US 20080092556A1

(19) **United States**

(12) **Patent Application Publication**

Stein et al.

(10) **Pub. No.: US 2008/0092556 A1**

(43) **Pub. Date: Apr. 24, 2008**

(54) **CRYOGENIC COOLING DEVICE**

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(21) Appl. No.: **11/572,836**

(22) PCT Filed: **Jul. 28, 2005**

(86) PCT No.: **PCT/EP05/53707**

§ 371 (c)(1), (2), (4) Date: **Nov. 5, 2007**

(30) **Foreign Application Priority Data**

Jul. 28, 2004 (DE) 10 2004 036 483.4
Sep. 10, 2004 (DE) 10 2004 043 900.1

Publication Classification

(51) **Int. Cl.**
F25D 3/10 (2006.01)

(52) **U.S. Cl.** **62/45.1**; 62/529

(57) **ABSTRACT**

The present invention relates to a cryo temperature cooling device (**1**)comprising 5 a tank (**2**), being filled up at least in part with a coolant (**3**), and a heat conducting element (**4**), whereas the heat conducting element (**4**) can be brought into thermal contact with the coolant (**3**), so that the coolant has a phase transition occurring below a temperature of −100° C., so that the cryogenic cooling device more or less consumes no coolant during operation.

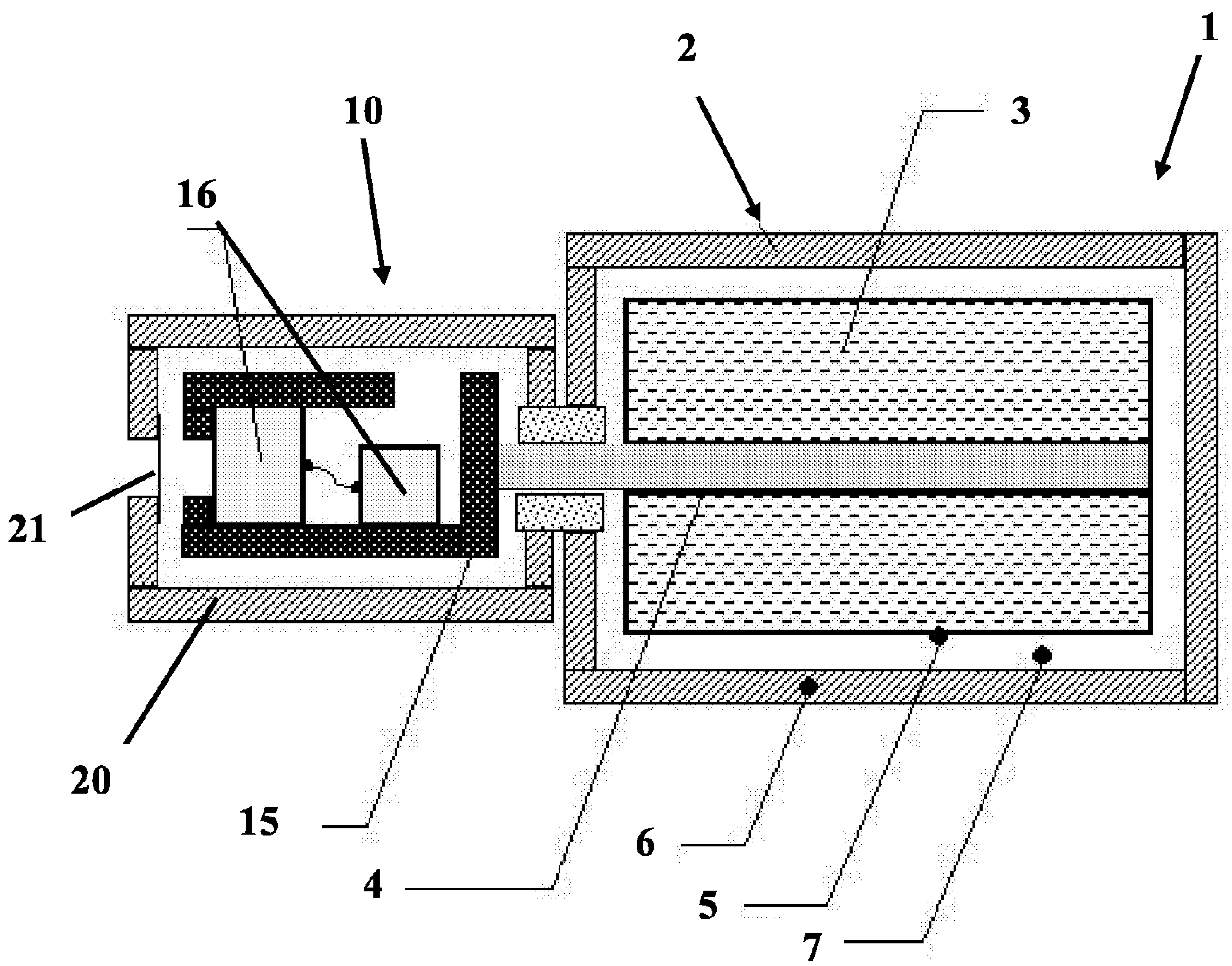


Figure 1

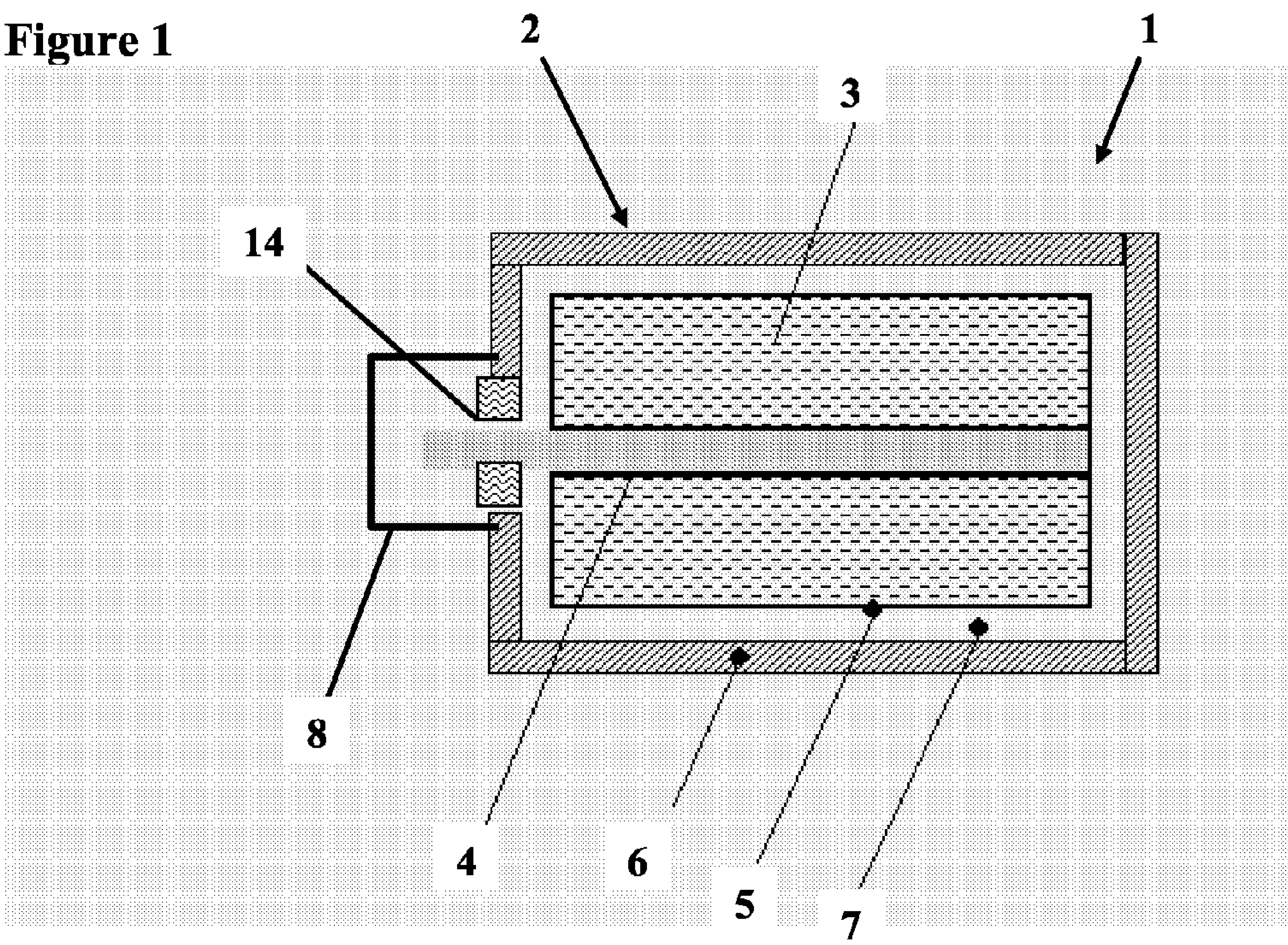


Figure 2

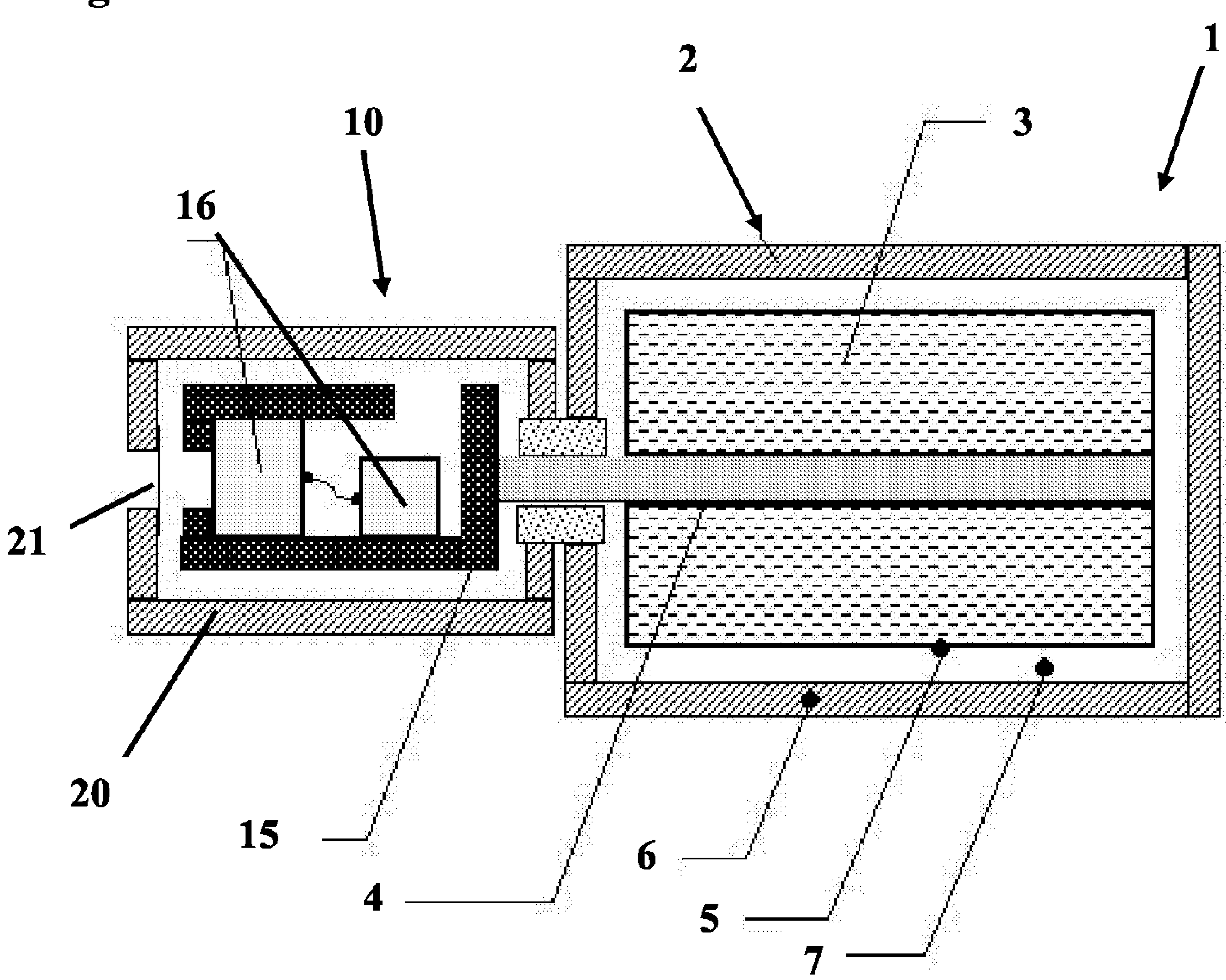


Figure 3

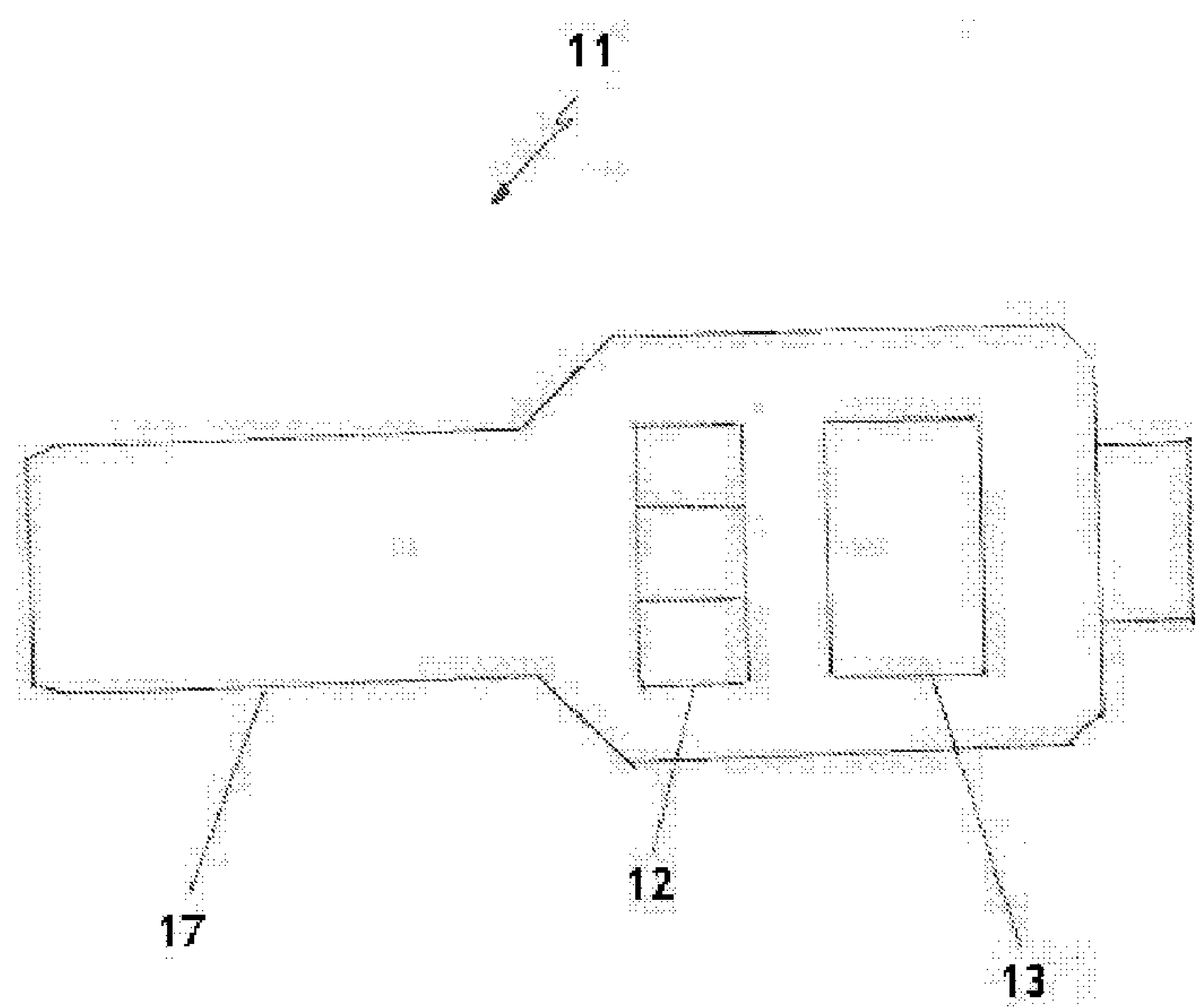


Figure 4

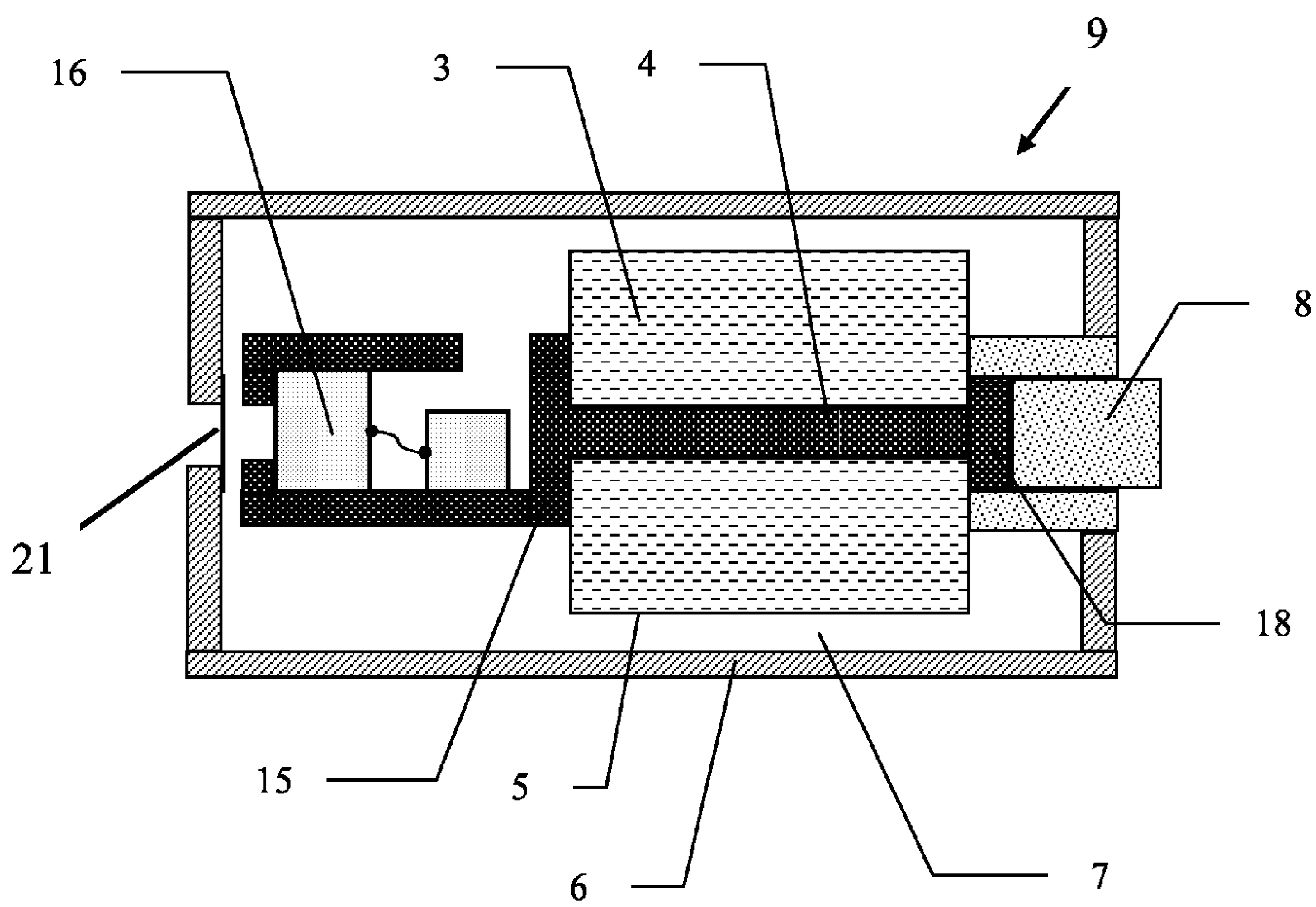
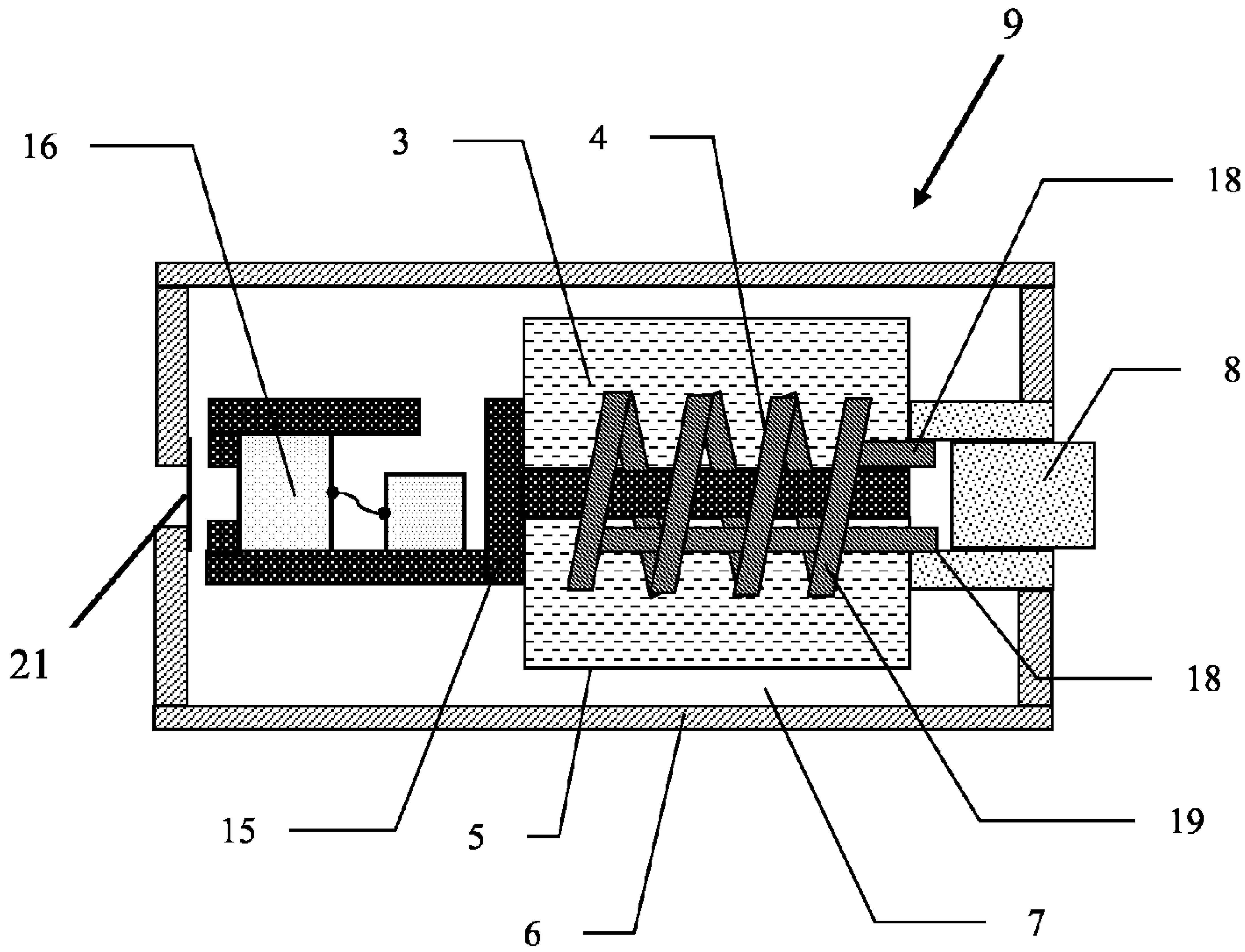


Figure 5



CRYOGENIC COOLING DEVICE

[0001] The invention refers to a cryogenic cooling device, a device, comprising a component to be cooled, which is cooled by a cryogenic cooling device, as well as to a cooling element for the cooling of the cryogenic cooling device.

[0002] From the prior art, a multitude of cooling devices are known, being used in order to cool down, for example, sensors, electric circuits or detectors and others. The cooling of radiation detectors is of specific importance, as the measured spectra are imprecise if there is no appropriate cooling, as especially the energy and time resolution of the measured values are strongly dependent from the temperature. Just among radiation detectors, using semiconductor crystals, for example germanium, a good cooling of mostly below −100° C. is of essential importance.

[0003] It is known in addition that different cooling temperatures are necessary for different detectors. Germanium or silicon detectors for the detection of x-ray or gamma-radiation for example do need a cooling to about 95 K to 130 K in order to achieve sufficiently good measurement results.

[0004] In order to achieve such cooling temperatures, especially in order to achieve a cooling down to a cryogenic temperature, that is below −100° C., the prior art is using liquid nitrogen, helium or other liquefied gas. It is also known to use a stirling cooling, a Peltier transition, the Joule-Thomson-effect or others. Those known cooling systems do, nevertheless, need large space, are heavy and therefore not or only very limited suitable for the cooling of handheld devices.

[0005] Comparably large and heavy, but, nevertheless, portable radiation detectors for the measurement of gamma radiation are, according to the prior art, cooled mechanically, whereby accumulator cells, for example NiCd accumulators, are used for the operation of the cooling devices.

[0006] From UCRL-JC-118973 and UCRL-JC-119679, an electro mechanical cooling mechanism is known, used for a portable germanium detector. As with all mechanical cooling devices, the cooling device described here has the disadvantage that mechanical vibrations affect the quality of the measurement. The detector system with the cooling device has a power consumption of 37 to 97 Watt, therefore requiring big and heavy batteries. The complete system described, consisting of detector, cryo cooler and battery, weights 18.2 kg, therefore being not well suited for the mobile use in the field already because of its weight and its size.

[0007] In IEEE Transactions on Nuclear Science, Vol. 40, No. 4, August 2003, page 1043-1047, a portable germanium detector is described, which is cooled by the use of a stirling cooler on the basis of electricity also. The cooling described therein also leads to a reduced resolution because of vibrations. In addition, the necessary cooling power could be upheld for two hours only by using 6 AH NiMH accumulators.

[0008] All mentioned cooling systems, receiving the energy from battery powered power sources, do not provide enough power in order to cool down a semiconductor crystal to its operating temperature sufficiently fast. Only when the cooling occurs fast enough, the cryo pump, being part of the detector, comprising regularly activated charcoal, is activated, thereby improving the vacuum inside the detector. When the cooling process is slow, no activation occurs, which again leads, because of the additional impurities remaining in the crystal, to a deterioration of the resolution.

[0009] Known cooling systems in the form of cooling accumulators, which do not show those disadvantages and which would be suitable for portable use, for example cooling accumulators for the cooling of beverages or for the treatment of swellings, which for example make use of eutectic cooling, cannot provide a cryo temperature, being necessary for the operation of the semiconductor detectors. Nevertheless, only when using cooled semiconductor crystals, energy resolutions better than 1% at 662 keV can be achieved.

[0010] Portable radiation detectors, which could be easily used mobile, especially for the measurement of gamma radiation, do therefore make use only of crystals and materials, which may be practically used in the respective surrounding temperature field, that is preferably in a temperature area between −25° C. to +50° C., offering a sufficient resolution in that temperature area. Regularly, NaI or CsI crystals are used here, but also plastic scintillators as well as so called room temperature semiconductor crystals (CdZnTe), which, nevertheless, by far do not achieve the measurement accuracy, which can be achieved with cooled semiconductor crystal detectors.

[0011] The problem underlying the present invention is therefore to provide a cryo temperature cooling device, being suitable for the cryo cooling of portable devices, avoiding the described disadvantages. This problem is, according to the invention, solved by a cryo temperature cooling device with the features according to claim **1**. Preferred embodiments of the cryo temperature cooling device as described in the invention are provided in the dependent claims.

[0012] The cryo temperature cooling device according to the invention comprises a holding tank, being filled up at least in part with a coolant, and a heat conducting element, whereas the heat conducting element is in thermal contact with the coolant. The coolant serves as a heat sink during operation, that is in other words as a "cooling accumulator". It can take particularly more heat, if there is a phase change within the temperature area of interest, preferably providing a high phase transition energy, which is when looking at a phase transition solid-liquid, a preferably high latent heat of fusion. Nevertheless, a coolant without a phase transition in the temperature area of interest is also providing good results, as long as the cooling device is sufficiently insulated.

[0013] According to the invention, the coolant preferably provides for a phase transition from the group solid-solid, solid-fluid, and fluid-fluid, occurring below a temperature of −100° C., so that the cryogenic cooling device more or less uses or consumes no coolant during operation, as the volumes of the various phases can be kept constant, being the reason that mainly no coolant has to be sent to the surrounding, that is to be consumed. The constant volumes are achieved by either providing a sufficiently solid pressure tank, being pressure resistant and able to surround the coolant in the complete area of temperatures during operation of up to about 55° C., and/or by selecting suitable coolants, their vapor pressure being low in the complete temperature field during operation, preferably not being larger than the surrounding air pressure.

[0014] According to a preferred embodiment, the coolant comprises an organic compound, comprising a heat of fusion of less than −100° C. Said coolant preferably comprises one or more of the following compounds: vinyl bromide (brome ethylene), ethyl bromide (brome ethane), butane, butene-2-cis, ethyl acetylene, butene-1 and isobutene. The suitable compounds are known in principle and can be found in respective tables, for example from the CRC Handbook of Chemistry and Physics.

[0015] Vinyl bromide (C_2H_3Br) is of especial advantage as a coolant, as it has a melting point of −138° C. (=135.2 K), a heat of fusion of about 15.7° C. as well as a vapor pressure of 1.20 bar at room temperature (21° C.). An additional advantage is the high density of 1.5 kg/dm^3 of vinyl bromide. Therefore, the volume of the coolant, necessary for a sufficient cooling, is reduced, thus reducing the volume of the inventive device and at the same time increasing its portability.

[0016] The energy radiation and therefore the thermal loss during storage and operation of the inventive device is nearly proportional to the difference of the 4^{th} power of the coolant temperature and the 4^{th} power of the surrounding temperature (Law of Stefan-Bolzmann). As the cooling temperature of −138° C. of vinyl bromide is sufficient for the cooling of semiconductor detectors, especially of germanium detectors, the energy loss by thermal radiation is much smaller compared to a cooling with liquid nitrogen. This is increasing the effective cooling time even with respect to conventional nitrogen cooling substantially.

[0017] Using vinyl bromide as a coolant, the inventive cryo temperature cooling device can be kept at a nearly constant temperature of substantially lower than −100° C., more specifically of −138° C., for a time period of at least eight hours with 0.5 to 1.0 liter of coolant only. At the same time, the cooling temperature is reached fast enough in order to activate a cryo pump within a germanium detector, comprising activated charcoal on a regular basis, serving for improving the vacuum within the detector crystal.

[0018] The cryo temperature cooling device may also use butane, butene-2-cis, ethyl acetylene, butene-1, isobutene or ethyl bromide as a coolant, as those substances do show similar properties than vinyl bromide. Also a mixture of various coolants may be used.

[0019] Preferably, the cryo temperature cooling device provides a coolant with a phase transition temperature (T_P) below −140° C., whereby it has proved a specific advantage, if the coolant provides a boiling temperature T_{SI} higher than 20° C., preferably higher than 50° C.

[0020] Furthermore, it has proved to be of advantage if the coolant has a phase transition energy of at least 35 kJ/ltr, preferably a phase transition energy of at least 50 kJ/ltr and especially preferred of at least 80 kJ/ltr.

[0021] It furthermore is an advantage if the coolant is selected in such a way that the vapor pressure of the coolant at room temperature (21° C.) is preferably below 3 bar, especially preferable 1.5 bar, where the vapor pressure is not increasing substantially at the maximum operation temperature. It is especially an advantage if the vapor pressure of the coolant at 20° C., preferably even at 50° C., does not exceed a value of 1 bar.

[0022] Especially during practical use it has been proven that it is an advantage to select the coolant in such a way that the product of the volume, being available for the coolant within the tank, and the vapor pressure of the coolant at room temperature, is lower than 30 bar ltr, preferably lower than 20 bar ltr and especially preferable lower than 10 bar ltr.

[0023] This is especially of advantage with regard to the tank, as this should be exposed preferably only to low strain in order to provide for a long durability with regard to the cryo temperature cooling device. In addition, when only providing limited stress to the tank, cost effective materials could be used. Furthermore, the safety requirements, especially in more sensitive areas, for example in aviation, are much less strict when using tanks with a low pressure only, which additionally increases the field of operation of the device according to the invention. Finally, materials with a lower mass are sufficient for the making of the tank, when the maximum vapor pressure is low only, preferably being only inessentially higher than the pressure of the surrounding. This leads to lighter tanks, therefore lowering the complete weight of the device according to the invention, thus further increasing their portability.

[0024] It is an advantage, when the heat conducting element is situated in the device and protruding to the outside, whereas the device preferably comprises a recess, being suitable to house the heat conducting element, whereas the recess is made in such a way that it allows for a thermal contact between the heat conducting element on one side and the coolant within the device on the other side. Preferably, the heat conducting element of the cryo temperature cooling device is formed as a cooling finger.

[0025] Preferably, the phase transition temperature T_P of the coolant matches roughly the temperature, to which an object should be cooled by using the cryo temperature cooling device.

[0026] In order to further increase the thermal transfer between the coolant and the heat conducting element within the device, further substances are added to the coolant, increasing the heat conductivity according to a further preferred embodiment of the invention.

[0027] For a specific application it can be vice-versa necessary to lower the heat conduction. In that case, substances are mixed to the coolant, which lower the thermal transfer.

[0028] The tank of the cryo temperature cooling device preferably comprises an inner wall and an outer wall, having a distance from the inner wall. In order to provide a good isolation of the cryo temperature cooling device between the inner wall and the outer wall of the pressure resistant tank, an intermediate area is provided, comprising, according to a preferred embodiment of the invention, a vacuum and/or a heat isolating material, for example styrofoam.

[0029] The cryo temperature cooling device preferably is set up as a mainly closed cooling accumulator, which can be cooled again with a cooling device, for example with a compression refrigerating machine, preferably at least down to the temperature of the phase transition.

[0030] Furthermore, the heat conducting element, which is designed to be within the tank of the cryo temperature cooling device, is preferably adapted in order to be connected thermally to an object to be cooled, especially to a detector, preferably a semiconductor detector for the measurement of ionizing radiation.

[0031] It is possible to combine the heat conducting element with the tank in such a way, that it protrudes out of this tank at the same time being in thermal contact to the coolant in the inside. For example, the semiconductor detector to be cooled then is connected to the heat conducting element, for example plugged to it. Vice-versa, the heat conducting element can also be connected to the detector, maybe even fixed to the detector. The tank then preferably provides a recession, with which the heat conducting element can be connected to, for example by plugging, the recess. The recess then is made up in such a way that it allows for thermal contact between the coolant and the heat conducting element. Preferably, the heat conducting element is formed as a cooling finger.

[0032] This adoption can be made in such a way at the same time so that it can act as a fixation of the cryo temperature cooling device to an object to be cooled, when the object to be cooled provides a respective plug for the heat conducting element. Thereby, the tank of the cryo temperature cooling device may provide additional devices in order to fix the cryo temperature cooling device to the object to be cooled. Preferably, the heat conducting element itself is fixed to the tank also.

[0033] Furthermore, the cryo temperature cooling device preferably comprises a protective cap, which is detachably fixed to that part of the heat conducting element, especially the cooling finger, protruding from the tank. It is made shape congruent to the cooling finger, whereby the protective cap preferably comprises a thermal isolating material. The protective cap preferably is plugged to that part of the cooling finger, protruding from the pressure tank, as long as the device according to the invention is not in operation mode, that is used for cooling, for example as long as it is not coupled to a detector in order to cool it. In order to activate the cooling function, the protective cap is removed from the cooling finger.

[0034] According to a further aspect of the present invention, a device is provided, comprising an element to be cooled and a cryo temperature cooling device. This cryo temperature cooling device comprises a tank, being filled at least partly with coolant. It is further comprising a heat conducting element, whereas the heat conducting element can be brought into thermal contact with the coolant.

[0035] Thereby the device preferably comprises the following features: it is designed as handheld device, the element to be cooled is brought to an intended temperature below −100° C., preferably below −140° C., the cooling is effected by the cryo temperature cooling device, whereas the coolant is working as a low temperature reservoir, respectively as a heat sink, the coolant not being consumed or sent to the environment during operation, but remaining mainly within the tank. The cryo temperature cooling device is re-loadable with the help of a charge station, which may be designed stationary or portable, by removing sufficiently enough heat from the coolant so that the following operation of the device is possible for a sufficient period of time, preferably at least one hour, especially preferred at least eight hours and even more preferred at least 24 hours.

[0036] Also provided is a measurement device, comprising a detector and a cryo temperature cooling device according to the invention, comprising at least one of the following features: the measurement device is set up as a portable handheld device, the measurement device is set up as a spectrometer, the detector comprises a semiconductor detector, preferably using germanium, for the measurement of ionizing radiation, and at least one cooling finger of the cryo temperature cooling device is in thermal contact to the detector.

[0037] Preferably, the coolant used within the device comprises at least one phase transition from the group solid-solid, solid-fluid and fluid-fluid, occurring below a temperature of −100° C.

[0038] It has been proven to be of further advantage, if the cryo temperature cooling device is detachable from the device, so that the reload of the cryo temperature cooling device can occur when separated.

[0039] The element to be cooled within the device may be an electronic element, whose essential characteristics depend from its temperature when used correctly, especially its operational ability, noise and amplification, mainly becoming worse with rising temperature. The electronic device thereby may be a sensor or a detector for the detection of radiation, especially electro magnetic and/or ionizing radiation, for example microwaves, infrared, visible or ultra violet light, or of x-ray or gamma-rays.

[0040] The term electronic device as used here has to be interpreted very broadly and especially includes all devices, making use of electro magnetic effects in the widest sense, that is especially also detectors and detector crystals, but also a detector crystal together with at least the first part of the signal amplifiers of said detector.

[0041] The detector described preferably comprises a semiconductor crystal, preferably comprising germanium or silicon. In addition, it is an advantage if the detector comprises evaluation electronics so that the measured radiation can be identified mainly within the detector, whereas the detector preferably is set-up portable as multi-purpose handheld Radio isotope Identifier Device (RID). Such RIDs preferably comply with the relevant norms of the International Atomic Energy Organization in Vienna (IAEO), especially with the classification "Technical/Functional Specification for Border Radiation Monitoring Equipment" as it has been ratified within the Coordinated Research Project "Improvement of Technical Measures to Detect and Respond to Illicit Trafficking of Nuclear and other Radioactive Materials", Research Coordination and Technical Meeting (M2-RC-927), Dec. 1-5, 2003, IAEA Headquarters, Vienna.

[0042] A second cryo temperature cooling device may be provided, allowing for a larger cooling capacity. Said second cooling device may be used stationary, whereas the detector preferably is connected to this second cryo temperature cooling device when it is not used in mobile mission. It, therefore, suits especially for the long-term cooling of the detector between various missions. Such a pre-cooling has the advantage that the limited cooling capacity of the cooling accumulator according to the invention must not be used first for the cooling down to the operation temperature, so that the mission time of the system is extended.

[0043] After the cryo temperature cooling device has been warmed up or at least used part of the cooling capacity, it can be reloaded in such a cooling device used as a charging device, that is it can be cooled down to a temperature preferably below the phase transition of the coolant. Instead of coupling the coolant to the object to be cooled, for example the semiconductor detector, the coolant within the, optional pressure-resistant, tank is coupled to the cooling device, whereby the cooling device preferably is a conventional cooling device, for example making use of electro mechanical cooling, for example of a compression refrigerating machine, or of liquid gases like nitrogen or helium.

[0044] The cryo temperature cooling device according to the invention may comprise also a second thermal coupling. The cryo temperature cooling device may therefore be connected with the object to be cooled, for example a circuit or a detector, the one side and on the other side with the cooling device or a cooling device with a higher capacity. In such a way, the complete system including the object to be cooled can be cooled down so that the complete system may be used for operational purposes immediately, at the same time allowing for the maximum cooling capacity at the beginning of the mission.

[0045] Furthermore, a cooling device for the cooling of the above described cryo temperature cooling device is claimed, whereby the cooling device may be coupled thermally to the cryo temperature cooling device and whereby the cooling mainly occurs via the thermal connection and mainly without a mass exchange between the cooling device and the cryo temperature cooling device to be cooled. This includes a cooling by using a flow of gas and/or a flow of liquids, as long as the coolant of the cryo temperature cooling device mainly remains within the cryo temperature cooling device. The cooling device itself may be cooled by using liquid gases, preferably with liquid nitrogen and/or liquid helium and/or by using electric and/or mechanical cooling devices, for example a compression refrigerating machine.

[0046] According to the invention, a compound, showing a phase transition temperature of below −100° C., is used as a coolant in the cryo temperature cooling device. The compound may be, according to one aspect of this invention, an organic compound, for example vinyl bromide, butane, butene-2-cis, ethyl acetylene, butene-1, isobutene or ethyl bromide.

[0047] According to even another aspect of the invention, the coolant has a vapor pressure at room temperature (21° C.) of preferably below 3 bar, especially preferred of lower than 1.5 bar, whereas it is explicitly an advantage if the vapor pressure of the coolant at 20° C., especially preferred at 50° C., does not exceed a value of 1 bar.

[0048] In the following, the invention is described by using a specific embodiment in the light of the enclosed figures.

[0049] The figures show:

[0050] FIG. **1** a cross sectional view through the cryo temperature cooling device according to the invention;

[0051] FIG. **2** a cross sectional view through the measurement device according to the invention;

[0052] FIG. **3** a top view to a portable measurement device according to the invention;

[0053] FIG. **4** a further embodiment with a cooling device integrated in the detector; and

[0054] FIG. **5** an embodiment with separate radiator coil.

[0055] FIG. **1** is a cross sectional view through the cryo temperature cooling device **1** according to the invention. The tank **2** is preferably made from pressure resistant material so that it can withstand the vapor pressure of the coolant **3** both at room temperature as well as at the maximum operation or storage temperature of the cryo temperature cooling device. A tank **2** in addition is made in such a way that it comprises an inner wall **5** and an outer wall **6**, having a distance from the inner wall **5** via an intermediate area **7**. The intermediate area **7** is filled with heat insulating layers so that tank **2** respectively the cryo temperature cooling device **1** separates the coolant sufficiently from the surrounding temperature and that it remains in the frozen state for a long term of time.

[0056] Within the tank **2** the coolant **3** is provided. The substances, coming into question as a coolant for the cryo temperature cooling device **1**, stand out by a low phase transition temperature, for example a low melting temperature, being roughly the temperature to which an object is to be cooled, a preferably high heat of fusion, preferably high boiling temperature and a preferably low vapor pressure at the maximum operation/storage temperature. Some of the substances to be considered and their relevant properties are listed in the following, not completed Table 1:

TABLE 1

Coolant	Formula	Melting Point T_S [° C.]	Heat of Fusion [kJ/l]	Boiling Temperature T_{SI} [° C.]
Pentaborane (11)	B5—H11	−122.0		65.0
Phosphorotioc bromide difluoride	PSBrF2	−136.9		35.5
Trichlorosilane	SiHCl3	−128.2		33.0
Sulfur dichloride	SCl2	−122.0		59.6
1,2,2-Trichloro-1,1-difluoroethane	C2—H—Cl3—F2	−140.0		71.9
1,2,2-Trichloro-1,2-difluoroethane	C2—H—Cl3—F2	−174.0		72.5
1,1-Dichloroethene	C2—H2—Cl2	−122.6	81.5	31.6
Bromoethene, Bromoethylene, Vinyl bromide	C2—H3—Br	−139.5	71.8	15.8
Acetaldehyde	C2—H4—O	−123.4	41.1	20.1
Ethyl bromide, Bromo ethane	C2—H5—Br	−118.7	54.1	38.4
Ethane thiol	C2—H6—S	−147.9	66.7	35.1
1-Chloropropane	C3—H7—Cl	−122.9	62.8	46.5
1-Propanol	C3—H8—O	−124.4	71.5	97.2
2-Propanethiol	C3—H8—S	−130.5	61.4	52.6
Butane	C4—H10	−138.0	81.2	−0.5
Butene-2 cis	C4—H8	−139.0	130.2	3.7
Ethyl acetylene	C4—H6	−125.7	111.5	8.1
Butene-1	C4—H8	−185.4	68.6	−6.3
Isobutene	C4—H8	−140.0	105.7	−6.9
cis-1,3-Pentadiene	C5—H8	−140.8	57.2	44.1
1,4-Pentadiene	C5—H8	−148.2	59.4	26.0
2-Methyl-1,3-butadiene	C5—H8	−145.9	49.2	34.0
Cyclopentene	C5—H8	−135.0	38.1	44.2

TABLE 1-continued

Coolant	Formula	Melting Point T_S [° C.]	Heat of Fusion [kJ/l]	Boiling Temperature T_{SI} [° C.]
1-Pentene	C5—H10	−165.1	54.3	30.0
cis-2-Pentene	C5—H10	−151.4	66.5	36.9
trans-2-Pentene	C5—H10	−140.2	76.6	36.3
2-Methyl-1-butene	C5—H10	−137.5	73.4	31.2
3-Methyl-1-butene	C5—H10	−168.4	47.5	20.1
2-Methyl-2-butene	C5—H10	−133.7	71.8	38.6
trans-1,2-Dimethylcyclopropane	C5—H10	−149.6		28.2
Ethylcyclopropane	C5—H10	−149.2		35.9
Methylcyclobutane	C5—H10	−161.5		36.3
Pentane	C5—H12	−129.7	72.9	36.1
Isopentane	C5—H12	−159.8	44.3	27.9
2-Pentanethiol	C5—H12—S	−169.0		112.9
Diethylmethylamine	C5—H13—N	−196.0		66.0
4-Methylcyclopentene	C6—H10	−160.8		65.7
1,5-Hexadiene	C6—H10	−140.7		59.4
1-Hexene	C6—H12	−139.8	74.3	63.5
cis-2-Hexene	C6—H12	−141.1	72.0	68.8
Methylcyclopentane	C6—H12	−142.4	61.7	71.8
2,3-Dimethyl-1-butene	C6—H12	−157.3		55.6
Ethylcyclobutane	C6—H12	−142.9		70.8
cis-2-Hexene	C6—H12	−141.1		68.8
3-Methyl-1-pentene	C6—H12	−153.0		54.2
4-Methyl-1-pentene	C6—H12	−153.6		53.9
4-Methyl-trans-2-pentene	C6—H12	−140.8		58.6
2-Methylpentane	C6—H14	−153.6	47.3	60.3
3-Methylpentane	C6—H14	−162.9	40.6	63.3
2,3-Dimethylbutane	C6—H14	−128.1	6.1	57.9
2-Hexanethiol	C6—H14—S	−147.0		142.0
Triethylsilane	C6—H16—Si	−159.0		109.0
1-Heptene	C7—H14	−118.9	88.1	93.6
Methylcyclohexane	C7—H14	−126.6	52.9	100.9
4-Methy-1-hexene	C7—H14	−141.5		86.7
trans-2-Methyl3-hexene	C7—H14	−141.6		85.9
2,2-Dimethylpentane	C7—H16	−123.7	39.1	79.2
3,3-Dimethylpentane	C7—H16	−134.4	47.4	86.1
1-Ethyl-1-methylcyclopentane	C8—H16	−143.8		121.6
3-Methylheptane	C8—H18	−120.5	71.8	118.9
4-Methylheptane	C8—H18	−121.0	66.6	117.7

[0057] It is to be understood that Table 1 does not list all coolants to be used according to the invention, but only a selection. Especially, this selection is mainly limited to substances with a boiling temperature T_{SI}>20° C. and a melting temperature T_S<−120° C. Only butane, butene-2 cis, ethyl acetylene, butene-1 and isobutene have been mentioned in addition, even if their boiling temperature T_{SI} is lower than 20° C. Suitable as coolants are propane and propene also, but they do have a vapor pressure of 8.7 and 10.3 bar at 21° C., therefore requiring higher standards with regard to the pressure resistance of the tank **2**.

[0058] As a comparison, liquid nitrogen has a boiling temperature of −196° C. and a heat of fusion of about 161 kJ/ltr. Suitable as coolants are also substances like propane and propene, which nevertheless do have a vapor pressure of already 8.7 respectively 10.3 bar at 21° C. and therefore having to meet higher demands when it comes to the pressure stability of the tank.

[0059] Furthermore, a heat conducting element **4** in the form of a cooling finger, protruding from tank **2** through an opening **14** through the inner wall **5** and the outer wall **6**, is seen in the cryo temperature cooling device **1**. The cooling finger **4** is surrounded nearly completely from the coolant **3** within the tank **5**. Mounted to the part of the cooling finger **4**, protruding from the cryo temperature cooling device **1**, is heat insulating protective cap **8**. So, the complete cryo temperature cooling device **1** is isolated from the surrounding temperature as long as it is not in operation respectively not used for the cooling of an object, therefore, being able to be stored. The cooling finger **4** preferably also comprises material, providing for a good heat transfer and at the same time for the thermal connection between coolant and the object to be cooled. It may for example be made from copper. In order to further improve the heat transfer of the coolant **3** to the cooling finger, further substances could be added to the coolant **3** in order to promote this property.

[0060] The cryo temperature cooling device is used as follows: the cryo temperature cooling device **1** is charged by bringing the cooling finger **4** to a temperature below the melting point of the coolant. When using vinyl-bromide, this would, for example, be a temperature below −138° C. (135.2 K). This cooling process continues until the coolant is mainly frozen. The cooling, respectively the charging of the cryo temperature cooling device **1**, is conducted with a charging device, for example a compression refrigerating machine or with liquid nitrogen.

[0061] Afterwards, in order to store the cryo temperature cooling device **1** until it is used for operational purposes, the protecting cap **8** is mounted to the cooling finger **4**. Therefore, a good heat insulation of the cryo temperature cooling device **1** with regard to the outside is achieved and the frozen state of the coolant **3** can be kept fairly long.

[0062] When the cryo temperature cooling device **1** should be used for cooling purposes, for example of a detector, the protective cap **8** is removed from the cooling finger **4** and the cooling finger **4** is connected to the object to be cooled or included therein.

[0063] FIG. **2** shows a cross section at view of a cryo temperature cooling device **1** according to the invention, which might be coupled to a detector **10**, comprising a detector support **15**, a detector crystal **16**, being connected to a preamplifier, also mounted on the detector support **15** and therefore cooled also, as well as an outer wall **20**. The outer wall in the embodiment is comprising a window, being mainly transparent for the radiation to be measured, namely a radiation entry window **21**.

[0064] The cooling finger **4** of the detector **10** is thermally mounted to the detector support **15**, supporting also the detector crystal **16**, for example a germanium crystal. There are, nevertheless, other detector crystals suitable in order to be cooled by the inventive cryo temperature cooling device **1**, for example silicon crystal detectors, CdTe-detectors and others. Preferably, the preamplifier is thermally connected to the detector support **15** also so that this is cooled, too. When the measurement respectively the operation time of the detector **10** has ended, the cryo temperature cooling device **1** can be removed from the detector **10** again in order to be recharged for a further measurement.

[0065] As the size of the cryo temperature cooling device **1** is small, it is especially suitable for the operation in combination with a measurement device in the form of a handheld device **11**, which is shown schematically in a top view in FIG. **3**.

[0066] Because of its low weight and volume this handheld device **11** is especially suitable for mobile missions, for example as gamma ray detector for luggage control at airports, borders or at big events. The handheld device **11** is touched at its handle **17** and hold thereon during the measurement. Input keys **12** allow the selection for example of various functions or are designed to start and end the measurement operation. Measurement results may be metered either acoustically, for example when excessing the detected limits, or via reading the display **13**.

[0067] FIG. **4** shows a further embodiment in which, according to the invention, the cryo temperature cooling device is integrated to the detector, forming one measurement device **9**. Thereby the detector, comprising a detector support **15** and a detector crystal **16** including pre-amplifier, the heat conducting element **4** and the inner tank **5** together with the coolant **3** are forming a fixed mounted device. Thereby, the heat conducting element **4** and the detector support **15** can be made from one piece. The inner tank **5** is made to withstand pressure in this embodiment, so that it can withstand the vapor pressure of the used coolant at the maximum operating temperature.

[0068] Via a connection **18**, which may be protected and isolated by a removable heat insulating cap **8**, it is possible—after removal of cap **8**—to "load" the cryo temperature cooling device as described above, that is it could be cooled, by keeping the heat conducting contact of the connection **18** at a temperature T until the detector is cooled and the coolant is mainly frozen. For the temperature T it is true that $T<T_P$, whereby T_P is the phase transition temperature of the coolant used according to the invention. After removing the charging device from the connection **18** and attaching the protection cap **8**, the detector is kept cooled for several hours ready for operation.

[0069] FIG. **5** shows another embodiment, at which the "charging" occurs not via the heat conducting element **4**, but via a cooling coil **19** mounted within the inner tank **5**. Instead of the heat conducting element **4**, the cooling coil **19** is led to the connection **18**, so that during the "charging process" the coolant **3** is cooled via the cooling coil **19**.

[0070] The use of cooling coil **19** for the charging of the cryo temperature cooling device **1** is especially an advantage when cooled (liquefied) gases, for example nitrogen or helium or others, liquid coolants are available for the cooling process. Those cooled (liquefied) gases or coolants could then be piped directly through the inner part of the cooling coil, which allows for a higher heat transport so that the cooling can take place faster. Furthermore, the connections **18** of the cooling coil, being directed to the outside, may consist of materials, being bad heat conductors, so that the heat insulation of the cryo temperature cooling device with regard to the surrounding is improved, so that the operation time can even be improved with regard to the device shown in FIG. **4**.

[0071] In addition to the use for the cooling of detectors, the cryo temperature cooling device according to the invention can be used in any devices where cryo temperatures are necessary or wanted. This is especially true for, but not limited to further measurement applications, not the least for such applications, using superconductors, especially high Tc superconductors. One has to think firsthand to electronics, here especially to noise sensitive preamplifiers, to IR sensors, night vision devices, to SQUIDs or to applications for radar.

LIST OF REFERENCES

[0072] **1** cryo temperature cooling device
[0073] **2** tank
[0074] **3** coolant
[0075] **4** heat conducting element
[0076] **5** inner wall (inner tank)
[0077] **6** outer wall (outer tank)
[0078] **7** intermediate space
[0079] **8** protecting cap
[0080] **9** measurement device
[0081] **10** detector
[0082] **11** handheld device
[0083] **12** input key
[0084] **13** display
[0085] **14** opening
[0086] **15** detector support
[0087] **16** detector crystal, eventually with preamplifier
[0088] **17** handle
[0089] **18** connection
[0090] **19** cooling coil
[0091] **20** outer wall of the detector
[0092] **21** radiation entry window

1. Cryo temperature cooling device comprising a tank, being filled up at least in part with a coolant, and a heat conducting element, whereas the heat conducting element can be brought into thermal contact with the coolant, characterized in that the coolant has a phase transition occurring below a temperature of −100° C., so that the cryogenic cooling device more or less consumes no coolant during operation.

2-25. (canceled)

26. Measurement device, comprising a detector and a cryo temperature cooling device according to claim **1** for cooling the detector, comprising at least one of the following features:

the measurement device is set up as a portable handheld device,

the measurement device is set up as a spectrometer,

the detector comprises a semiconductor detector, preferably using germanium, for the measurement of ionizing radiation,

at least one cooling finger of the cryo temperature cooling device is in thermal contact to the detector.

27-41. (canceled)

42. Cooling device for the cooling down of a cryo temperature cooling device according to claim **1**, characterized in that the cooling device for the cooling down of the cryo temperature cooling device can be connected thermally with said cryo temperature cooling device and where the cooling down is provided mainly via said thermal connection and mainly without material exchange between cooling device and the cryo temperature cooling device to be cooled down.

43. (canceled)

44. (canceled)

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