manner. The housing part has a closed edge that is supported by the circuit board. In doing so, the housing part delimits a gas volume that is closed on five sides by the housing part and on the sixth side by the circuit board. In doing so, the circuit board extends, at least in part, beyond the edge of the housing part. In other words the footprint of the housing part is preferably smaller than the contour of the circuit board. However, it is also possible to install the circuit board in a housing opening of the housing part in order to enclose the circuit board.

[0009] Outside the housing part, the circuit board may be loaded with additional electronic, electrical or electromechanical components. In doing so, it is useful to be able to arrange critical components that could potentially lead to an ignition of explosive gas mixtures within the housing part and the other components that do not pose an ignition hazard outside the housing part.

[0010] The housing part may be fastened to the circuit board itself so that the circuit board forms a sixth housing wall. It is possible for several such equally or differently configured housing parts to be arranged at or on the circuit board in order to form several spaces that are delimited relative to the environment.

[0011] Furthermore, it is possible to arrange an additional housing part on the side of the circuit board that faces away from the housing part. Preferably, said additional housing part has the same footprint as the first-mentioned housing part. The two housing parts may be connected to each other by one or more fastening means extending through the circuit board. Such fastening means, for example, may be detent fingers, detent lugs, screws, rivets, pins glued into boreholes, or the like. In this way, a limited space is created through which extends the circuit board.

[0012] Electrical contacting of the electrical components arranged in the housing part may be accomplished by conductor strips that are arranged on the side of the circuit board that faces away from the housing part. It is also possible to provide conductor strips that extend between the circuit board and the housing part or extend within the circuit board. Alternatively, contact means may be provided on the housing part that contact conductor strips of the circuit board.

[0013] The hollow space of the housing is preferably clear, i.e., does not contain any casting compound. However, in order to reduce the volume it may be partially or completely filled with loose material, for example, glass spheres.

[0014] If needed, the housing part may be provided with a gas-permeable opening that is closed by means such as metal nets, metal screens, sintered metal plates, or the like, that prevent a flame transmission. The housing part may consist of a synthetic material or a metal. Housing parts of a synthetic material may be transparent—at least in sections but also fully—in order to allow, for example, signaling devices or the like to be visible from the outside. Metal housings may be used for the removal of heat developed by electronic or electrical components.

[0015] A casting compound may be applied to the circuit boards in accordance with the invention, and particularly, outside the housing. The casting compound may be applied to one or both sides of the circuit board. However the interior space of the housing part is kept as free as possible of such a compound.

[0016] The circuit board assembly in accordance with the invention may be designed so as to be maintenance-friendly. For example, the fastening means that are used for fastening the housing part to the circuit board or to an oppositely arranged housing part may be releasable connecting means such as, for example, screws. Thus, access to the encased components is possible for maintenance or repair purposes.

[0017] A casting compound aging that could lead to failures of the electrical circuit is precluded due to the omission of a casting compound in the interior space of the housing part.

[0018] The housing part that delimits a partial space on the circuit board may itself be a part of a housing that accommodates or encloses the circuit board such as, for example, an apparatus housing. In other words one or more pocket-like structures may be provided on the inside of one housing wall of such an apparatus housing, whereby the circuit board can be mounted to said pocket-like structures so that said circuit board forms a seal with the edge of the respective pocket-like structure. The respective pocket then accommodates components that are loaded on the circuit board and that are to be protected.

[0019] Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. **1** is a schemattic perspective of an illustrated explosion protected circuit board assembly in accordance with the invention;

[0021] FIG. **2** is an enlarged vertical fragmentary section the circuit board assembly shown is FIG. **1**; and

[0022] FIGS. **3**-**8** are vertical sections of further alternative embodiments of circuit board assemblies according to the invention.

[0023] While the invention is susceptable of various modifications and alternative constructions, certain illustrative embodiments thereof have been shown in the drawings and will be described below in detail. It should be understood, however, that there is no intention to limit the invention to the specific forms disclosed, but on the contrary, the intention is to cover all modificatons, alternative constructions, and equivalents falling within the spirit and scope of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] Referring now more particularly to FIGS. **1** and **2** of the drawing, there is shown an illustrative circuit board assembly **10** in accordance with the invention comprising a circuit board **11** and at least one housing part **12**. The circuit board **11** comprises a plate-shaped carrier **13** (see FIG. **2**) having a first flat side **14** and a second flat side **15**. The circuit board is provided with appropriate conductor strips arranged on the carrier **13**. More particularly conductor strips **16** may be provided on at least one of the two flat sides **14**, **15**. Additional conductor strips **17** may be provided on the other flat side.

[0025] The conductor strip **16** or **17** form a non-intrinsically safe circuit with at least one electrical component **18**. The electrical component **18** may be an energy-storing component such as, for example, an inductor or a capacitor, a transformer; or a dissipative component such as, for example, an electrical resistor; an electronic component such as, for example, a diode a Z-diode, a transistor, an integrated circuit; or an electro-optical component such as, for example, a light-emitting diode, a connecting terminal, a female connector or the like. Additionally, the electrical component may be an electromechanical component such as, for example, a relay or the like. Referring to the exemplary embodiment as in FIG. **2**, the electrical components are shown as an electrical resistor **19**, a capacitor **20** and a transformer **21**. Due to the voltages and currents occurring at the components **18** and/or due to the energy stored in the components, the associate electrical circuits or circuits are non-intrinsically safe.

[0026] The housing part **12** defines a hollow space **22** on five sides. To accomplish this, the housing part **12** is preferably designed without openings. Its closed edge **23** is preferably configured as a planar surface that is supported by the first flat side **14** and fastened thereto, such as by glue. The housing part **12** further may consist of a synthetic material and is held on the circuit board **11** by suitable fastening means. In the present exemplary embodiment, this is accomplished with several fastening screws that extend through suitable channels of the housing part **12** and the circuit board **11**. They may be secured on the flat side **15** that faces away from the housing part **12**, for example, by nuts **25**. Optionally, the flat side **14** may also be provided with a casting compound. Such a casting compound **48** may also, or alternatively, be applied to the flat side **15**.

[0027] In this embodiment, there are electrical components **18** which are potentially active as ignition sources enclosed in the hollow space **22**. The wall thickness and the strength of the housing part **12** as well as that of the body **13** of the circuit board **11** is such that a detonation or explosion inside the hollow space **22** cannot result in an escape of the flames or hot particles from the hollow space **22**. When an explosion occurs in the hollow space **22**, such an explosion is restricted to the hollow space **22** and does not lead to an ignition of explosive gases that might potentially be present outside the hollow space **22**. In other words the circuit board or the part of the circuit board **11** delimited by the edge **23** of the housing **12** forms a part of the Ex-d housing, with the other part being represented by the housing part **12**.

[0028] FIG. **3** shows a modified embodiment of the circuit board assembly **10**, wherein the previous description using the already introduced reference signs again apply.

[0029] In addition to the housing part **12**, there is another housing part **26**. While the edge **23** of the housing part **12** is seated on the flat side **14** of the body **13** of the circuit board **11**, the edge **27** of the housing part **26** abuts against the appropriate flat side **15**. Preferably, the edges **23**, **27** are essentially congruent and are configured as uninterrupted plane surfaces. The housing part **26**, like the housing part **12**, may be made of synthetic material and provided with threaded bores for receiving the fastening screws **14**. Matching passage openings of the upper housing part **12** and the circuit board **11** are in alignment with the threaded bores of the housing part **26**.

[0030] The housing part **26** may bridge a hollow space **28** that is able to accommodate at least one electrical component. However, as is shown by FIG. **3**, said hollow space may also only bridge the solder connections of the electrical components **18**, or it may even be empty.

[0031] The conductor strips **16** present on the circuit board **11** may extend from the hollow space **22** between the edge **23** and the carrier **13**. Additionally or alternatively, conductor

strips **17** may also extend from the hollow pace **28** between the edge **27** and the body **13** or within the circuit board.

[0032] A casting compound **48** may optionally be provided outside the hollow spaces **22**, **28**. At least one of the housing parts **12**, **26** may be part of a bigger housing encasing the circuit board **11**. This is shown in an exemplary manner by FIG. **3** for the lower housing part **26** that is arranged like a mounting base on the inside of an apparatus wall **29**.

[0033] Additional modifications are possible. FIG. **4** shows the embodiment of the upper housing part **12** as a part of an apparatus housing **30**. The circuit board **11** is arranged in this apparatus housing. Again, non-intrinsically safe circuits are arranged in a space that is delimited by the apparatus housing **30**. This space is formed by the two hollow spaces **22**, **28**. In this exemplary embodiment, the housing part **26** is designed as a snap-on lid. The detent fingers **31** project from the edge **23** of the housing part **12**, with the detent fingers engaging into corresponding openings of the circuit board **11**. The detent fingers **31** come into engagement with corresponding detent recesses of the housing part **26**, as a result of which the circuit board **11** is held between the two housing parts **12**, **26**. The type of connection of the two housing parts **12**, **26** shown by FIG. **4** can also be effectively used in the other embodiments comprising two housing parts **12**, **26**.

[0034] At least one of the two housing parts **12**, **26**—in FIG. **4** the housing part **12**, for example—can be provided with a pressure relief opening **32** that terminates in the interior of the apparatus housing **30** or—as shown in FIG. **4**—toward the outside. The pressure relief opening **32** establishes a gas-permeable connection between the hollow space **22** and the environment. A transmission-arresting body **33**, e.g., in the form of a sintered metal body or a body consisting of metal fibers or a similar means that allows a gas exchange, but not a flame transmission due to the existing narrow passage channels, is installed in the pressure relief opening **32**. Such a pressure relief opening with the body **23** arranged therein also can be used in each of the embodiments described herein.

[0035] FIG. **5** illustrates another embodiment of the circuit board assembly **10**, the special feature of this embodiment being that the housing part **12** consists of metal. Consequently, said housing part may act as a cooling body for a component **18** arranged in the hollow space **22**, which may, for example, be a high load resistor or a transistor **34** connected with the housing part **12** in a thermally conductive manner. Other than that, the description as in FIG. **2** applies correspondingly.

[0036] In all of the embodiments of the circuit board assembly **10** in accordance with the invention the circuit board **11** may be transparent as depicted by the example of FIG. **5**. This opens up the possibility of using the circuit board **11** as a light-transmitting surface, for example for an LED **35** arranged in the hollow space **22** on the flat side **14**. In this case, the LED **35** is preferably a light emitting diode such as a reverse mount LED for emitting light toward the assembly surface.

[0037] The LED **35** or any other electrical components that tends to heat up can be cooled by using larger copper surfaces **36** that are arranged on the flat side **14**. As illustrated, these copper surfaces **36** may extend under the edge **23** and beyond, i.e. out of the hollow space **22** toward the outside. Hence, the copper surface **26** may extend beyond the housing part **12** toward the outside, as indicated in FIG. **1**. In this manner, the copper surface **36** itself may act as the cooling surface. If the housing part **12** is designed so as to be thermally conductive, it may also be disposed for cooling the LED **35** or another electrical component due to the thermal contact with the copper surface **36**.

[0038] FIG. **6** shows another embodiment, based on the embodiment of FIG. **3**. Optionally, the housing part **26** may be a part of an apparatus housing or, as shown, be separate. The housing parts **12** and/or **26** may be provided with contact means **37**, **38** in order to contact the conductor strips **16** or **17**. Such contact means are, for example, conductors embedded in the housing part **26** and connected, e.g., soldered, on the outside to the conductor strips or other lines. In this case, the contact means **37**, **38** are connected to the conductor strips **17**, for example, in the hollow space **28**, by suitable connecting means, for example contact springs **39**. Alternatively, the electrical connection between a conductor strip **17** and the contact means **38** may also take place within the edge **27**, as is schematically shown on the right side of FIG. **6**.

[0039] In each of the above-described embodiments that the hollow space **22** and, if existing, the hollow space **28** may be filled, as needed, with a loose filler material, for example glass spheres **40** that are disposed to reduce the gas volume in the hollow space **22** or **28**. As needed, filling openings for pouring in the glass spheres **40** or another filler material may be provided on the housing part **12**, housing part **28** or in the circuit board **11**. The openings may be provided with closing means such as, for example, screw plugs. In the embodiment as in FIG. **4**, the glass spheres **40** may optionally also be filled through the pressure relief opening **32** into the hollow space **22**. This is the case, for example when the body **33** is held in a fitting that can be inserted into the apparatus housing **30** from the outside, for example, a screw socket.

[0040] Each of the above-described circuit board assemblies **10** comprises at least one electrical component **18** that is arranged in the at least one housing part **12**. Additional components **41**, **42**, **43** may be provided (FIG. **1**), these being arranged on the circuit board **11** outside the housing part **12**. Preferably, the components **41**, **42**, **43** are parts of intrinsically safe circuits or electrical circuits that, even in an error situation, cannot act as an ignition source for an explosive atmosphere.

[0041] By dividing the electrical circuit arranged on the circuit board **11** into intrinsically safe parts that are arranged outside the housing part **12** and non-intrinsically safe parts that are arranged inside the hollow space **22**, the volume enclosed by the housing protecting against explosion can be substantially reduced in comparison with an explosion-safe encasing of the entire circuit board **11**. The hollow space **22** has a smaller volume than the interior of the housing that accommodates the entire circuit board **11**. Consequently, in the case of an explosion triggered by one of the electrical components **18**, the exploding gas volume is substantially reduced. Accordingly, the housing part **12** can be a simpler, smaller and more cost-effective housing compared to housings that encase the entire circuit board **11**.

[0042] FIG. **7** illustrates another embodiment of the circuit board assembly **10**. The description hereinabove applies correspondingly with the use of the same reference signs. The housing part **12** is provided with a housing opening **44** that is closed by the circuit board **11**. The circuit board may be held by screws **45** that are screwed into corresponding threaded bores of the housing part **12**. Instead of the fastening screws, it is also possible to use other connecting means. For example, the housing part **12** may be glued to the circuit board **11**. An appropriate casting compound also may be applied for cov-

ering the outside of the circuit board **11** and adjoining the part of the housing part that projects beyond the circuit board **11**.

[0043] As in FIG. **8**, the circuit board **11** may also have one or more extensions **46**, **47** that extend through corresponding recesses of the housing wall of the housing part **12**. These extensions **46**, **47** may carry additional components, connecting elements **48** or the like. Also in the case of this embodiment, a casting compound may be applied to or on the circuit board **11**. The circuit board **11** may be screwed to the housing part, glued to it or otherwise connected. Other than that, the description hereinabove similarly applies.

[0044] From the foregoing, it can be seen that the invention is suitable for electronic assemblies that are used in areas that pose an explosion hazard, i.e., in areas in which an explosive atmosphere may occur. In conjunction with this, it is possible to use non-intrinsically safe circuits with the electrical components **18** thereof being encased by at least one housing part **12** held on the circuit board **11**, thus producing an Ex-d space. In doing so, the circuit board may close the housing part **12** on one side. Alternatively, a second housing part **26** may be provided, in which case the housing parts **12**, **26** then accommodate the circuit board **11** between them. In doing so, the circuit board may act as a conductive passage and also be a component of the Ex-d housing. The Ex gap between the circuit board **11** and the upper housing part **12** and/or the lower housing part **26** prevents a flame transmission. Hence, with the arrangement in accordance with the invention, the potting of non-intrinsically safe electrical circuits or electronic assemblies becomes superfluous. Errors that could occur due to tensions between the casting compound and the circuit board or the electrical components **18** are thereby precluded.

[0045] It will be understood that the use of the terms "a" and "an" and "the" and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms "comprising," "having," "including," and "containing" are to be construed as open-ended terms (i.e. meaning "including, but not limited to,") unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. The use of any and all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0046] A preferred embodiment of this invention is described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

1-11. (canceled)

12. An explosion protected circuit board assembly (**10**) comprising:

a circuit board (**11**) having a carrier plate (**13**) with conductor strips (**16**, **17**),

an electrical component (**18**) mounted on the circuit board carrier plate (**13**), and

a first housing part (**12**) supported a side of said circuit board and defining a hollow space (**22**) for encasing the electrical component (**18**) in an explosion-proof manner.

13. The explosion protected circuit board assembly of claim **12** in which said circuit board (**11**) carries at least on additional electrical component (**41**, **42**, **43**) outside the housing part (**12**)

14. The explosion protected circuit board assembly of claim **12** in which said housing part (**12**) is fastened to said circuit board (**11**).

15. The explosion protected circuit board assembly of claim **12** in which said circuit board (**11**) supports an additional housing part (**26**) on a side (**15**) opposite the side said first housing part (**12**) is supported.

16. The explosion protected circuit board assembly of claim **15** in which said housing parts (**12**, **26**) are connected to said circuit board (**11**).

17. The explosion protected circuit board assembly of claim **12** in which said first housing part (**12**) has an edge (**23**) that is seated no one flat side (**14**) of said circuit board (**11**), at least one of said conductor strips (**16**) being disposed between said edge (**23**) of the housing part (**12**) and said circuit board (**11**) and extending out of a region of the circuit board (**11**) encased by said housing part (**12**) into a region of the circuit board (**11**) that is not encased by the housing part (**12**).

18. The explosion protected circuit board assembly of claim **12** including a casting compound (**48**) on at least one side (**14**) of the circuit board (**11**).

19. The explosion protected circuit board assembly of claim **12** including a casting compound (**48**) on both sides of said circuit board (**11**).

20. The explosion protected circuit board assembly of claim **15** including a fastener (**24**, **31**) extending through said circuit board (**11**) for connecting said first housing part (**12**) to said additional housing part (**26**).

21. The explosion protected circuit board assembly of claim **12** including a loose filling of particulate material (**40**) in the hallow space (**22**) defined by said first housing part (**12**).

22. The explosion protected circuit board assembly of claim **12** in which said circuit board (**11**) and first housing part (**12**) are glued together.

* * * * *