

VACUUM SOLAR THERMAL PANEL WITH A
VACUUM TIGHT GLASS-METAL SEALING

The present invention relates to a vacuum
5 solar thermal panel and a method for the production
of said vacuum solar thermal panel according to the
preamble of the main claims.

Evacuated tube solar panels are normally
obtained by connecting in parallel multiple heat
10 pipes, with heat absorber fins attached thereto,
sealed in individual evacuated glass tubes.

This design has the drawback of providing
significant dead space in between heat absorbers as
well as having a significant portion of the heat
15 transfer fluid circuitry outside vacuum insulation.

To overcome these limitations, flat vacuum
solar thermal panels have been developed comprising
a flat vacuum tight envelope with a glass plate
transparent to the visible solar radiation. Inside
20 the vacuum envelope there are disposed heat
absorbers and a pipe entering and exiting the
envelope connected to the heat absorbers. The solar
radiation enters the envelope through the glass
plate, is absorbed by the heat absorbers and
25 converted into heat, which is transferred to the
pipe and to the thermal fluid flowing in the pipe.
High vacuum is kept inside the envelope enclosing
the heat absorbers and the pipe connected thereto,
in order to prevent heat from escaping to the
30 external environment by means of convection.

US 4,332,241 and EP 1706678 disclose a vacuum
solar thermal panel comprising two parallel glass
plates and a metallic spacing frame for supporting
the glass plates in a spaced-apart arrangement.

Surface portions of the glass plates have a metallic coating, in order to allow soldering to the metallic spacing frame, thus providing a vacuum tight sealing between the glass plates and the metallic spacing frame. Furthermore, the spacing frame preferably comprises deformable bars or ribbons made of lead or soft metal to be soldered to the metallic coating of the glass plates, in order to limit the stress induced in the glass-metal seal by thermal expansion and pressure differences.

GB 2259732 discloses a thermal insulation panel with two parallel plates and a flexible peripheral seal, preferably made of silicon rubber or polysulfide, to allow a movement of the plates relative to each other due to the thermal expansion of the gas contained inside the panel.

Both these technologies have severe intrinsic limitations. Most soft metals (i.e. lead) are toxic and their use is becoming more and more restricted. Metallization of glass relies on surface coatings which can deteriorate much faster than bulk materials due to the fact that they extend only for few atomic layers. On the other hand glues, silicon rubber or polysulfide allow gas permeation over time, because of their organic constituents, thus preventing their use for long term high vacuum applications.

An object of the present invention is to overcome these limitations by providing a vacuum solar thermal panel comprising a long lasting and reliable vacuum envelope.

Another object of the present invention is to reduce the stress applied to the glass-metal seal

due to atmospheric pressure and differential thermal expansion of the panel constituents when heated during the bake-out cycle.

Another object of the invention is to provide
5 a flat vacuum solar thermal panel with two parallel plates.

Another object of the invention is to provide a flat vacuum solar thermal panel with enhanced efficiency at temperatures above 200°C.

10 A further object of the invention is to provide a method for obtaining such a vacuum solar thermal panel.

The present invention will be more fully understood and appreciated from the following
15 detailed description taken in conjunction with the attached drawings, in which:

Fig. 1 shows a perspective view of a vacuum solar thermal panel according to the invention;

Fig. 2 shows an exploded view of the panel;

20 Fig. 3 shows a cross section of the peripheral wall of the vacuum solar thermal panel;

Fig. 4 shows an enlarged cross section of the peripheral wall of the vacuum solar thermal panel, showing a matched bulk glass-metal seal, having the
25 edge of the peripheral belt embedded in the glass plate, according to a first embodiment of the invention;

Fig. 5 and 6 show an enlarged cross section of a first and a second embodiment of the peripheral
30 wall of the vacuum solar thermal panel, showing a compression bulk glass-metal seal, having the edge of the peripheral belt embedded in a ribbon of frit glass joining the peripheral belt to the glass plate, according to a second embodiment of the

invention.

The vacuum solar thermal panel according to the invention (fig. 1 and 2) comprises a vacuum envelope 30 defining a sealed volume, able to
5 withstand atmospheric pressure when evacuated, with at least a first plate 1 made of glass transparent to the visible solar radiation. A pipe 13 for the thermal fluid with attached multiple heat absorbers 12 in good thermal contact with the same pipe is
10 enclosed in the vacuum envelope to avoid heat transfer to the environment due to convection. Said pipe 13 enters and exits the vacuum envelope 30 through the exit ports 20. Of course more than one such a pipe 13 can be present.

15 The vacuum envelope 30 can have a first and a second parallel plate 1 and 2, both made of glass, or a first plate 1, made of glass, and a second plate 2, made of metal, kept in a spaced-apart arrangement by a chassis 18, disposed inside the
20 envelope 30 between the plates 1 and 2, and a peripheral frame 3. Said chassis 18 and the peripheral frame 3 can also support parts of the pipe 13 inside the envelope 30 and the heat absorbers 12 connected thereto.

25 As shown in fig. 1 the solar thermal panel is flat. The vacuum envelope 30 of the panel comprises a first and a second plate 1 and 2, made of glass, and a metallic peripheral frame 3. It also comprises two metallic peripheral belts 4 and 5
30 each one joining the glass plates 1 and 2 with the metallic peripheral frame 3. If the above plates are made of glass, the solar panel has two active surfaces (double sided flat panel), one collecting the solar radiation directly from the sun and the

other collecting the solar radiation reflected by a suitable mirror (not shown in the figure).

In case the first plate 1 should be made of glass and the second plate 2 of metal the solar panel would be single sided, i.e. with only one side capable of collecting solar radiation. When the second plate is made of metal, the peripheral frame can be directly joined to the second plate by means of conventional metal-metal soldering, without the presence of a flexible peripheral belt, or as shown in figure 6 said peripheral frame 3A is in one piece with the second metal plate 2A.

Glass plate composition should be chosen such as to maximise transparency (transmission coefficient $\geq 0,91$).

Moreover, it is commonly known to the experts in the field that by applying a coating to the glass plate, as it reduces the glass transparency, it will also reduce the amount of solar energy entering the panel and thus the panel efficiency. According to the invention, the opposite can be achieved. In fact, by applying an infra red low emitting coating (1C, 2C) to the inner side of the glass plates, even reducing transmission in the visible part of the solar spectrum, the efficiency of the panel is increased at high temperature because of the predominant effect of reduction of radiation losses deriving from the heat absorber infrared emissions.

To get this result, the low emitting coating is chosen in such a way: that the reflectivity for wavelengths comprised between 4 and 6 micron (corresponding to a temperature range of 200-400°C) is more than 0,9 and that the transmission for

wavelengths comprised between 0,25 and 1 micron is more than 0,7.. A panel operating for example at 265°C would have an infra red emission from the heat absorber peaked at 5.4 micron.

- 5 It has been found that a coating according to the invention may increase the panel efficiency at 265°C of more than 30%

 According to the invention it has also been found that the panel efficiency may be further
10 increased by applying a second coating (1B, 2B) to the outer surface of the glass plates. This second coating being a commonly used anti reflective coating.

 According to the invention it has also been
15 found that, in the case of a single sided panel, the efficiency may be further increased by applying a third coating (fig. 6) to the inner surface of the metal plate to lower its emissivity. This third coating being for example a commonly used
20 electrodeposited copper layer.

 Additionally, glass should be thermally pre-stressed or stratified to improve safety and reduce thickness. In the case of thermally pre-stressed extra-clear soda lime float glass, the thickness of
25 glass plates should be about 5 mm, when considering a chassis 18 with support structures spaced 120 - 160 mm apart.

 Fig. 2 shows an exploded view of the panel, wherein the elements thereof are separated, in
30 order to be better identified.

 Figs. 3, 4 and 5 show a cross section of the peripheral wall of the vacuum envelope, said peripheral wall comprising the peripheral frame 3, supporting the two plates 1 (or 101 in fig. 5) and

2 in a spaced-apart arrangement, and the two peripheral belts 4 (or 104 in fig. 5) and 5 joined to the peripheral frame 3 with a vacuum tight metal-metal seal 6 (or 116 in Fig. 5) and 7 and 5 joined to the first and second glass plates 1, 101 and 2, by means of a vacuum tight bulk glass-metal seal 8 (108 in Fig. 5) and 9.

Fig. 6 shows a single sided solar panel comprising a glass plate 1A supported by a frame 21 10 comprising a single metallic piece providing the functions of both the metal peripheral frame 3A and the bottom plate 2A, and a chassis 18A for supporting the glass plate 1A and parts of the pipe 13 and the heat absorber 12 (not shown in figure 6) 15 connected thereto.

The peripheral frame is connected to the glass plate by a metallic peripheral belt 5A as described above. A controlled expansion alloy with 48% Ni content (NiFe alloy 48) is preferably used for the 20 peripheral belt 4 and 5, because of the close match between its thermal expansion coefficient and that of soda-lime glass.

In the present contest with the term vacuum tight it should be understood following: a seal or 25 component is generally considered to be vacuum tight, if when tested on a helium-peaked mass spectrometer leak detector, shows a leakage rate of less than $10E-10 \text{ cm}^3 \text{ s}^{-1}$

By the expression "bulk glass-metal seal" 8, 30 9, 108 a vacuum tight seal between a glass plate 1, 2 or 101 and a metallic peripheral belt 4, 5 or 104 is meant, comprising glass 14 or 114 (fig. 5) embedding an edge 16, 116 (fig. 5) of the metallic peripheral belt 4, 5 or 104. The vacuum tight bulk

glass-metal seal 8, 9, 108 is obtained by fusion and subsequent solidification of the glass 14, 114 embedding the edge 16, 116 (Fig. 5) of the peripheral belt 4, 5, 104, in order to make the
5 glass 14, 114 directly adhere to the peripheral belt.

The vacuum tight bulk glass-metal seal can be of two kinds, according to the first or to the second embodiment of the invention, respectively:

- 10 a) it can be a matched glass-metal seal 8 having the edge 16 of the peripheral belt 4 embedded in the glass material 14 resulting from local melting and subsequent solidification of the glass plates 1, 2 (fig. 4);
- 15 b) it can be a compression glass-metal seal 108, having the edge 116 of the peripheral belt 104 embedded in the glass material 114, resulting from the melting of the frit glass material joining the peripheral belt 104 to the glass plate 101 (fig.
20 5).

In both embodiments, the glass material 14, 114 adheres directly to the metallic peripheral belt 4, 104. In the first embodiment the glass material 14 is part of the first plate 1, which is
25 always made of glass, whereas in the second embodiment the glass material 114 is some added frit glass forming a meniscus at the edge of the metallic peripheral belt 104.

When a glass plate is heated, it first becomes
30 soft at a certain temperature and subsequently it melts at a higher temperature becoming liquid or fused.

In the matched glass-metal seal 8 (fig. 4) the embedding of the edge of the peripheral belt 4 and

the adhesion of the glass material 14 to the metallic peripheral belt 4 are achieved by means of localized fusion of the glass plate 1. Localized glass fusion is obtained by heating the peripheral belt together with the glass plate at a temperature close to, but not exceeding, the glass softening point (for soda-lime glass about 720 °C). The peripheral belt 4 is then further heated (e.g. by induction) above the glass softening temperature (about 800 °C), inserted into glass plate 1 for about 1-2 mm and eventually retracted to allow fused glass to form a meniscus at both sides of the peripheral belt. Eventually, the glass plate 1 is quickly cooled to induce the required pre-stress level, following standard rules for tempering.

In the compression glass-metal seal 108 (Fig. 5) the embedding of the edge of the metallic peripheral 104 belt and the adhesion to the metallic peripheral belt 104 are achieved by melting a frit glass having a much lower softening temperature compared to that of the glass plate, and by joining the peripheral belt 104 to the glass plate 101, once solidified. Frit glass, either vitreous or devitrifying, could be chosen to have a thermal expansion coefficient (λ) slightly lower than that of the components to be sealed, in order to provide some additional compression to the seal. In the case of soda-lime glass and NiFe alloy 48, both having a thermal expansion coefficient $\lambda=90 \cdot 10^{-7} \text{ K}^{-1}$, a frit glass with λ around $75 \cdot 10^{-7} \text{ K}^{-1}$ could be used. The compression glass-metal seal 104 is obtained by first applying a thick paste, obtained by mixing frit glass powder with a binder

and a suitable solvent (for example nitrocellulose and amyl acetate) as a continuous ribbon of about 2 mm height and width on top of a glass plate, then by inserting the peripheral belt in said frit glass
5 paste ribbon and then firing the realised assembly, kept together by a suitable support structure, in a suitable oven.

In particular it has been found advantageous to dry the ribbon of frit glass before inserting
10 the peripheral belt, then to place the glass plate with the dried ribbon up-side down and touching the top edge of the peripheral belt, kept in place by a suitable support structure and then firing the realised assembly in the oven. In such a way the
15 frit glass ribbon once it reaches its melting temperature will flow down along both sides of the peripheral belt thus realizing a perfectly symmetric and homogeneous meniscus for the glass metal seal such as that represented in figure 5.

20 Frit firing should follow usual thermal cycle as described in material datasheets (for a typical frit glass, firing temperature will reach 450 °C for about 30 minutes). The support structure should be made such as to compensate for thermal expansion
25 difference with respect to the remaining assembly components.

This may be achieved for example by realizing a support structure or firing gig, in a suitable steel (for example AISI430) and to dimension it in
30 such a way that it reaches the desired dimensions at the frit melting temperature and in that at this temperature it stretches the peripheral metal belt
5 5A 104 and position such belt in the desired location in respect to the glass plate 2 while

keeping it in contact with the fused frit.

According to a further aspect of the invention the bulk glass-metal seal can be advantageously improved if at least the metal component embedded
5 in the frit glass is oxidized prior to creating such bulk glass-metal seal; said oxidation being preferably such to produce an approximately uniform and stable oxide layer 4A, 5B approximately regular in thickness and preferably also such to improve
10 bond strength of glass to metal by at least 10% when measured by a shear test.

Said pre-oxidation of the metal component being preferably realized by means of heating in an oven at a temperature suitable to grow a uniform
15 oxide layer on the metal component surface. Of course, other treatments could be envisaged, including for example heating in oxygen enriched atmosphere.

The compression bulk glass-metal seal can also
20 be obtained in a less preferred way by first placing the peripheral belt 104 (fig. 5) on the surface of the glass plate 1 and subsequently adding the ribbon of frit glass paste 114 on top of the surface of the glass plate 1 at one or both
25 sides of the peripheral belt 104. Said ribbon of frit glass is subsequently melted and solidified again to obtain the glass-metal seal. This latter technique is more complicated than the one described here before, and the presence of a ribbon
30 of frit glass on only one side of the peripheral belt would render the glass metal seal more fragile.

Both matched and compression glass-metal seals 8 and 108 can be reinforced by means of suitable

epoxy resin encapsulation at one or both sides of peripheral belt. Epoxy resin for the vacuum side should be chosen such as to have very low outgassing and good stability at high temperature, in order to later withstand a bake-out cycle (i.e. an epoxy resin known with the commercial name of "Torr Seal by Varian" can be used).

The thickness of the peripheral belt 4, 104 should be preferably chosen in the range 0,1 - 1 mm such as to avoid fissuring under atmospheric pressure, while reducing thermal conduction during welding, to prevent heating of the glass-metal seal, which in turn could make such seal no more vacuum tight.

It should be noted that according to the invention the metallic peripheral belt is continuous i.e. welded to form a continuous belt), vacuum tight and it comprises at least one elastically deformable portion being at least elastically deformable such that it avoids that the bulk glass-metal seal gets damaged and is no more vacuum tight when subject to the evacuation process of said envelope and the thermal treatments of the panel and the potential reciprocal displacements of the glass plate and the joined metallic peripheral belt.

It should be noted that the wording "thermal treatments" of the panel refers both to the glass metal sealing process and to other treatments such as a bake-out thermal treatment of the panel performed at more than 200°C in order to lower internal pressure while limiting cleaning requirements for the panel by means of pyrolysis.

The above mentioned at least one elastically

deformable portion 10, 110 of the metallic peripheral belt 4, 5; 104 is preferably at least elastically deformable such that it permits an elongation of said belt of 0,1 - 0,3 mm with
5 respect to an axis perpendicular to the glass plate.

According to a further aspect of the invention the metallic peripheral belt 4; 104 comprises an intermediate portion provided between a first and a
10 second portion of said metallic belt, said first portion joining the first glass plate 1; 101 and comprising the vacuum tight bulk glass metal seal 8, 108, said second portion of said metallic belt 4; 104 joining the peripheral frame 3, and
15 comprising a vacuum tight metal-metal seal 6, 116; the at least one elastically deformable portion being provided in said intermediate portion.

According to a further aspect of the invention the at least one elastically deformable portion 10, 110 comprises preferably at least one non
20 rectilinear part or at least one at least partially curved part or at least one ribbing 10, 110. This ribbing 10, 110 is preferably of semicircular form, has a radius comprised between 2 and 4 mm, running
25 for the whole length of the peripheral belt.

When plates 1 and 2 are both made of glass, the peripheral belt is attached thereto by means of a bulk vacuum tight glass-metal seal. If the first plate 1 is made of glass and the second plate 2 is
30 made of metal; a vacuum tight metal-metal seal, obtained for instance by conventional soldering, welding or brazing, can be directly provided to join the peripheral frame to the metal plate, or as described before the peripheral frame and the

bottom metal plate may be realized in one single metal piece.

The vacuum envelope of the solar panel according to the invention also comprises a pumping
5 port 19, typically made of a copper tube, connected to a vacuum pump (not shown). After evacuation of the vacuum envelope, the pumping port 19 may be sealed by pinch-off, a typical method used in refrigeration circuits.

10 An exit port, typically made of a stainless steel tube 20 or bellow, bringing heat absorber pipe 13 outside the vacuum envelope 30, through the peripheral frame 3, while minimizing heat transfer to the same should also be present.

15 A getter pump of known type may also be present inside the vacuum envelope in order to continuously pumping any residual gas with the notable exception of noble ones.

The invention also relates to a method for the
20 production of a vacuum solar thermal panel comprising a vacuum envelope defining a sealed volume, able to withstand atmospheric pressure, when evacuated, and having at least a first plate 1, 2, 101 made of glass, a metallic peripheral belt
25 4, 5, 104 and a vacuum tight bulk glass-metal seal between the glass plate 1, 2, 101 and the metallic peripheral belt 4, 5, 104.

According to the present invention, glass material 14, 114 is disposed close to the edge 16,
30 116 of the peripheral belt 4, 104. Said glass material can be part of said first plate 1 or some added frit glass material 104. Said glass material 14, 114 is heated above its melting temperature and subsequently cooled below said temperature to make

the glass material adhering to the peripheral belt and joining it to the glass plate 1, while embedding the edge of the peripheral belt. This can be obtained in two ways: said glass material, 5 positioned close to the edge of the peripheral belt, melted and subsequently solidified again, can come from the glass plate or it can come from a ribbon of frit glass paste, which, when the peripheral belt is disposed with its edge on the 10 surface of the glass plate 101, is placed at both sides of the peripheral belt 104.

When glass forming the bulk glass-metal seal is coming from the glass plate 1 (matched glass-metal seal), the method can be described by the 15 following steps:

- the glass plate 1 is heated to a temperature close to but not exceeding its softening temperature;
- the peripheral belt 4 is heated to a 20 temperature above the glass plate 1 softening temperature;
- an edge 16 of the peripheral belt 4 is pressed against the surface of the glass plate 1 in order to achieve localized fusion and to 25 insert the edge into the glass plate 1, so that the edge 16 of the peripheral belt 4 is embedded by the glass 14 of the glass plate 1;
- the peripheral belt 4 is retracted from the glass plate 1, to form a meniscus at both 30 sides of the edge 16 of the peripheral belt 4;
- the glass plate 1 and the peripheral belt 4 are cooled to below the glass plate softening temperature, providing a vacuum tight glass-metal seal between the glass plate 1 and the

metallic peripheral belt 4.

When the glass forming the bulk glass-metal seal is coming from a ribbon of frit glass paste (compression glass-metal seal), the method can be
5 described by the following steps:

a frit glass paste comprising frit glass material is provided, said frit glass paste being obtained by mixing together a powder of frit glass material, a solvent and a binder;

10 the frit glass paste is placed on the top of the surface of the glass plate 101, to form a continuous ribbon;

then two possible ways of prosecuting the method are possible:

- 15 - the ribbon is dried, then the glass plate 101 with the dried ribbon is placed upside down on the peripheral belt 104 touching the edge 116 of the peripheral belt 104, kept in place by a suitable support structure
- 20 - the edge 116 of the peripheral belt 104 is inserted in the ribbon of the frit glass paste contacting also the surface of the glass plate 101;
- the frit glass paste is heated and melted to
25 form a meniscus of fused frit glass between the side of the peripheral belt 104 and the surface of the glass plate 101;
- the frit glass is cooled and solidified thus
30 providing a vacuum tight bulk glass-metal seal between the glass plate 101 and the metallic peripheral belt 104.

The method for producing a matched glass-metal seal is preferred when thermal pre-stress of glass plate is required, since it can be applied during

pre-stress treatment at practically zero-cost, while the method for producing a compression glass-metal seal should be used when no thermal pre-stress of glass plate is envisaged (i.e. in the case of stratified glass), since it requires much lower temperature.

In both cases (matched or compression glass-metal seal) the glass metal seal could then be reinforced by means of suitable epoxy at one or both sides of the peripheral belt as described above.

One advantage of the present invention is that it provides a solar thermal panel provided with a vacuum tight envelope having a glass-metal seal very simple to realize and yet very reliable.

The peripheral belt is made deformable by the presence of ribbing. This allows lowering the stresses induced in the glass-metal seal by the pressure difference between the inside and the outside of the envelope during evacuation of the same and by differential thermal expansion of the panel components during thermal treatments of the panel and in particular a bake-out cycle at a temperature above 200°C.

A further advantage is that the envelope makes no use of toxic or dangerous materials.

It is finally to be noted that many of the inventions described might be incorporated in a vacuum solar panel independently one from the other. This refers in particular to following inventions:

a1) a vacuum solar thermal panel comprising a glass-metal seal realized according to claim 1 and preferably comprising one or more of the features

described in attached claims 2-6,

a2) a method for producing a vacuum solar thermal panel according to claim 21, and preferably comprising one or more of the claims 22-25,

5 b) a vacuum solar thermal panel comprising the features of the pre characterising portion of claim 1 characterised in that the metallic peripheral belt is a continuous and vacuum tight belt, and it comprises at least one elastically deformable
10 portion being at least elastically deformable such that it avoids that the bulk glass-metal seal gets damaged and becomes non vacuum tight when subject to the evacuation process of the envelope and the thermal treatments of the panel and the potential
15 reciprocal displacements of the glass plate and the joined metallic peripheral belt. It is to be noted that this belt comprise preferably also one or more of the features described in the attached claims 10-13.

20 c1) a vacuum solar thermal panel comprising on the inner side of its glass plates (1, 2) an infra red mirror coating and/or on the external side of the glass plate an anti reflective coating, and or on the inner side of a bottom metal plate and infra
25 red mirror coating. It is to be noted that this coatings comprise preferably also the features described in the characterising portion of attached claims 14-16.

c2) a method for increasing the efficiency of a
30 vacuum solar thermal panel characterised by applying anti-reflective and/or infrared mirror coatings on the outer and/or inner surfaces, respectively of the glass and/or on the inner side of a bottom metal plate(1, 2, 1A, 2A). It is to be

noted that this method comprises preferably also the steps described in the characterising portion of attached claims 26-28.

- d) a single sided vacuum solar thermal panel according to the pre characterising portion of claim 1 and further comprising a metal frame realized in one piece comprising both the peripheral frame 3 and a bottom metal plate of the panel,
- 10 e) a support structure or firing gig for a vacuum solar panel according to the pre characterising portion of claim 1, preferably realized in a suitable steel (for example AISI430) and dimensioned in such a way that it reaches the
- 15 desired dimensions at the frit melting temperature and in that at this temperature it stretches the peripheral metal belt and position such belt in the desired location in respect to the glass plate, while keeping it in contact with the fused frit,
- 20 f) a vacuum solar panel having a vacuum tight glass-metal seal, made using a glass based frit in which at least the metal component embedded in the frit is oxidized prior to creating such bulk glass-metal seal; said oxidation being preferably such to
- 25 produce an approximately uniform and stable oxide layer approximately regular in thickness and preferably also such to improve bond strength of glass to metal by at least 10% when measured by a shear test.
- 30 Said pre-oxidation of the metal component being preferably realized by means of heating in an oven at a temperature suitable to grow a uniform oxide layer on the metal component surface (for NiFe alloy 48 typically 10' at 560°C). It is

further to be noted that other treatments could be envisaged, including heating in oxygen enriched atmosphere.

CLAIMS

1 Vacuum solar thermal panel comprising a vacuum envelope (30) defining a sealed volume, able to withstand the atmospheric pressure when evacuated,
5 at least one heat absorber (12) being disposed inside the vacuum envelope (30), a pipe (13) entering and exiting the envelope (30) and being in contact with the heat absorber (12), said vacuum envelope (30) comprising a first plate (1; 101)
10 made of glass, a peripheral frame (3) disposed substantially at the periphery of the first plate (1; 101), a metallic peripheral belt (4, 5; 104) joining the peripheral frame (3) to the first plate (1; 101), **characterised** in that said metallic
15 peripheral belt (4; 104) is joined to the first glass plate (1; 101) by means of a vacuum tight bulk glass-metal seal (8; 108), comprising glass material (14; 114), said vacuum tight glass-metal seal (8; 108) being obtained by fusion and
20 subsequent solidification of said glass material (14; 114).

2. Vacuum solar thermal panel according to claim 1, characterised in that said glass material (14; 114) of the vacuum tight bulk glass-metal seal (8; 108) embeds an edge (16; 116) of the peripheral
25 belt (4; 104).

3. Vacuum solar thermal panel according to claim 1, characterised in that said glass material (14; 114) of said vacuum tight bulk glass-metal seal (8; 108) directly adheres to the metallic peripheral
30 belt (4; 104).

4. Vacuum solar thermal panel according to claim 1, characterised in that said vacuum tight bulk glass-metal seal (8) is obtained by localised

fusion and subsequent solidification of glass material (14) of the first plate (1) close to the edge (16) of the peripheral belt (4).

5 5. Vacuum solar thermal panel according to claim 1, characterised in that said vacuum tight bulk glass-metal seal comprises a meniscus of frit glass (114) joining the metallic peripheral belt (104) to the first plate (101).

10 6. Vacuum solar thermal panel according to claim 1, characterised in that said metallic peripheral belt (4; 104) comprises at least one ribbing (10; 110) making said metallic peripheral belt (4; 104) elastically deformable.

15 7. Vacuum solar thermal panel according to claim 1, characterised in that it comprises a second plate (2), substantially parallel to the first plate (1), in order to obtain a flat solar thermal panel, the heat absorber (12) being placed between the first and the second plate (1, 2) inside the
20 vacuum envelope (30).

8. Vacuum solar thermal panel according to claim 7, characterised in that said second plate (2) is made of glass, in order to have a double sided solar panel.

25 9. Vacuum solar thermal panel according to claim 1, characterised in that the metallic peripheral belt is a continuous and vacuum tight belt, and it comprises at least one elastically deformable portion (10, 110) being at least elastically
30 deformable such that it avoids that the bulk glass-metal seal gets damaged and is no more vacuum tight when subject to the evacuation process of the envelope and the thermal treatments of the panel and the potential reciprocal displacements of the

glass plate (1, 2) and the joined metallic peripheral belt (4,5; 110).

10. Vacuum solar thermal panel according to claim 9, characterised in that the at least one
5 elastically deformable portion (10, 110) of the metallic peripheral belt (4, 5; 104) is at least elastically deformable such that it permits an elastic elongation of said belt of at least 0,1 mm with respect to an axis perpendicular to the glass
10 plate (1).

11. Vacuum solar thermal panel according to claim 9, characterised in that the metallic peripheral belt (4; 104) comprises an intermediate portion provided between a first and a second portion of
15 said metallic belt, said first portion joining the first glass plate (1; 101) and comprising the vacuum tight bulk glass metal seal (8, 108), said second portion of said metallic belt (4; 104) joining the peripheral frame (3), and comprising a
20 vacuum tight metal-metal seal (6, 116); the at least one elastically deformable portion (10, 110) being provided in said intermediate portion.

12. Vacuum solar thermal panel according to claim 9, characterised in that the at least one
25 elastically deformable portion (10, 110) comprises at least one non rectilinear part, or at least one at least partially curved part, or at least one ribbing (10, 110).

13. Vacuum solar thermal panel according to claim 12, characterised in that the ribbing (10, 110) is
30 of semicircular form, has about 2 mm radius, and runs for the whole length of the peripheral belt.

14. Vacuum solar thermal panel according to claim 1, characterised in that it comprises on the inner

side of the glass plates (1, 2) an infra red low emitting coating (1C, 2C) and that said coating is chosen in such a way: that the reflectivity for wavelengths comprised between 4 and 6 micron is
5 more than 0,9 and that the transmission for wavelengths comprised between 0,25 and 1 micron is more than 0,7.

15. Vacuum solar thermal panel according to claim 14, characterised in that the glass plate on its
10 external side comprises an anti reflective coating (1B, 2B).

16. Vacuum solar thermal panel according to claim 14, characterised in that it is a single sided flat vacuum solar thermal panel comprising a metal plate
15 (2A) with its internal side comprising a low emissivity coating (2D) to enhance reflectivity for wavelengths comprised between 4 and 6 micron.

17. Vacuum solar thermal panel according to claim 1, characterised in that it is a single sided flat
20 vacuum solar thermal panel comprising a metal frame realized in one piece comprising both the peripheral frame (3) and the bottom metal plate (2).

18. Vacuum solar thermal panel according to claim
25 2, characterised in that the edge (16; 116) of the peripheral belt (4; 104) embedded in the vacuum tight bulk glass-metal seal (8; 108) is approximately perpendicular to the glass plate (1, 2)

30 19. Vacuum solar thermal panel according to claim 1, characterised in that the peripheral belt (4; 104) has a thickness comprised between 0,1 and 1 mm.

20. Vacuum solar thermal panel according to claim

1, characterised in that at least the metal portion of the belt (4, 104) embedded in the vacuum tight bulk glass-metal seal (8; 108) comprises an approximately uniform and stable oxide layer (4A, 5B) approximately regular in thickness and/or also such to improve the bond strength of glass to metal by at least 10% when measured by a shear test.

21. Method for the production of a vacuum solar thermal panel comprising a vacuum envelope (30) defining a sealed volume, able to withstand the atmospheric pressure when evacuated, said envelope (30) comprising a first plate (1; 101) made of glass and a metallic peripheral belt (4; 104), said method providing a vacuum tight glass-metal seal (8; 108) between the first plate (1; 101) and the metallic peripheral belt (4; 104), **characterised** in that the glass material (14; 114) is disposed close to the edge (16; 116) of the peripheral belt (4; 104), heated above its melting temperature and subsequently cooled to below said temperature, in order to allow the glass material (14; 114) to adhere to the metallic peripheral belt (4; 104) and join the metallic peripheral belt (4; 104) to the first plate (1; 101).

22. Method according to claim 21, characterised by the following steps:

- the first glass plate (1) is heated to a temperature close to but not reaching its softening temperature;
- the peripheral belt (4) is heated to a temperature above the first plate (1) melting temperature;
- an edge of the peripheral belt (4) is pressed against the first plate (1) in order to achieve

localized fusion and to insert the edge (16) into the first plate (1), so that the edge (16) of the peripheral belt (4) is embedded in the glass (14) of the first plate (1);

- 5 - the first plate (1) and the peripheral belt (4) are cooled to below the first plate (1) softening temperature, providing a matched vacuum tight glass-metal seal (8) between the first plate (1) and the metallic peripheral belt (4).

10 23. Method according to claim 21, characterised in that after the insertion of the edge (16) of the peripheral belt (4) into the first glass plate (1), the peripheral belt (4) is at least partially retracted from the first plate (1) to form a
15 meniscus at both sides of the edge (16) of the peripheral belt (4).

24. Method according to claim 21, characterised by the following steps:

- a frit glass paste comprising frit glass
20 material and a binder is provided;
- the frit glass paste is placed on the top of the surface of the first plate (101), to form a continuous ribbon;
- the edge 116 of the peripheral belt 104 is
25 inserted in the ribbon of the frit glass paste, contacting also the surface of the glass plate 101;
- the frit glass paste is heated and melted to form a meniscus of fused frit glass between the side of the peripheral belt (104) and the surface
30 of the first plate (101);
- the frit glass is cooled and solidified thus providing a compression vacuum tight bulk glass-metal seal (108) between the first plate (101) and the metallic peripheral belt (104).

25. Method according to claim 21, characterised by the following steps:

- a frit glass paste comprising frit glass material and a binder is provided;
- 5 - the frit glass paste is placed on the top of the surface of the first plate (101), to form a continuous ribbon;
- the ribbon is at least partially dried,
- the plate (101) with the dried ribbon is
10 placed upside down on the peripheral belt (104) touching the top edge of said peripheral belt, said ribbon being unable to flow over said peripheral belt because of said previous ribbon drying step,
- the frit glass paste is heated and melted so
15 that it may at least partially flow down along both sides of the belt and form a substantially symmetric and homogeneous meniscus of fused frit glass between the side of the peripheral belt 104 and the surface of the glass plate 101,
- 20 - the frit glass is cooled and solidified thus providing a compression vacuum tight bulk glass-metal seal (108) between the first plate (101) and the metallic peripheral belt (104).

26. Method according to claim 21, characterised by
25 applying on the inner side of the glass plate (1, 2) an infra red low emitting coating (2C 1C) being chosen such that the reflectivity of said coating for wavelengths comprised between 4 and 6 micron is more than 0,9 and that the transmission for
30 wavelengths comprised between 0,25 and 1 micron is more than 0,7.

27. Method according to claim 26, characterised in that the glass plates (1, 2) on its external side comprise an anti reflective coating (2B, 1B).

28. Method according to claim 26, characterised in that it is a single sided flat vacuum solar thermal panel comprising a metal plate (2A) with its internal side comprising a low emissivity coating(2D) to enhance reflectivity for wavelengths comprised between 4 and 6 micron.

29. Method according to claim 21, characterised by performing after the glass-metal sealing a bake-out thermal treatment on the panel, at a temperature of above 200°C.

30. Method according to claim 21, characterised by using a support structure for positioning of the glass material (14; 114) close to the edge (16; 116) of the peripheral belt (4; 104), and the heating of said glass material above its melting temperature, said support structure being dimensioned in such a way that it reaches the desired dimensions at the glass material melting temperature, said support structure at this temperature stretching the peripheral metal belt (5, 5A, 104) and positioning such belt in the desired location in respect to the glass plate (2) while keeping it in contact with the fused glass material.

31. Method according to claim 21, characterised by oxidizing at least the peripheral metal belt (5, 5A, 104) portion embedded in the vacuum tight glass-metal seal (8; 108) prior to creating such bulk glass-metal seal; said oxidation being such to produce an approximately uniform and stable oxide layer (4A 5B) approximately regular in thickness.

32. Method according to claim 21 characterised in that said oxidation is such to improve the bond strength of glass to metal by at least 10% when

measured by a shear test.

33. Method according to claim 21, characterised in that the pre-oxidation of the metal portion is realized by means of heating in an oven at a
5 temperature suitable to grow an approximately uniform oxide layer on metal component surface.

34. Method according to claim 21, characterised in that the oxidation treatment is made in an oxygen enriched atmosphere.