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(54) **CONTAINER FOR TRANSPORTING TEMPERATURE-SENSITIVE GOODS**

(57) Container (1) for transporting temperature-sensitive goods, comprising a wall structure which surrounds a loading space for receiving the goods and comprising an opening for loading and unloading the loading space, further comprising a door device (5) for selectively opening and closing the opening, wherein at least one coolant reservoir (7) for holding a coolant is arranged and/or fastened in the loading space on at least one wall of said wall structure, in particular an upper wall, wherein the at least one coolant reservoir (7) or a coolant contained therein is exchangeable via a coolant access portion of the opening, wherein a barrier element (15) is arranged to separate the loading space from the outside in a remaining portion of the opening when the door device (5) is in an open position.

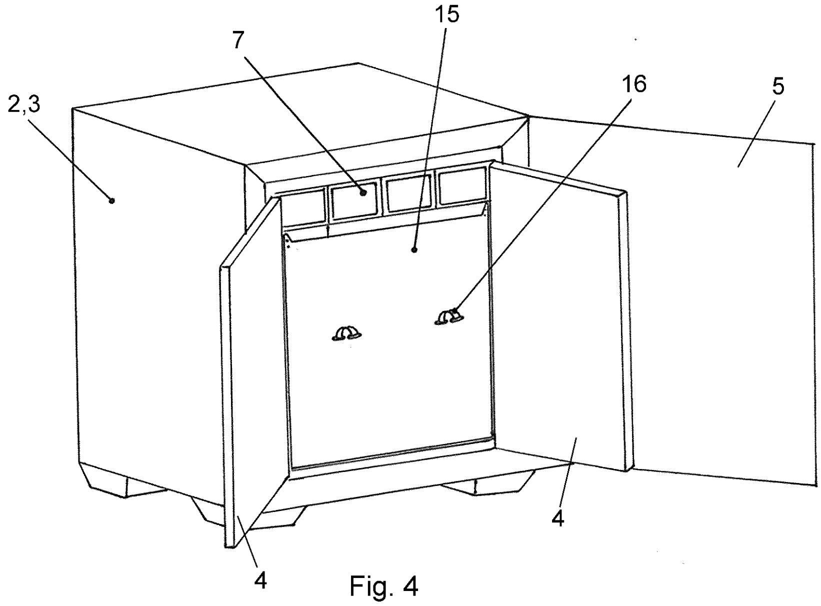

Fig. 4

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Description

[0001] The invention refers to a container for transporting temperature-sensitive goods, comprising a wall structure which surrounds a loading space for receiving the goods and comprising an opening for loading and unloading the loading space, further comprising a door device for selectively opening and closing the opening, wherein at least one coolant reservoir for holding a coolant is arranged and/or fastened in the loading space on at least one wall of said wall structure, in particular an upper wall, wherein the at least one coolant reservoir or a coolant contained therein is exchangeable via a coolant access portion of the opening.

[0002] In the pharmaceutical supply chain and logistics, a wide range of products need to be transported in temperature controlled environments. Several temperature domains can be controlled for, ranging from room temperature, around +25°C, to deep frozen temperatures, i.e. down to -90°C.

[0003] To fulfill that need, transport containers that maintain an internal temperature for a sustained amount of time are used. Such containers limit the heat transfer between the surrounding environment and their loading space by preventing the three types of heat transfer: conduction, convection and radiation. Several insulation layers, integrated in the structure of the container, prevent all three types of heat transfers when the container is closed.

[0004] However, such transport containers regularly need to be opened, either to load and unload them, or to perform routine operation during a shipment. During that phase, all three types of heat transfer are poorly accounted for, and a mass transfer of air occurs between the internal loading space and the outside environment.

[0005] Existing types of shipping containers are generally categorized by the International Air Transport Association (IATA) as active containers or passive containers. Active containers are maintained at a target temperature by means of a heat pump, requiring an electricity source to function. Passive containers do not require an energy input and rely on their insulation and on passive coolants to maintain their temperature, such as a phase-changing material (PCM), including ice or dry ice for example.

[0006] In standard operating conditions, active and passive containers are only opened to load and unload the shipped goods. However, depending on the type of coolant, some passive containers may need to be opened during a shipment to refill them with coolant and guarantee the desired interior temperature. This is particularly the case with containers cooled with dry ice.

[0007] Opening the container creates challenging conditions for the transported goods. When opening the container doors, the cold air in the loading space leaves the container within seconds, due to the difference of density between the gases present within the loading space and outside of it. This difference of density is due to the temperature difference between the two environments and can be estimated using the ideal gas law.

[0008] For a controlled temperature between +25°C and -20°C, this can be avoided by performing all operations requiring the container to be opened in a temperature controlled environment. However, when handling frozen or deep frozen containers, having a target temperature of below -20°C, environments controlled at temperatures as low as the loading space are rarely available.

[0009] This causes two issues for the goods transported in the container:

- Once the cold air has left the loading space, the transported goods find themselves in an environment that is not at the right temperature compared to the requirements. This can spoil the transported goods while operators perform refilling operations.
- After the container is closed, the hot air that has entered the container needs to be cooled again to the desired temperature, which significantly impacts the runtime of the container.

[0010] Finally, according to the ideal gas law, the greater the temperature difference between inner and outer environments, the bigger the density difference between the gases inside and outside the container. This means that the two issues described above are amplified for frozen and deep frozen containers, which are also the ones used for the transport of the most sensitive products, like vaccines.

[0011] Therefore, the instant invention aims at protecting such sensitive goods from potential temperature excursions during shipment, in particular when containers need to be opened to refill them with coolant, and thus prolonging the runtime of the transporting containers, thereby providing additional security in the transport of life-saving medicine.

[0012] In order to achieve this and other objects, the instant invention provides a container of the type mentioned at the outset, which comprises at least one coolant reservoir that is arranged and/or fastened in the loading space on at least one wall of said wall structure, in particular an upper wall, wherein the at least one coolant reservoir or a coolant contained therein is exchangeable via a coolant access portion of the opening, and which is characterized by a barrier element being arranged to separate the loading space from the outside in a remaining portion of the opening when the door device is in an open position.

[0013] The invention is based on the idea to limit the airflow between the internal loading space and the external environment, hence preventing or reducing the mass transfer of cold air from inside the container to the outside and preventing hot air from entering into the loading space when opening the container door(s). According to the invention, limiting the air exchange when opening the container door(s) is achieved by means of the barrier element. The barrier element shields the loading space from external heat. In other use cases, the barrier element may be useful to prevent or reduce mass transfer of warm air from inside the container to the outside and preventing cold air from entering into the loading space when opening the container door(s).

[0014] The barrier element is arranged so as not to impair the access to the coolant reservoir for exchanging or refilling the same. Therefore, the invention provides that the barrier element is arranged to keep clear the coolant access portion of the container opening and is thus arranged in the remaining portion of the opening.

[0015] In order to minimize the loss of energy during opening of the door(s), the barrier element shall be configured to cover as much as possible of the remaining portion of the opening, i.e. of the air flow sectional area between the loading space and the environment of the container. Therefore, a preferred embodiment of the invention provides that the barrier element covers at least 50 %, preferably at least 80%, more preferably at least 90 %, of an air exchange flow sectional area between the loading space and the outside.

[0016] Herein, the air exchange flow sectional area is preferably defined as a rectangular area enclosed by three walls of the wall structure and the coolant reservoir arranged on a fourth wall, preferably the upper wall.

[0017] Due to cold air having a higher density than warm air, cold air tends to escape from the loading space in lower areas of the available air exchange flow sectional area. Therefore, a preferred embodiment provides that a distance between the barrier element and a bottom wall of the wall structure is less than 50mm, preferably less than 30mm.

[0018] Further, the barrier element is preferably arranged to cover at least 70 %, preferably et least 90 %, more preferably at least 98 % of a width of the opening.

[0019] In order to further enhance the barrier effect of the barrier element, a preferred embodiment provides that the barrier element comprises elastic sealing elements on at least one lateral rim thereof.

[0020] Preferably, the barrier element is substantially impermeable to ambient air.

[0021] The barrier element may be made of a sheet of material, such as metal, wood, fabric, plastic or a combination thereof. Preferably, the barrier element is made of metal, which is advantageous due to its sturdiness and rigidity.

[0022] By limiting as much as possible the air exchange flow sectional area between the two spaces, the airflow is limited as much as possible. The mass transfer of cold air can be calculated as follows. The pressure difference between the top and the bottom of the container can be considered linear and expressed as $\Delta P_{vertical} = -\rho g \Delta h$. Herein, ρ represents the density of the gas, g represents the gravity of Earth and h represent the height along which the pressure difference is evaluated. The density for each volume shall be approximated as being constant given the small height of the container.

[0023] The density of gas in each volume (in the container and outside of the container) can be estimated using the ideal gas law $PV = nRT$. In this equation, P represents the pressure in a given volume, V the volume, n the amount of substance of the gas occupying the volume, R the ideal gas constant and T the temperature of the gas in the considered volume.

[0024] Because of the difference in temperature between inside and outside the container, the density and thus pressure of the gases is different inside and outside of the container. As such, this pressure difference drives the outflow of cold air out the container.

[0025] Finally, the mass flow through a constricted surface area can be expressed as $\dot{M} = C_f S \sqrt{\Delta P_{across} \rho}$. Here, C_f represents the friction coefficient, S the surface area through which the gas can flow, ΔP_{across} the pressure difference across the exchange area and ρ the density of the gas flowing out through the constricted area. ΔP_{across} is expressed as $P_{in}-P_{out}$. The inner and outer pressures are expressed according to the expression of $\Delta P_{vertical}$ and vary depending on the height at which the opening is positioned.

[0026] This shows two important relations:

First, the mass flow is directly proportional to the exchange surface area ($\dot{M} \propto S$), and that the time needed for the cold air to leave the container is inversely proportional to the exchange surface area $(t \propto \frac{1}{S})$. This shows that the exchange surface covered by the barrier element is a decisive factor in the efficiency of the barrier element.

Second, the mass flow is proportional to the square root of the height at which the opening is positioned $(\dot{M} \propto \sqrt{h})$, and the time needed for the cold air to leave the container is inversely proportional to the square root of the height at which the opening is positioned $(t \propto \sqrt{h})$. This shows that the second determining factor of the efficiency of the barrier element is the position of openings not covered by the barrier element. Indeed, since the pressure varies vertically, the container empties faster with an opening at the bottom.

[0027] The container of the invention is preferably configured for transporting temperature-sensitive goods, such as pharmaceuticals, over a period of several days, wherein specified temperature ranges must be maintained during storage and transport in order to ensure the usability and safety of the goods being transported. Preferably, the container of the invention is configured to maintain the loading space at a temperature of -60°C to -80°C over at least 3-5 days, which corresponds to specified storage and transport conditions for various drugs and vaccines.

[0028] Preferably, dry ice (solid CO_2) is used as a coolant, which is ideal for this temperature range due to its sublimation temperature of approx. -78.5°C. In addition, an amount of energy of 571.1 kJ/kg is required for the phase transition from solid to gas (sublimation), which enables a very large cooling effect with low weight compared to commercially available phase change material in a similar temperature range (≈200 kJ/kg). Another advantage of dry ice is its residue-free dissolution. It is only necessary to ensure safe drainage of the gaseous carbon dioxide, which at normal pressure and a temperature of 0°C occupies about 760 times the volume of the dry ice. For air transport, there are usually maximum sublimation rates or dry ice quantities per flight, which must not be exceeded. Minimizing the amount of dry ice used per kg of cargo therefore directly affects the total amount of cargo allowed per flight.

[0029] An efficient use of the coolant, such as dry ice, may preferably be achieved, if the wall structure and/or the door device is designed as a layered structure comprising, from the outside to the inside, a first insulating layer, optionally a second insulating layer, and an energy distribution layer bounding the loading space and made of a material with a thermal conductivity of > 100 W/(m.K).

[0030] By combining a coolant reservoir for holding the coolant, such as dry ice, that is arranged and/or fastened in the loading space on at least one wall, with an energy distribution layer bounding the loading space, efficient heat distribution is achieved over the entire interior shell so that the amount of coolant can be minimized. Due to the heat distribution, it is sufficient here to arrange the coolant on only one wall. However, it is also conceivable to provide the coolant on two or more walls. The highly heat-conductive inner shell allows very efficient use of the dry ice, with heat input at any location of the container being conducted to the coolant and absorbed there, so that asymmetrical heat input is compensated and a non-uniform consumption of the dry ice is avoided.

[0031] Preferably, the at least one coolant reservoir or its support structure is directly connected to the energy distribution layer in a thermally conductive manner, the thermally conductive connection preferably having a thermal conductivity of > 100 W/(m.K).

[0032] The energy distribution layer bounding the loading space is preferably in direct contact with the loading space, so that direct heat transfer between the loading space and the energy distribution layer is ensured.

[0033] Since convection is not required for heat distribution over the entire loading space, the loading space can be used entirely for the payload. No air gaps are required to maintain air circulation.

[0034] The highly efficient use of dry ice by internal heat distribution in combination with a two-layer insulation of the container wall results in a running time of more than 100-140h at an average outside temperature of 30°C with a dry ice quantity of 80-120 kg and a payload volume of 1 to 1.5 m^3 with an outside volume of 2-4 m^3. This is a significant improvement by a factor of 2 to 20 compared to conventional solutions, allowing a payload volume of 1 to 1.5 m^3 per RKN aircraft position, or 4 transport containers to be arranged on a PMC pallet with a total payload volume of $4 \times 1.5 m^3$ or $6 m^3$.

[0035] As far as the layered structure of the container wall is concerned, it is preferably provided that the first insulation layer, the second insulation layer, if present, and the energy distribution layer lie directly on top of each other.

[0036] Preferably, the first insulating layer, the second insulating layer, if present, and the energy distribution layer surround the loading space on all sides and without interruption, with the exception of the opening. The energy distribution layer completely surrounds the loading space with the exception of the opening, i.e. each wall of the container wall comprises the energy distribution layer as the innermost layer, the energy distribution layers of all walls being connected to one another in the adjacent edges and corners in a thermally conductive manner, i.e. by means of a joint which has a thermal conductivity of > 100 W/(m.K).

[0037] Preferably, the door device also comprises the layered structure used for the container wall structure. In particular, the door device consists of a layered structure comprising, from the outside to the inside: a first insulation layer, optionally a second insulation layer, and an energy distribution layer bounding the loading space and made of a material with a thermal conductivity of > 100 W/(m.K).

[0038] For sufficient heat distribution, a thermal conductivity of the energy distribution layer of at least 100 W/(m.K) is specified. The higher the thermal conductivity of the energy distribution layer is selected, the more efficient the utilization of the coolant. According to a preferred embodiment, it may be provided that the thermal conductivity of the energy distribution layer of the wall structure and/or the door device is at least 140 W/(m.K), more preferably at least 180 W/(m.K). The energy distribution layer of the container wall and/or the door device may, for example, be made of aluminum, of graphite or of a graphite composite material, in particular graphite sheets coated on both sides with carbon fiber-reinforced plastic. Such materials also result in mechanical reinforcement of the container wall at low weight.

[0039] In the case of aluminum, 0.5-5 mm thick aluminum plates can be used, which have a thermal conductivity of about 150 W/(m.K), distributing local heat inputs across the inner shell and resulting in a uniform temperature distribution in the loading space. The joints of the individual aluminum panels on the sides and corners can be reinforced with rivets so that they can withstand the forces generated by thermal stresses.

[0040] In the case of the design of the energy distribution layer made of carbon graphite composite plates, for example, composite plates can consist of a 0.2-1 mm thick graphite core laminated on both sides with 0.2-2 mm thick plates made of carbon fiber reinforced plastic (CFRP). Since graphite exhibits thermal conductivities of up to 400 W/(m.K) depending on density, carbon graphite composite sheets can achieve similar or higher average thermal conductivities than comparable aluminum sheets. In addition, CFRP has a better mechanical strength-to-weight ratio than aluminum, allowing for weight savings. Another advantage of carbon graphite composite panels is the low coefficient of thermal expansion of CFRP. Typical values in the fiber direction are $\alpha_{CFK} = 0.6 \cdot 10^{-6}\ K^{-1}$. For comparison, the coefficient of thermal expansion of a common aluminum alloy: $\alpha_{EN\text{-}AW\ 5754} = 23.8 \cdot 10^{-6}\ K^{-1}$. This reduces thermal stresses and resulting mechanical loads on the inner shell.

[0041] In a particularly preferred manner, the at least one coolant reservoir is designed as a drawer that is guided in a guidance element such that it can be pulled out of and pushed into the loading space. Such a design permits extremely simple handling, in which the coolant can be filled or renewed without having to disassemble the container or remove the payload. The running time of the container can be extended as desired by refilling the coolant.

[0042] Preferably, the drawer(s) has/have dimensions such that the entire dimension of a wall of the container wall structure is covered by the drawer(s).

[0043] Preferably, the at least one coolant reservoir, in particular the drawer(s) as well as the drawer guide, which is attached to at least one wall, also consists of a highly heat-conductive material, so that the heat introduced is distributed evenly over the coolant. Here, it is preferably provided that the at least one coolant container is made of a material with a thermal conductivity of > 100 W/(m.K), preferably > 140 W/(m.K), in particular > 180 W/(m.K), for example of aluminum, of graphite or of a graphite composite material, in particular of graphite sheets coated on both sides with carbon fiber-reinforced plastic.

[0044] In order to enable an easy installation and removal of the barrier element, a preferred embodiment provides that the barrier element is removably fixed to the wall structure and/or the guidance element of the drawer. Alternatively, the barrier element may be pivotably mounted to a wall of the wall structure and/or to the guidance element of the drawer.

[0045] Different fixture methods may be used, including ropes, hooks, hinges, zippers, tape, handles, glue, screws, rivets, buckles, cable ties, Velcro. The solution that guarantees the most easy handling of the heatshield is to use hooks to hang the barrier element to the coolant reservoir, in particular to the drawer guide.

[0046] The thermal insulation of the container is preferably achieved by a first and, if necessary, a second insulation layer. The structure of the container wall with at least two insulation layers allows each insulation layer to be optimized with regard to its respective insulation function. Preferably, one of the insulation layers, in particular the first, outer insulation layer, is designed to minimize heat transfer to the loading space via thermal radiation. The other insulation layer, in particular the second, inner insulation layer, may be formed to minimize heat transfer to the loading space occurring via heat conduction.

[0047] Preferably, the first insulation layer may have a thermal conductivity of 4 to 300 mW/(m.K) and the second insulation layer may have a thermal conductivity of 1 to 30 mW/(m.K), with the first insulation layer preferably having a higher thermal conductivity than the second insulation layer.

[0048] This can result in a U-value for the transport container of 0.1-0.2 W/m^2K, which corresponds to a very low heat input compared to containers commonly used in the industry.

[0049] With regard to the design of one of the insulation layers, preferably the first insulation layer, as a barrier against thermal radiation, it may comprise a heat-reflective coated substrate, such as a substrate provided with a metal coating. Preferably, the heat-reflective coating is formed by a metallic, in particular gas-tight coating, preferably a coating with an emissivity of < 0.5, preferably < 0.2, particularly preferably < 0.04, such as a coating of aluminum. Preferably, it is provided that said insulation layer comprises a multilayer structure of honeycomb-shaped thermoformed plastic films, which is provided on both sides with a heat-reflecting coating, in particular of aluminum.

[0050] An advantageous design results if said insulation layer has a plurality of, in particular, honeycomb-shaped hollow chambers, a honeycomb structural element according to WO 2011/032299 A1 being particularly advantageous. Alternatively, said insulation layer may be made of a conventional porous insulation material, such as polyurethane, polyisocyanurate or expanded polystyrene. Preferably, said insulation layer has a thickness of 60-80 mm.

[0051] With regard to the design of the other insulation layer, preferably the second insulation layer, as a barrier against heat conduction, said insulation layer may preferably be designed as vacuum insulation and preferably comprise or consist of vacuum insulation panels.

[0052] Preferably, the second insulation layer has a thickness of 30-50 mm.

[0053] Preferably, the vacuum insulation panels have a porous core material as a support body for the vacuum present in the interior and a gas-tight envelope surrounding the core material, the core material preferably consisting of an aerogel, open-pore polyurethane or open-pore polyisocyanurate. The advantage of these core materials over conventional fumed silica is their lower density, which can result in weight savings over conventional vacuum panels. The density of aerogel, for example, is in the range 80-140 kg/m^3, whereas fumed silica typically has a density of 160-240 kg/m^3, both materials having similar thermal conductivity properties in the range 2-6 mW/(m.K).

[0054] Alternatively, the second insulation layer may have an outer wall, an inner wall spaced therefrom, and a vacuum chamber formed between the outer and inner walls, the vacuum chamber being a continuous vacuum chamber surrounding the loading space on all sides except for the opening. This insulation layer of the container wall is thus designed as a double-walled vacuum container which surrounds the loading space on all sides with the exception of the container opening. In contrast to the use of conventional vacuum panels, the insulation therefore does not consist of individual vacuum elements that have to be assembled to form an envelope, but instead encompasses in one piece all sides of the container with the exception of the opening. Since a continuous vacuum chamber is formed between the inner and outer walls of the insulation layer, which surrounds the loading space on all sides with the exception of the opening, joints between the separate vacuum panels that would otherwise be required and the associated thermal bridges can be avoided. The double-walled design of the insulation layer is also self-supporting, so that in addition to insulation it also has a stabilizing function. This means that load-bearing structural components can be eliminated.

[0055] The term "vacuum chamber" means that the space between the inner and outer walls of the insulation layer is evacuated, thereby achieving thermal insulation by reducing or preventing heat conduction of the gas molecules through the vacuum. Preferably, the air pressure in the vacuum chamber is 0.001-0.1 mbar.

[0056] Preferably, it is provided here that the outer and inner walls consist of a metal sheet, in particular stainless steel, aluminum or titanium, and preferably have a thickness of 0.01 to 1 mm. This ensures on the one hand the required stability and on the other hand the gas-tight design of the walls. In such an embodiment, the inner wall of the insulation layer, when arranged as the second insulation layer, can simultaneously form the energy distribution layer.

[0057] In order to be able to withstand the compressive forces of the surrounding air without having to make the outer and inner walls of the insulation layer excessively thick, the outer wall and the inner wall are preferably connected by a plurality of spacers, which are preferably made of a synthetic material with a thermal conductivity of < 0.35 W/(m·K), such as polyetheretherketone or aramid. The spacers ensure the desired distance between the outer and inner walls so that the intervening cavity, i.e., the vacuum chamber, remains. Since the spacers form thermal bridges, it is advantageous to form them from a material with the lowest possible thermal conductivity.

[0058] In order to further increase the thermal insulation performance of the insulation layer, a preferred further embodiment provides that a plurality of insulation foils lying at a distance above one another are arranged in the vacuum chamber, the foil plane of which runs essentially parallel to the plane of the outer and inner walls. In particular, the insulation foils are present in stacked form, with a foil stack preferably being arranged in each wall of the container wall and extending substantially over the entire wall. Preferably, the insulation foils are arranged to surround the loading space on all sides except for the opening.

[0059] Preferably, the insulation foils are arranged in such a way that a space (protective space) remains between the inner surface of the outer wall or the inner wall facing the vacuum chamber and the foil stack in each case, so that the foil stack is not compressed by possible deformations of the walls. In addition, the space provides room for structural stabilization of the spacers and facilitates vacuuming.

[0060] A further preferred embodiment provides that the insulation foils are held spaced apart from one another by planar spacer elements, the planar spacer elements preferably being formed by a textile sheet material, in particular being formed as a polyester nonwoven.

[0061] In particular, the insulation foils can be designed as metal-coated or metal-vaporized plastic films. Such insulation foils are also referred to as superinsulation films. The metal coating is made of aluminum, for example.

[0062] The overall performance of the insulation of the transport container naturally also depends on the thermal insulation properties of the door device closing the opening of the interior. As already mentioned, the door device can in this case consist of a layered structure corresponding to the layered structure of the container wall and comprising, from the outside to the inside, a first insulation layer, a second insulation layer and an energy distribution layer bounding the loading space and made of a material with a thermal conductivity of > 100 W/(m.K).

[0063] In a particularly preferred embodiment, the door device comprises at least one inner door leaf and at least one outer door leaf. In particular, the door leaves are hinged doors attached to the container by means of a hinge. The arrangement of at least one outer door leaf and at least one inner door leaf gives rise to a two-layer construction, in which the at least one outer door leaf preferably forms the first insulation layer of the door device and the at least one inner door leaf forms the second insulation layer of the door device, reference being made to the functions and properties described above in connection with the insulation layers of the container wall with respect to the properties and construction of the first and second insulation layers.

[0064] The at least one outer door leaf and the at least one inner door leaf can preferably be opened and closed separately and independently of each other. The double-walled construction of the door device results in a temperature around 0°C (between -20°C and 8°C) on the outside of the at least one inner door leaf at an interior temperature of - 60°C to -80°C. This makes it possible to open the inner door leaf manually (i.e., without risk of cold burn) during operation. Preferably, this effect is achieved by the at least one inner door leaf having a higher insulation performance (1 to 30 mW/(m.K)) than the at least one outer door leaf (4 to 300 mW/(m.K)).

[0065] In a preferred embodiment, the door device comprises a single outer door leaf and two inner door leaves to form an inner double door.

[0066] Preferably, the at least one outer door leaf and the at least one inner door leaf are each sized to entirely cover the opening, including the coolant reservoir(s) and the barrier element. Thus, after having opened the at least one outer door leaf and the at least one inner door leaf, the loading space of the container remains at least partly closed by means of the barrier element, while the coolant reservoir, such as in the form of a drawer, can be pulled out of the loading space.

[0067] When containers are carried by air, containers must allow pressure equalization between the loading space and the pressurized cabin of the aircraft, especially since the cabin pressure prevailing in the passenger cabin and the cargo hold is set lower than this corresponds to the ambient air pressure during takeoff and landing. For pressure equalization, containers are usually equipped with a valve or door seal that allows air to flow out of the loading space to the outside (during climb) or from the outside into the loading space (during descent) when a predetermined differential pressure between the environment and the loading space is exceeded. In the latter case, however, warm ambient air enters the loading space with the air flow, which has a significantly colder temperature compared to the surroundings, so that the temperature can fall below the dew point and water can condense from the air. The occurrence of condensate in the loading space is undesirable because it affects the transported goods.

[0068] In order to avoid condensation in the interior of the container, it is preferably provided that at least one inner circumferential seal is provided between the at least one inner door leaf and the opening of the container wall and at least one outer circumferential seal is provided between the at least one outer door leaf and the opening of the container wall, and that a buffer space is arranged between the at least one inner door leaf and the at least one outer door leaf. This measure is based on the idea of cooling the air entering from the environment due to pressure equalization before it enters the loading space of the container. For this purpose, a buffer space is created, formed between the outer and inner circumferential seals, into which the ambient air flows before entering the loading space, if necessary. The double-walled door structure consisting of an inner and outer door leaf, together with the internal temperature of -60 to -80°C as described above, ensures that a temperature of around 0°C prevails on the outside of the inner door leaf, so that the buffer space formed in the intermediate space between the outer and inner door leaf is cooled. Due to the pre-cooling of the ambient air in the buffer space, drying also takes place, with any condensate occurring along the flow path of the air upstream of the loading space and in particular in the buffer space, but in any case not in the loading space itself.

[0069] At the same time, it should be taken into account that in the case of dry ice, CO_2 gas is generated during consumption of the same, which should escape from the loading space. The inner and outer seals therefore preferably each comprise at least one sealing element which can be displaced by pressure difference and which opens a gas passage from the inside to the outside when a predetermined pressure difference is exceeded.

[0070] The generation of CO_2 gas in the loading space can also compensate for a pressure equalization during descent, where otherwise an airflow from the outside into the loading space (during descent) would occur. This further reduces the risk of air ingress, including humidity, compared to using a non-sublimating coolant.

[0071] In this case, the inner circumferential seal can be designed in such a way that it allows the CO_2 gas produced to escape, but at the same time largely prevents warm ambient air from flowing in. Together with the outer circumferential seal, this creates a labyrinth which, on the one hand, allows the CO_2 gas to escape and, on the other hand, ensures that the moisture of incoming air condenses on the outside of the at least one inner door leaf, which has a temperature of around 0°C (between -20°C and 8°C). This prevents the moisture in the air from penetrating into the loading space and the associated formation of ice.

[0072] A preferred design of the thermal insulation provides that the at least one inner door leaf comprises an inner aluminum shell and an outer aluminum shell and that a vacuum thermal insulation, preferably vacuum insulation panels, is or are arranged between the inner and outer aluminum shells for their thermal decoupling. For example, 30-50 mm thick vacuum insulation panels can be used. The inner and outer aluminum shells can be held together with connecting elements made of low-heat-conducting, cold-resistant plastic (e.g. PEEK).

[0073] The outer door leaf may be insulated with a 60-80 mm thick multi-layered structure of honeycomb thermoformed PET films coated on both sides with aluminum.

[0074] The insulation of the outer door leaf can be further improved by inserting additional vacuum panels or partially replacing the existing insulation with vacuum panels. This reduces the heat input through the outer door leaf and therefore has a beneficial effect on the transit time of the container.

[0075] The container or container wall can be of various geometric shapes, in which a plurality of walls adjacent to each other at an angle are provided. Preferably, it is a cuboid container having six walls, of which the wall structure forms five walls and the door device forms the sixth wall.

[0076] The container according to the invention is preferably designed as an air freight container and therefore preferably has external dimensions of at least 0.4x0.4x0.4 m, preferably 0.4x0.4x0.4 m^3 to $1.6\times1.6\times1.6$ m^3, preferably $1.0\times1.0\times1.0$ m^3 to

1.6×1.6×1.6 m^3.

[0077] Preferably, the first insulation layer of the container wall forms the outer surface of the container so that no other layers or elements are attached to the outer wall. Alternatively, another thermal insulation layer can be arranged on the outside of the first insulation layer, or a layer that protects the container from mechanical impact and damage.

[0078] Dry ice is preferably used as a coolant. However, other phase change materials are also possible. Common phase change materials based on kerosene or salt hydrate or other materials with high enthalpy are suitable as coolants. The target temperature that can be achieved in the loading space of the container depends on the selection of the coolant and is not limited to specific temperature ranges within the scope of the present invention. Therefore, the transport container can be operated not only in a range of -60 to -80°C, but also in a range of 25 to -15°C, for example.

[0079] In order to be able to detect any damage to the container, it is preferably provided that at least one temperature sensor is arranged in the loading space, and preferably at least one temperature sensor on each side of the container. Based on the measured values of the at least one temperature sensor, the performance of the insulation can be continuously monitored. In addition, a sensor can be arranged to measure the ambient temperature, whereby the insulation performance of the container wall can be continuously calculated from the temperature difference curve of the at least one temperature sensor arranged in the loading space and the external temperature sensor. This data can be continuously transmitted to a central database by wireless data transmission means, so that the functional efficiency of the container can be globally monitored and ensured.

[0080] The invention will now be described in more detail with reference to the attached drawings. Therein, Fig. 1 shows a perspective view of a container according to the invention with the barrier element being unmounted, Fig. 2 shows a cross section of the container of Fig. 1 with the doors being closed, Fig. 3 shows a detailed view of region A of

[0081] Fig. 2, Fig. 4 shows the container of Fig. 1 with the barrier element being mounted und Fig. 5 shows a detailed view of the fixation of the barrier element to the container.

[0082] Fig. 1 shows a cuboid container 1 whose container wall surrounds a loading space on all sides except for an opening. The container wall comprises two side walls, a rear wall, a bottom and a top wall.

[0083] The container wall consists of multilayer insulation 2 and 3, an inner double door 4, an outer door 5, an energy distribution layer 6 forming the inner shell, drawers 7 with dry ice and a drawer guide 8, which are attached to the energy distribution layer 6 of the top wall.

[0084] As can be seen in the sectional view according to Fig. 2, the insulation consists of an outer, first insulation layer 2 and an inner, second insulation layer 3. The first insulation layer has a thickness of, for example, 60-80 mm and consists of a multilayer structure of honeycomb-shaped deep-drawn PET films coated on both sides with aluminum. This achieves an insulation performance of the first insulation layer of 4 to 300 mW/(m.K). The second insulation layer 3 has a thickness of 30-50 mm and consists of a high-performance insulation, such as vacuum insulation panels (VIP) or aerogel, thus achieving an insulation performance of 1 to 30 mW/(m.K).

[0085] In the area of the front opening of the container, the inner double door 4 can be attributed to the inner, second insulation layer 3 and the outer door 5 to the outer, first insulation layer 2. As shown in Fig. 3, the inner double door 4 consists of an inner 13 and an outer aluminum half-shell 14, respectively, with the inner and outer shells being thermally decoupled. The decoupling is achieved with an inner insulation 3 made of a 30-50 mm thick high-performance insulation, such as vacuum panels, and connecting elements made of low-heat conducting, cold-resistant plastic 12 (e.g., PEEK). The outer door 5 is insulated with a 60-80 mm thick, multilayer structure of honeycomb deep-drawn PET films coated on both sides with aluminum. The combination of high insulation performance of the inner double door 4 (1 to 30 mW/(m.K)) and medium insulation performance of the outer door 5 (4 to 300 mW/(m.K)) results in a temperature of around 0°C (between - 20°C and 8°C) on the outside of the inner double door 4 at an interior temperature of -60°C to -80°C. This makes it possible to open the inner double door 4 manually (without risk of cold burns) during operation.

[0086] On the edge of the inner door 4 there is a seal 11 which allows the CO_2 gas produced to escape, but at the same time largely prevents warm ambient air from flowing in. Seals 10 are also located on the outer door so that, together with the inner door seal 11, a labyrinth is created which, on the one hand, allows the CO_2 gas that is generated to escape and, on the other hand, ensures that the moisture of incoming air condenses on the outside of the inner double door 4, which has a temperature around 0°C (between -20°C and 8°C). This prevents the moisture in the air from penetrating into the interior and the associated formation of ice.

[0087] The energy distribution layer 6 consists, for example, of 0.5-5 mm thick aluminum plates. These have a thermal conductivity of about 150 W/(m.K), which distributes local heat inputs across the inner shell and results in a uniform temperature distribution in the loading space. The joints between the individual aluminum panels at the sides and corners are reinforced with rivets so that they can withstand the forces generated by thermal stresses.

[0088] The drawers 7 as well as the drawer guides 8, which are attached to the top of the inner shell 6, are also made of 0.5-5 mm thick aluminum plates with a thermal conductivity of 150 W/(m.K). The dry ice 9 is introduced directly into the drawers.

[0089] Fig. 4 shows the container 1 with a plate-like barrier element 15 being installed, in order to minimize heat exchange between the loading space and the environment when the inner doors 4 and the outer door 5 are open. As can be seen, the barrier element 15 covers essentially the entire area of the opening through which air could be exchanged between the loading space and the environment, but leaves the drawers 7 unobstructed. Handles 16 are arranged in order to facilitate manipulation of the barrier element 15.

[0090] As shown in Fig. 5, the barrier element 15 may be fixed to the container by means of a hook 18 that engages with a bearing element 17 arranged on the drawer guide 8 or a wall of the container. A hook 18 is arranged on each of the two lateral sides of the barrier element 15.

Claims

1. Container for transporting temperature-sensitive goods, comprising a wall structure which surrounds a loading space for receiving the goods and comprising an opening for loading and unloading the loading space, further comprising a door device for selectively opening and closing the opening, wherein at least one coolant reservoir for holding a coolant is arranged and/or fastened in the loading space on at least one wall of said wall structure, in particular an upper wall, wherein the at least one coolant reservoir or a coolant contained therein is exchangeable via a coolant access portion of the opening, **characterized in that** a barrier element is arranged to separate the loading space from the outside in a remaining portion of the opening when the door device is in an open position.

2. Container according to claim 1, **characterized in that** the barrier element is substantially impermeable to ambient air.

3. Container according to claim 1 or 2, **characterized in that** the barrier element is made of a sheet of material, such as metal, wood, fabric, plastic or a combination thereof.

4. Container according to claim 1, 2 or 3, **characterized in that** the barrier element covers at least 50 %, preferably at least 80%, more preferably at least 90 %, of an air exchange flow sectional area between the loading space and the outside.

5. Container according to claim 4, **characterized in that** the air exchange flow sectional area is defined as a rectangular area enclosed by three walls of the wall structure and the coolant reservoir arranged on a fourth wall, preferably the upper wall.

6. Container according to any one of claims 1 to 5, **characterized in that** a distance between the barrier element and a bottom wall of the wall structure is less than 50mm, preferably less than 30mm.

7. Container according to any one of claims 1 to 6, **characterized in that** the barrier element is arranged to cover at least 70 %, preferably et least 90 %, more preferably at least 98 % of a width of the opening.

8. Container according to any one of claims 1 to 7, **characterized in that** the barrier element comprises elastic sealing elements on at least one lateral rim thereof.

9. Container according to any one of claims 1 to 8, **characterized in that** the at least one coolant reservoir is a drawer which is guided in a guidance element such that it can be pulled out of and into the loading space.

10. Container according to any one of claims 1 to 9, **characterized in that** the barrier element is removably fixed to the wall structure and/or the guidance element of the drawer.

11. Container according to any one of claims 1 to 9, **characterized in that** the barrier element is pivotably mounted to a wall of the wall structure and/or to the guidance element of the drawer.

12. Container according to any one of claims 1 to 11, **characterized in that** the wall structure and/or the door device is designed as a layered structure comprising, from the outside to the inside, a first insulating layer, optionally a second insulating layer, and an energy distribution layer bounding the loading space and made of a material with a thermal conductivity of > 100 W/(m.K).

13. Container according to any one of claims 1 to 11, **characterized in that** the door device comprises at least one inner door leaf and at least one outer door leaf.

14. Container according to any one of claims 1 to 13, **characterized in that** dry ice is arranged in the at least one coolant reservoir.

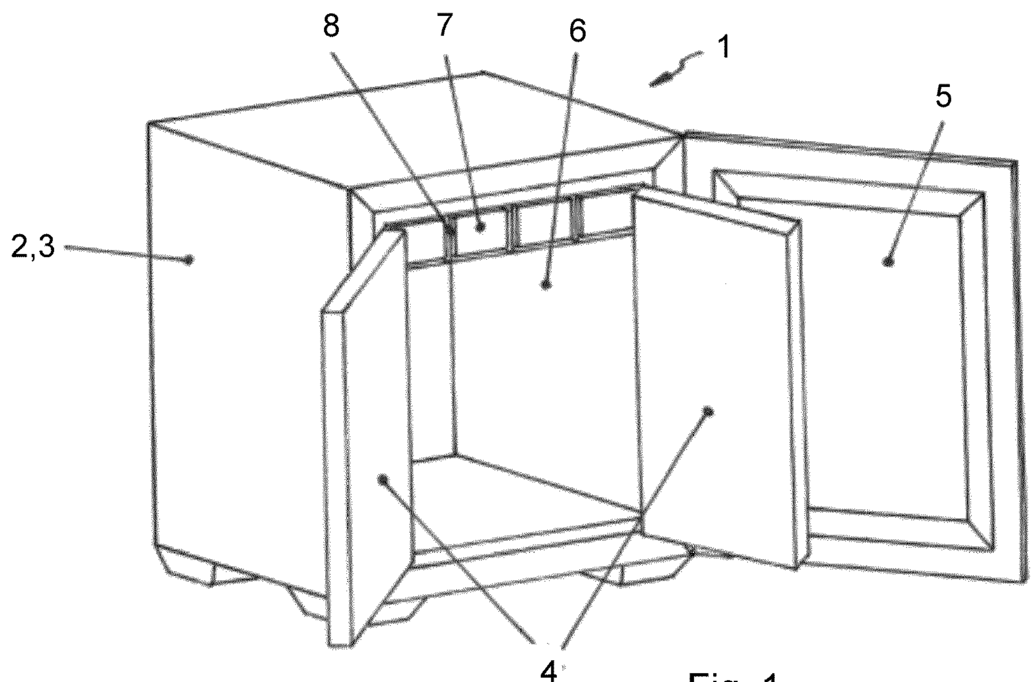

Fig. 1

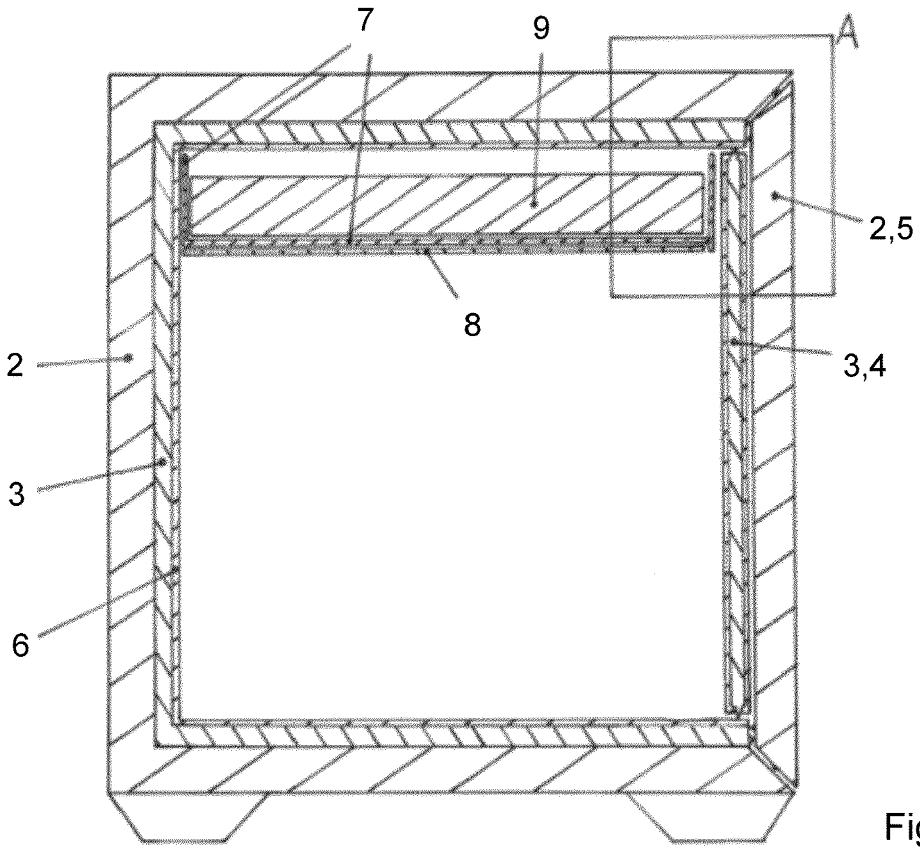

Fig. 2

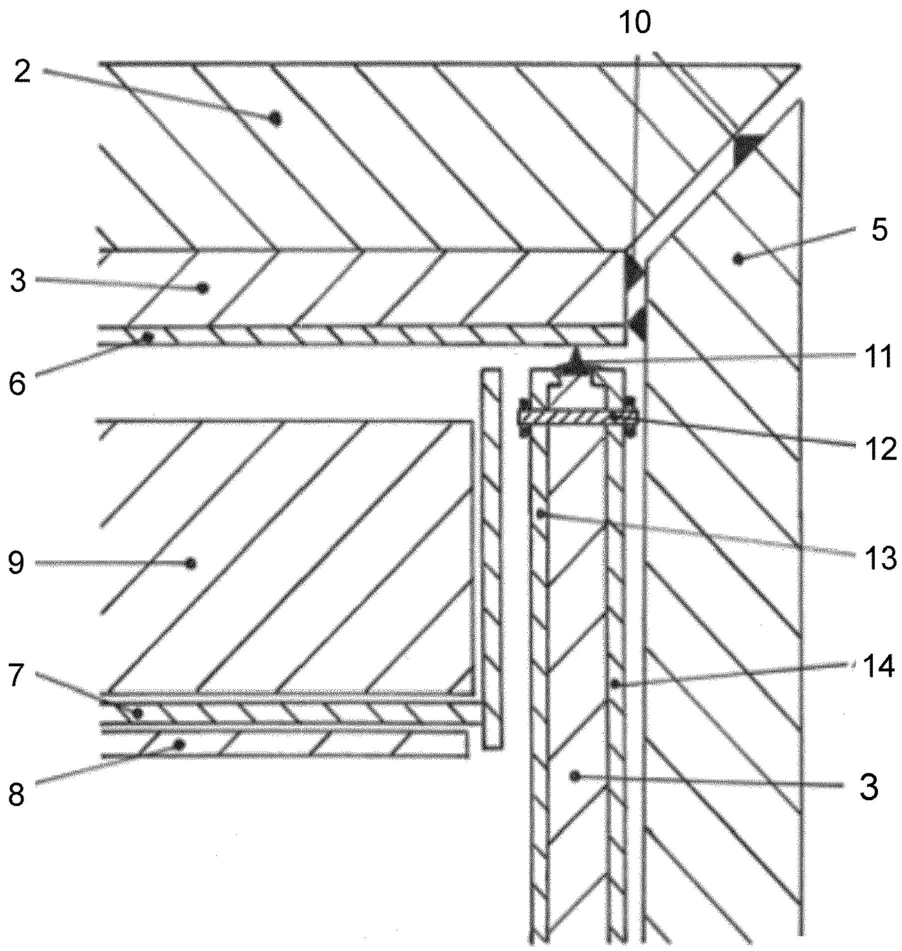

Fig. 3

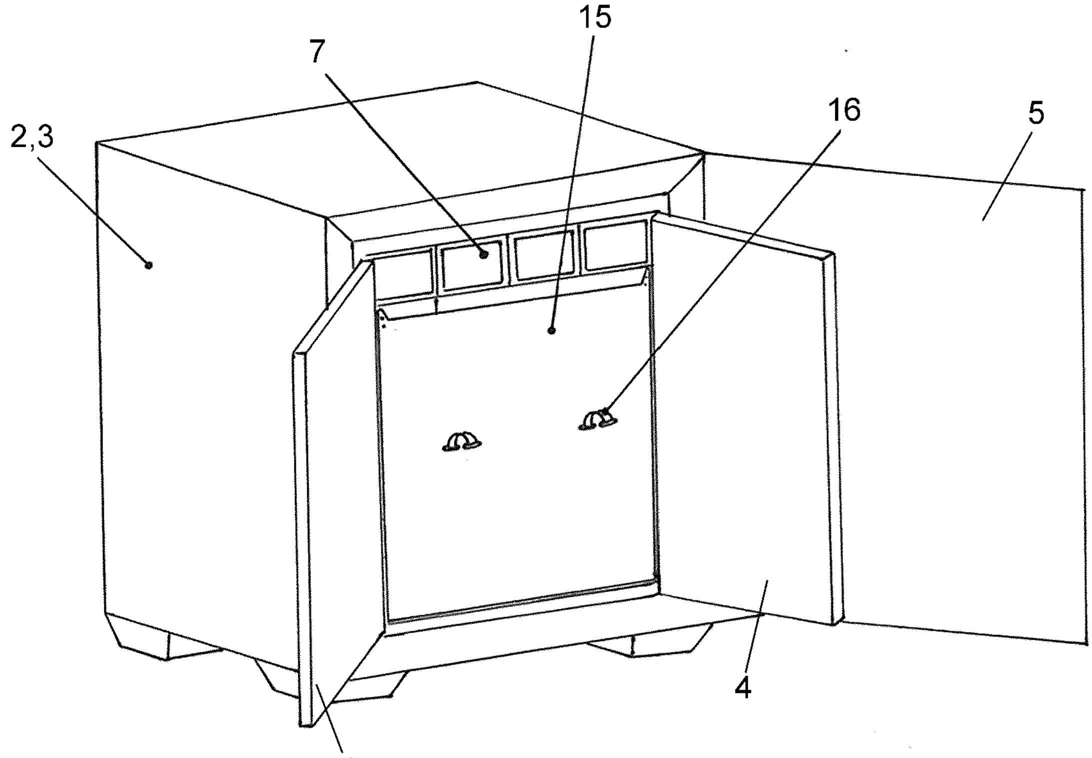

Fig. 4

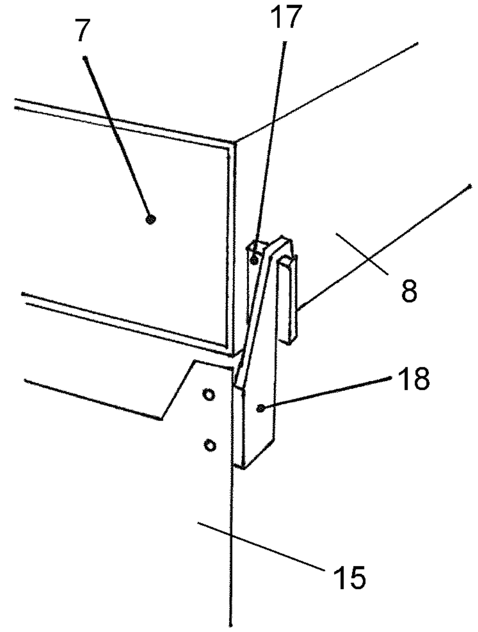

Fig. 5

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Application Number
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	14 December 2022	Correia dos Reis, I

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EUROPEAN SEARCH REPORT

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