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(54) **CABLING SUBSYSTEM, CRYOSTAT, AND METHOD FOR ASSEMBLING A CABLING SUBSYSTEM TO A CRYOSTAT**

(57) A cabling subsystem for a cryostat comprises an instrument (401, 402, 417, 418, 801, 805) that comprises a temperature sensor (401, 417, 801), a heater (402, 418, 805), or a wired connector (1101), and a wired coupling (403, 404, 1004, 1102) thereto. An elongate enclosure (405) of low thermal conductivity has mechanical interfaces (406, 407) for joining to corresponding further structures (408, 409) of the cryostat in a gastight manner. Inside said enclosure (405) is an internal part (410, 411, 419, 420, 802, 806) of high thermal conductivity. Outside at the same location is an external part (412, 413, 421, 422, 803, 807) of high thermal conductivity. A thermally conductive connection exists between said internal part (410, 411, 419, 420, 802, 806) and said external part (412, 413, 421, 422, 803, 807). The instrument (401, 402, 417, 418, 801, 805) and/or the wired coupling (403, 404, 1004, 1102) is attached to said internal part (410, 411, 419, 420, 802, 806) inside the enclosure (405).

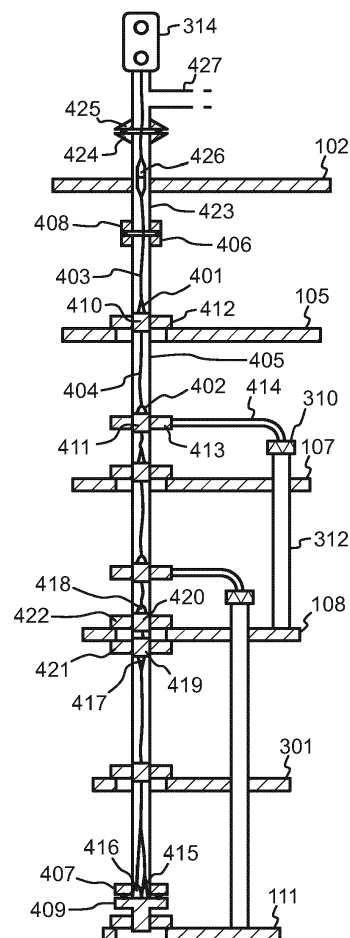


Fig. 4

Description

FIELD OF THE INVENTION

[0001] The invention is related to the technical field of instrumentation hardware in cryogenic cooling systems. In particular the invention is related to establishing wired connections between a room temperature environment and instruments inside the cryostat, such as heaters, temperature sensors, and other wired instrumentation.

BACKGROUND OF THE INVENTION

[0002] Cryogenic cooling systems comprise various pieces of internal instrumentation that are necessary for their operation. For example, temperature sensors are used to measure the temperatures of the various cooling stages and other parts inside the cryostat. Heaters are needed to controllably increase the temperature of selected components like e.g. adsorption pumps and the still of a dilution refrigerator. The sample, experiment, quantum processing circuit, or other object for the cooling of which the cryostat is used may benefit from many kinds of wired connections.

[0003] Fig. 1 is a simplified schematic illustration of a cryostat that is equipped with a dilution refrigerator and a mechanical pre-cooler. The outermost structure of the cryostat is a vacuum can 101, which is shown with dashed lines in fig. 1. The topmost flange 102 is the lid of the vacuum can. The room temperature stage 103 of the mechanical pre-cooler is attached thereto. The first stage 104 of the mechanical pre-cooler is attached to a first flange 105 and the second stage 106 of the mechanical pre-cooler is attached to a second flange 107. The first and second flanges may be called the 50 K flange and the 4 K flange for example, reflecting their temperatures during operation.

[0004] Further below there are more flanges, like the still flange 108 to which the still 109 of the dilution refrigerator is attached. In fig. 1 the mixing chamber 110 of the dilution refrigerator is attached to the base temperature flange 111. Reference designator 112 illustrates the payload that is to be refrigerated, frequently referred to as the sample. It is firmly attached to the base temperature flange 111 in order to ensure as good thermal conductance as possible.

[0005] Cylindrical radiation shields, which are not shown in fig. 1 for graphical clarity, are typically attached to the flanges in a nested configuration, in order to keep radiated heat from surrounding, higher-temperature parts from reaching the colder parts inside. The structure may comprise other, intermediate flanges like a so-called 100 mK flange between the still flange 108 and the base temperature flange 111. Aligned apertures 113, 114, and 115 may exist in the flanges to provide, together with a cover 116 at the top, a so-called line-of-sight port to the sample 112.

[0006] Fig. 2 illustrates a cryostat that is otherwise the

same as in fig. 1 but comprises the possibility of loading samples with a fast sample exchanging mechanism, often called a sample changer for short. It comprises a load lock 201 that can be attached to a gate valve 202. The cryostat depicted in fig. 2 is of the top-loading type, so the gate valve 202 is in the lid 102 of the vacuum can 101. The sample holder 203 is at the lower end of an elongate probe 204, which can be moved in its longitudinal direction (vertical direction in fig. 1) to eventually attach the sample holder 203 in place at the target region 205 on the base temperature flange.

[0007] Fig. 3 illustrates a known way of making wired connections between the outside and inside of a cryostat. The flanges are shown in cross section in fig. 3, but the vacuum can and radiation shields are omitted for graphical clarity. The vacuum can lid 102, the 50 K flange 105, the 4 K flange 107, the still flange 108, and the base temperature flange 111 are the same as in fig. 1. Additionally there is the 100 mK flange 301 between the two last-mentioned. Temperature sensors 302, 303, 304, and 305 are located at the 50 K flange 105, the 4 K flange 107, the still flange 108, and the base temperature flange 111 respectively. Heaters 306, 307, 308, and 309 are placed in various locations, like at the adsorption pumps 310 and 311, the still flange 108, and the base temperature flange 111. Each of the adsorption pumps 310 and 311 is located at one end of a respective heat switch tube 312 or 313. The heaters 306 and 307 are needed to warm up the active carbon or other substance in the adsorption pump in order to release the adsorbed exchange gas into the corresponding heat switch tube 312 or 313.

[0008] A connector box 314 is located and accessible in the room temperature environment above the vacuum can lid 102. The connector box 314 sits at the top of a short tube section 315, which joins a pipe fitting 316 in the vacuum can lid 102. A pair of matching flanges and a rubber O-ring 317 make the connection.

[0009] In order to ensure that the wired connections do not conduct heat into the coldest parts inside the cryostat, it is advantageous to thermalize the wires at each intermediate stage. Thermalization at the 50 K flange 105 may be considered as an example. The wires 318 that originate from the connector box 314 are placed in tight connection with a so-called bobbin 319, so that the thermal conductance between the wires 318 and the bobbin 319 is as good as possible. The bobbin 319 is further connected to an annular plate 320, which is bolted onto the 50 K flange 105. Taken that the 50 K stage of the mechanical cooler (not shown in fig. 3) is thermally coupled to the 50 K flange and keeps it at 50 K, also the wires 318 assume the same temperature at the bobbin 319. Similar arrangements may be used at all those locations where a wire or a plurality of wires must be thermalized with a flange.

[0010] While the prior art arrangement shown in fig. 3 is adequate for many purposes, it has drawbacks that become significant if the vacuum can of the cryostat is to be pumped down to ultrahigh vacuum (UHV) levels.

Rubber O-rings, such as the rubber O-ring 317 between the flanges that join the tube section 315 to the pipe fitting 316, may not stand such high vacuum levels. The materials of the wires, and sometimes even the temperature sensors and/or heaters, may be prone to prolonged outgassing that contaminates the surrounding vacuum.

SUMMARY

[0011] An objective is to present a cabling subsystem that allows making wired connections between the surrounding room temperature environment and internal parts of a cryostat even if the last-mentioned is to be pumped down to ultrahigh vacuum. Another objective is that the cabling system causes little or no problems related to outgassing from its materials. A further objective is that the cabling subsystem facilitates straightforward assembling and disassembling of the cryostat according to need.

[0012] These and further advantageous objectives are achieved by placing the wired connections inside a separate, elongate housing that separates them from the main vacuum chamber in a gastight manner, and using heat conducted through walls of said housing for the purposes of heating and temperature measurements.

[0013] According to a first aspect there is provided a cabling subsystem for a cryostat. The cabling subsystem comprises an instrument that comprises a temperature sensor, a heater, and/or a wired connector, and a wired coupling to or from said instrument. The cabling subsystem comprises an elongate enclosure made of a gastight material of low thermal conductivity. At or close to both ends of said enclosure are mechanical interfaces for joining said enclosure to corresponding further structures of the cryostat in a gastight manner. Inside said enclosure, at an intermediate location between the ends of the enclosure, is an internal part comprising material of high thermal conductivity. Outside said enclosure, at said intermediate location, is an external part comprising material of high thermal conductivity. A thermally conductive connection exists between said internal part and said external part. Said instrument and/or its wired coupling is attached to said internal part inside the enclosure.

[0014] According to an embodiment the cabling subsystem comprises a bridge of material of high thermal conductivity connecting said internal part to said external part through a wall of said enclosure. This involves the advantage that the inherently lower thermal conductivity of the material of which the wall is made does not significantly reduce the conduction of heat between the internal and external parts.

[0015] According to an embodiment said internal part is an insert inside said enclosure, and said external part is a clamp squeezed against said insert with a wall of said enclosure therebetween. This involves the advantage that the structure is relatively easy to make without risking the gastight nature of the enclosure.

[0016] According to an embodiment said instrument

comprises a temperature sensor, and said external part comprises a mechanical interface for making a thermally conductive coupling between the external part and a part of the cryostat the temperature of which is to be measured with said temperature sensor. This involves the advantage that reasonably reliable temperature measurements can be obtained from parts of the cryostat employing only structural solutions that are fully compatible with ultrahigh vacuum conditions.

[0017] According to an embodiment said instrument comprises a heater, and said external part comprises a mechanical interface for making a thermally conductive coupling between the external part and a part of the cryostat that is to be heated with said heater. This involves the advantage that the temperature of desired internal parts of the cryostat can be controllably increased employing only structural solutions that are fully compatible with ultrahigh vacuum conditions.

[0018] According to an embodiment one of the ends of the elongate enclosure is an inner end, so that the mechanical interface at said inner end is configured for connecting to a base temperature region inside the cryostat in a gastight manner. The cabling subsystem may then comprise a temperature sensor available for a thermally conductive coupling at said inner end of the enclosure. This involves the advantage that the cabling subsystem can be utilized for measuring also temperatures at the base temperature region of the cryostat employing only structural solutions that are fully compatible with ultrahigh vacuum conditions.

[0019] According to an embodiment the cabling subsystem comprises a heater available for a thermally conductive coupling at said inner end of the enclosure. This involves the advantage that the cabling subsystem can be utilized also for controllably increasing temperatures at the base temperature region employing only structural solutions that are fully compatible with ultrahigh vacuum conditions.

[0020] According to an embodiment said inner end of the elongate enclosure is open, making at least said temperature sensor available for directly connecting to the base temperature region of the cryostat to which said mechanical interface at said inner end is configured to be connected. This involves the advantage that very accurate temperature readings can be obtained at the base temperature region employing only structural solutions that are fully compatible with ultrahigh vacuum conditions.

[0021] According to an embodiment one of the ends of the enclosure is an outer end and comprises a flange for joining the enclosure to a fixed flange inside or outside the cryostat. This involves the advantage that the gastight connection between the enclosure and the cryostat can be achieved with standardized mechanical means, preferably by inserting the enclosure from below the cryostat in the assembling sequence.

[0022] According to an embodiment the outer end of the enclosure extends beyond said flange and comprises

a further flange for joining the enclosure to an external device. This involves the advantage that the interface between the enclosure and the external device can be designed separately, with different design aims than the interface at which the upper end of the enclosure joins the gastight structures of the cryostat.

[0023] According to an embodiment the further flange is configured to make a less gastight joint than said flange that is provided for joining the enclosure to a fixed flange inside or outside the cryostat. This involves the advantage that less critical requirements are placed to the external device that is to be connected to the enclosure and its cabling.

[0024] According to an embodiment the internal part is configured to block the propagation of thermal radiation in the longitudinal direction of the enclosure inside the enclosure. This involves the advantage of causing less thermal loading on the coldest parts of the cryostat.

[0025] According to an embodiment the instrument comprises a wired connector at an inner end of an UHV-compliant feedthrough. This involves the advantage that the cabling subsystem can be tailored for various specific needs.

[0026] According to an embodiment said inner end being located inside the enclosure or being available for connections at a place where the inner end of the enclosure comes at in the cryostat. This involves the advantage that the cabling subsystem can be used to build a custom wire harness.

[0027] According to a second aspect there is provided a cryostat that comprises a vacuum can and a cabling subsystem of the kind described above located at least partly inside said vacuum can.

[0028] According to an embodiment the cryostat comprises an adsorption pump, the adsorbing effect of which depends on its temperature. The instrument in the cabling subsystem may then comprise a heater. The external part in said cabling subsystem may comprise a mechanical interface for making a thermally conductive coupling between the external part and the adsorption pump. This involves the advantage that the operation of the adsorption pump can be fully controlled employing only structural solutions that are fully compatible with ultrahigh vacuum conditions.

[0029] According to an embodiment the cryostat comprises a thermal stage, the instrument in the cabling subsystem comprises a temperature sensor, and the external part in said cabling subsystem comprises a mechanical interface for making a thermally conductive coupling between the external part and the thermal stage. This involves the advantage that reasonably reliable temperature measurements can be obtained from such a thermal stage employing only structural solutions that are fully compatible with ultrahigh vacuum conditions.

[0030] According to an embodiment the internal part in the cabling subsystem is a first insert located at a first intermediate location between the ends of the enclosure that is on a first side of said thermal stage. The external

part in said cabling subsystem may then be a first clamp and comprise a mechanical interface for making a thermally conductive coupling between the first clamp and the thermal stage on a first side of the thermal stage. The cabling subsystem may comprise a second insert inside said enclosure at a second intermediate location between the ends of the enclosure that is on the other side of said thermal stage. The second insert may comprise material of high thermal conductivity. The cabling subsystem may comprise a heater attached to said second insert inside the enclosure, and a second clamp outside said enclosure at said second intermediate location, said second clamp comprising material of high thermal conductivity and being squeezed against said second insert with a wall of said enclosure therebetween. The second clamp may comprise a second mechanical interface for making a thermally conductive coupling between the second clamp and the thermal stage on a second side of the thermal stage. This involves the advantage that while the temperature sensor and the heater affect the thermal stage, the measurements obtained with the temperature sensor are more reliable than if heat could be conducted directly from the heater to the temperature sensor without such heat going through the thermal stage in between.

[0031] According to a third aspect there is provided a method for assembling a cabling subsystem to a cryostat. The method comprises attaching an instrument and/or its wired connection to an internal part comprising material of high thermal conductivity. Said instrument comprises a temperature sensor, a heater, and/or a wired connector. The method comprises placing said internal part inside an elongate enclosure made of a gastight material of low thermal conductivity, and making a wired coupling to said instrument inside the enclosure. The method comprises placing an external part comprising material of high thermal conductivity outside said enclosure at the same location between the ends of the enclosure where the insert is located. The method comprises making a thermally conductive connection between said internal part and said external part through a wall of said enclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] The accompanying drawings, which are included to provide a further understanding of the invention and constitute a part of this specification, illustrate embodiments of the invention and together with the description help to explain the principles of the invention. In the drawings:

Figure 1 is a schematic illustration of a cryostat equipped with a dilution refrigerator,
figure 2 is a schematic illustration of a cryostat additionally equipped with a sample changer,
figure 3 is a schematic cross-sectional view of a prior art cabling subsystem,
figure 4 is a schematic cross-sectional view of a ca-

bling subsystem according to an embodiment,

figure 5 is a schematic cross-sectional view of a detail in a cabling subsystem according to an embodiment,

figure 6 is a schematic cross-sectional view of a detail in a cabling subsystem according to an embodiment,

figure 7 is a schematic cross-sectional view of a detail in a cabling subsystem according to an embodiment,

figure 8 is a schematic cross-sectional view of a detail in a cabling subsystem according to an embodiment,

figure 9 is a schematic cross-sectional view of a detail in a cabling subsystem according to an embodiment,

figure 10 is a schematic cross-sectional view of a detail in a cabling subsystem according to an embodiment, and

figure 11 is a schematic cross-sectional view of a detail in a cabling subsystem according to an embodiment.

DETAILED DESCRIPTION

[0033] Fig. 4 illustrates a number of thermal stages 102, 105, 107, 108, 111, and 301 of a cryostat in a partial cross section. These may be flanges to be held at different temperatures during operation; for the sake of example and easy comparison a similar arrangement of flanges is shown as in the prior art cryostat of fig. 3. The cabling subsystem described here is not in any way particular to any specific configuration of thermal stages in the cryostat.

[0034] A cabling subsystem is provided that comprises instruments and wired couplings. The term "instrument" is used here as a general term that covers for example temperature sensors and heaters, to or from which wired couplings are typically needed in a cryostat. It is typical to this kind of instruments that their operation involves one or more conversions between electric energy and thermal energy: a temperature sensor essentially maps a sensed temperature into an electric signal, while a heater causes an intentional conversion from electric current to thermal energy. In the cabling subsystem described here this characteristic is utilized by passing electric energy through wires inside a gastight enclosure and making thermal energy flow through the gastight wall of the enclosure.

[0035] A wired coupling to a temperature sensor is needed in order to detect, with devices located in the room temperature environment, the effect on electric signals that takes place in the sensor as a function of its temperature. A wired coupling to a heater is needed in order to make an electric current flow through the heater, causing a desired increase in its temperature. In fig. 4 the reference designators 401 and 417 refer to temperature sensors and reference designators 402 and 418

refer to heaters. Examples of wired couplings are shown with reference designators 403 and 404.

[0036] A cabling subsystem like that schematically illustrated in fig. 4 comprises an elongate enclosure 405 made of a gastight material of low but finite thermal conductivity. An example of such a material is stainless steel. Thermal conductivity of materials is heavily dependent on temperature, but a person skilled in the art of cryogenic hardware understands what is meant: materials of low thermal conductivity are used when one wants to limit the effect of conducted heat to some desired extent. As an example, one may consider two thermal stages of a cryostat, each coupled to respective cooling means in order to keep one of these stages colder than the other during operation. Mechanical support and/or the provision of a passage for a fluid may require the existence of a solid part that connects these two parts to each other. Such a solid part must be made of a material of sufficiently low thermal conductivity, so that the amount of heat conducted from the warmer part to the colder part will remain smaller than what the respective cooling stage can continuously remove from the colder part.

[0037] The question of low thermal conductivity deserves some further consideration. If a part in a cryostat has solely a mechanical role, such as the role of a support strut for example, and if it connects parts that are at different temperatures during operation, it should be made of a material that has as low thermal conductivity as possible. If, on the other hand, the part should not conduct heat over longer distances but should allow some conducted heat to pass through at short distances, it should be made of a material that has a low but finite thermal conductivity. A low but finite thermal conductivity may be for example between 2 and 50 W/(m*K) at 100 K, between 0.2 and 5 W/(m*K) at 10 K, between 0.03 and 0.75 W/(m*K) at 1 K, between 0.003 and 0.075 W/(m*K) at 0.1 K, and between 0.0003 and 0.0075 W/(m*K) at 0.01 K.

[0038] Being gastight means that the material of the enclosure does not allow gaseous substances to leak through if the pressure difference across it is of the kind regularly encountered in ultrahigh vacuum systems.

[0039] The enclosure 405 may be for example a tube with a regular cross section, such as a circle or a regular polygon for example.

[0040] At or close to both ends of the enclosure 405 are mechanical interfaces 406 and 407 for joining the enclosure 405 to corresponding further structures of the cryostat in a gastight manner. The ends of the enclosure 405 may be called the inner end and the outer end, with reference to their location towards or out of the innermost regions of the cryostat respectively. Taken the orientation shown in fig. 4, the inner end is the lower end and the outer end is the upper end of the enclosure 405. In the example of fig. 4 the mechanical interface 406 at the outer end comprises a flange 406 for joining the enclosure to a fixed flange 408 inside the cryostat. The mechanical interface 407 at the inner end is configured for connecting

to a base temperature region inside the cryostat. As an example, the mechanical interface 407 may comprise another flange, for which there is a mating surface 409 that in turn is in fixed, thermally conductive connection with the base temperature flange 111 of the cryostat.

[0041] The gastight joint between the flanges 406 and 408 and that between the mechanical interface 407 and the mating surface 409 are both gastight to the extent that they stand ultrahigh vacuum conditions. As an example, they may involve metallic seals such as copper gaskets or indium seals, which perform better than e.g. rubber O-rings under ultrahigh vacuum conditions.

[0042] Inside the enclosure 405, at various intermediate locations between the ends of the enclosure 405, are so-called internal parts. In the embodiment of fig. 4 the internal parts are inserts that are made of (or otherwise comprise) material of high thermal conductivity, such as copper for example. As with the characterization of low thermal conductivity above, high thermal conductivity may be defined with typical temperature-dependent numeric ranges. A high thermal conductivity may be for example at least 100 W/(m*K) at or above 10 K, at least 10 W/(m*K) at 1 K, at least 1 W/(m*K) at 0.1 K, or at least 0.1 W/(m*K) at 0.01 K.

[0043] Inserts 410, 411, 419, and 420 are shown as examples. Each insert may be e.g. a copper plug of a certain length, the outline of which matches closely the inner surface profile of the enclosure 405. Most of the instruments mentioned above are attached to a respective one of the inserts inside the enclosure 405. For example, the temperature sensor shown with reference designator 401 is attached to the insert shown with reference designator 410.

[0044] Each insert that blocks the direct line-of-sight in the longitudinal direction inside the enclosure 405 also acts as a block of thermal radiation. In other words, any part higher up in the enclosure 405 that is at a higher temperature is kept from radiating heat further towards colder parts below the insert in question. On the other hand, it is not advisable to make the inserts gastight in the sense that they would block the flow of gaseous media between below and above the insert. This is because one of the aims in using an enclosure 405 like that in fig. is to pump the inside of the enclosure to a vacuum of sufficient degree, as will be described in more detail later in this text.

[0045] Outside the enclosure 405 are corresponding external parts. In the embodiment of fig. 4 the external parts are so-called clamps, of which clamps 412, 413, 421, and 422 are singled out as examples. The clamps are made of (or otherwise comprise) material of high thermal conductivity. The location of each clamp along the length of the enclosure 405 corresponds to the location of a corresponding insert inside the enclosure 405. In other words, at each intermediate location between the ends of the enclosure 405 where one of the inserts is located inside the enclosure, there is a corresponding clamp located outside the enclosure.

[0046] Each of the clamps 412, 413, 421, and 422 is squeezed against the corresponding insert 410, 411, 419, or 420 with a wall of the enclosure 405 therebetween. This is more easily seen in fig. 5, which is a partial enlarged cross section of the intermediate location where the insert 410 is located inside the enclosure 405 and the clamp 412 is located outside the enclosure 405. As schematically illustrated in fig. 5, in particular if the material of the enclosure 405 is malleable, the inner surface of the clamp 412 may be squeezed against the outer surface of the insert 410 so hard that it causes a local deformation in the wall of the enclosure 405.

[0047] In fig. 5 it is also seen how the clamp 412 comprises a mechanical interface for making a thermally conductive coupling (see 501) between the clamp 412 and that part of the cryostat the temperature of which is to be measured with the temperature sensor 401. In the embodiment of fig. 5 the mechanical interface consists of mating flat surfaces and holes through which bolts 502 can be attached. In this example the part of the cryostat the temperature of which is to be measured with the temperature sensor 401 is the 50 K flange 105.

[0048] A pumping hole 503 is schematically shown in fig. 5 going through the body of the insert 410. This is to remind that the inserts should allow gaseous media to flow through them. The pumping hole 503 (and the channel for thermalizing the through-going wire 404) is shown at an oblique angle to emphasize that blocking (or at least significantly reducing in dimension) line-of-sight paths through the insert 410 allows also utilizing the insert as a block of longitudinally propagating thermal radiation inside the enclosure 405.

[0049] Parts 410, 412, and 105 in fig. 5 are all made of (or otherwise comprise) material of high thermal conductivity. The 50 K flange 105 and the clamp 412 thermalize effectively due to the thermally conductive coupling 501 between them. The idea here is that although the wall of the enclosure 405 is made of a material of inherently low thermal conductivity, it does not create too difficult an obstacle for heat to be conducted there-through, between the parts made of materials of high thermal conductivity.

[0050] One aspect of keeping the wall of the enclosure 405 from becoming such an obstacle is making it relatively thin and using a material that has low but finite thermal conductivity. If the enclosure is made of stainless steel, its wall thickness may be in the order of between 0.07 and 0.7 mm for example. Another aspect is that the forces that squeeze the thin wall of the enclosure 405 between the clamp 412 and the insert 410 are large enough to ensure sufficient thermal boundary contact at the material-to-material interfaces. One of these interfaces is the contact surface between the clamp 412 and the outer surface of the wall of the enclosure 405. The other interface is the contact surface between the insert 410 and the inner surface of the wall of the enclosure 405. Thus, sufficient thermal conductance can be achieved between the clamp 412 and the insert 410 even if the

wall of the enclosure remains as a thin layer therebetween. As a consequence, the temperature measured by the temperature sensor 401 is that of the 50 K flange 105 at least at a sufficient accuracy.

[0051] Fig. 4 shows how one or more wires that make the wired couplings 403 and 404 come out of the outer end of the enclosure 405 (and continue inside the tubular fixed part 423 close to the top of the cryostat). In fig. 5 the wire 403 that conveys the signals of the temperature sensor 401 ends at the temperature sensor 401, while the wire 404 that in fig. 4 conveys the electric current to the heater 402 continues through the insert 410. In order to thermalize such a continuing wire to the temperature of the 50 K flange 105, the insert 410 also has the same function as the bobbins of the prior art cryostat in fig. 3. In other words, although the wire 404 continues through the insert 410 it is also in a good thermally conductive connection with the insert 410.

[0052] Reference designator 402 in fig. 4 shows a heater attached to the insert 411 inside the enclosure 405. Clamp 413 is squeezed against the insert 411 with the wall of the enclosure 405 therebetween. The clamp 413 comprises a mechanical interface for making a thermally conductive coupling 414 to adsorption pump 310, which is an example of a part of the cryostat that is to be heated with a heater. The thermally conductive coupling 414 may be for example an elongate piece of material of high thermal conductivity, attached mechanically to the clamp 413 at one end and to the adsorption pump 310 at the other end.

[0053] The part of the cryostat where accurately measuring temperature is both the most critical and the most challenging is the base temperature region at the base temperature flange 111. The cabling subsystem shown in fig. 4 comprises one temperature sensor 405 that is available for a thermally conductive coupling at the inner (lower) end of the enclosure 405. It would be possible to measure the temperature there using a similar arrangement as in fig. 5, but in order to achieve the best accuracy it is better to avoid different material layers and material-to-material interfaces between the base temperature region and the temperature sensor to the largest extent possible. For this reason, the inner end of the enclosure 405 is open, making the temperature sensor 415 available for directly connecting to the base temperature region 409, 111 of the cryostat. This is also where the mechanical interface 407 at the inner end of the enclosure 405 is configured to be connected.

[0054] In the embodiment of fig. 4 the cabling subsystem comprises also a heater 416 available for a thermally conductive coupling at the inner end of the enclosure 405. Similar to the temperature sensor 415, also the heater 416 is accessible through the open inner end of the enclosure 405. Both temperature sensor 415 and the heater 416 may be attached to that part 409 of the base temperature region that engages with the mechanical interface 407 at the inner end of the enclosure 405.

[0055] At the still flange 108 there are both a temper-

ature sensor 417 and a heater 418, both of which should cover the whole still flange 108. While it would be possible to use a common insert, to which both the temperature sensor 417 and the heater 418 would be attached, and a common clamp around the insert, such an arrangement would involve the drawback that the thermal coupling between the temperature sensor and the heater would be more direct than that between the temperature sensor and the still flange. In other words, the temperature sensor would tell more about the temperature of the heater than about the temperature of the still flange. For this reason the "hamburger" configuration shown in fig. 4 is more preferable.

[0056] Formally described, at the region of the still flange 108 the cryostat of fig. 4 comprises a first insert 419 located at a first intermediate location between the ends of the enclosure 405. This first intermediate location is on the first side of the thermal stage (the still flange) 108. Clamp 421 is a first clamp and comprises a mechanical interface for making a thermally conductive coupling between the first clamp 421 and the thermal stage 108 on a first side of the thermal stage 108. The cabling subsystem comprises a second insert 420 inside the enclosure 405 at a second intermediate location between its ends. The second intermediate location is on the other side of the thermal stage 108 than the first intermediate location. The second insert 420 comprises material of high thermal conductivity. The cabling subsystem comprises a heater 418 attached to the second insert 420. The cabling subsystem further comprises a second clamp 422 outside said enclosure 405 at said second intermediate location. The clamp 422 comprises material of high thermal conductivity and is squeezed against the second insert 420 with a wall of the enclosure 405 therebetween. The second clamp 422 comprises a second mechanical interface for making a thermally conductive coupling between the second clamp 422 and the thermal stage 108 on the second side of the thermal stage 108.

[0057] Figs. 4, 6, and 7 illustrate some alternative ways in which the outer (upper) end of the enclosure 405 can be constructed and joined to the other structures of the cryostat. As already mentioned above, in the embodiment of fig. 4 there is a tubular fixed part 423 attached to the vacuum can lid 102. The inner end of the tubular fixed part 423 comprises the flange 408 to which the outer end of the enclosure 405 attaches (through flange 406) with a gastight joint capable of standing ultrahigh vacuum conditions. At the outer end of the tubular fixed part 423 another pair of flanges 424 and 425 form a further joint to a connector box 314. While this further joint needs to be reasonably gastight, it does not need to stand ultrahigh vacuum conditions, so for example a rubber O-ring can be used between the flanges 424 and 425.

[0058] A connector arrangement 426 may be used inside or close to the tubular fixed part 423 to join one or more of the wires coming out of the outer end of the enclosure 405 to further wires to or from the connector box 314.

[0059] The inside of the enclosure 405 should be at vacuum during the operation of the cryostat. However, the level of vacuum inside the enclosure 405 does not need to be as high as the ultrahigh vacuum within the main vacuum can. It is sufficient to have the enclosure 405 evacuated to the extent that any gas remaining therein does not offer easier path than the enclosure walls for heat to transfer between parts that are to be held at different temperatures. Fig. 4 shows schematically a pipe fitting 427, to which a suitable vacuum pump may be coupled. It is possible to continue vacuum pumping the enclosure 405 during operation, but if all connections are tight enough, it is also possible to perform one-time pumping after assembling and to then keep the enclosure 405 sealed during the rest of the operating period of the cryostat.

[0060] The arrangement utilized in the embodiment of fig. 4 at the outer end of the enclosure 405 allows assembling the cabling subsystem from below. When the part 409 to which the inner end of the enclosure 405 is to be attached is not yet in place, there is a so-called clearshot (i.e. a series of aligned apertures in the flanges 111, 301, 108, 107, and 105) available for pushing the elongate enclosure 405 into place from below. One may first connect the connector arrangement 426 and then make the attachment of the outer end of the enclosure between the flanges 406 and 408. Thereafter one may attach all the clamps along the length of the enclosure 405 and squeeze them against the corresponding inserts so that the wall of the enclosure 405 remains therebetween. For this purpose it is advantageous if each clamp consists of at least two parts. Such a clamp may be assembled by bringing its parts into place on the appropriate sides of the enclosure 405 without having to slide the clamp in place over any of the ends of the enclosure 405.

[0061] At the inner end of the enclosure 405 one may make the attachments of the instruments 415 and 416 (if any) to part 409 and then close the joint between flanges 407 and 409. After completing the attachments at all mechanical interfaces where a clamp is to conduct heat to and/or from the corresponding part of the cryostat, the enclosure 405 may be evacuated, after which the cabling subsystem is ready for operating. Assembling from below is advantageous, because in most cases the cryostat is supported from above and there is more room available for assembling actions below it than above it.

[0062] Fig. 6 illustrates the outer end of a cabling subsystem according to another embodiment. Here the outer end of the enclosure 405 extends beyond the flange 601 that is provided for joining the enclosure to a fixed flange 602 that in this embodiment is outside the main vacuum chamber of the cryostat. The outer end comprises a further flange 603 for joining the enclosure 405 to an external device, which in this embodiment is the connector box 314 that is equipped with a flange 604 of its own. The fixed flange 602 is at the top end of a short tube fitting 605 that sticks out of the vacuum can lid 102.

[0063] The arrangement utilized in the embodiment of

fig. 6 at the outer end of the enclosure 405 allows assembling the cabling subsystem from above. Such an approach is particularly suitable for cryostats that include the so-called top loading arrangement for changing samples (see e.g. fig. 1 and the description of prior art). If there is sufficient room available above the cryostat for a top loading arrangement, there is also room for assembling actions from above.

[0064] Fig. 7 illustrates the outer end of a cabling subsystem according to yet another embodiment. This embodiment is suitable for cryostats in which cabling subsystem is assembled from below and/or in which the vacuum can lid 102 is a loose part and will be put into place from above. In this embodiment the thermal stages inside the cryostat (like the 50 K flange 105) and the fixed flange 702 in the extending tube fitting 703 have such large apertures that the further flange 603 at the very outer end of the enclosure 405 can be pushed therethrough. A flange 701 close to the outer end of the enclosure 405 matches the fixed flange 702 to make the gastight joint that stands even ultrahigh vacuum conditions.

[0065] Fig. 8 illustrates a detail of a cabling subsystem according to an alternative embodiment in a schematic cross-sectional view. A temperature sensor 801 is attached to an internal part 802 inside the enclosure 405. The internal part 802 is made of (or otherwise comprises) a material of high thermal conductivity. Outside the enclosure, at the same intermediate location between its ends (i.e. at the same height in fig. 8) is an external part 803, which too is made of (or otherwise comprises) a material of high thermal conductivity. In this embodiment the thermally conductive connection between the internal part 802 and the external part 803 comprises a bridge 804 of material of high thermal conductivity. The bridge 804 is an isthmus or neck of the material of high thermal conductivity, extending through an opening in the wall of the enclosure 405. The mechanical joint that involves the internal part 802, the external part 803, and the bridge 804 must naturally be made so that the gastight nature of the enclosure 405 is not compromised.

[0066] A similar arrangement is shown in fig. 8 on the left side, where a heater 805 is attached to an internal part 806, which has a thermally conductive connection to an external part 807 through a bridge 808 through the wall of the enclosure 405. The thermally conductive connection 501 to a further structural part (here: the 50 K flange 105) is shown similar to that of fig. 5 for both the temperature sensor 801 and the heater 805 in fig. 8, but naturally also other ways can be utilized, such as those shown for the heaters in fig. 4 for example.

[0067] The bridges 804 and 808 are shown only schematically in fig. 8. There are several ways in which such a bridge can be made without compromising the gastight nature of the enclosure 405. One possibility is to use spot welding, in which the internal and external parts are first assembled into place and an intense electric current is then made to flow between them through a very tightly confined channel in the solid materials. The heat induced

by the electric current partly melts the materials involved, creating a region of alloyed metal where the thermal conductivity is substantially higher than that of the pure wall material of the enclosure 405.

[0068] Fig. 9 illustrates another way of making a bridge between an internal part 802 and an external part 803. In this embodiment, copper gaskets 901 and 902 are placed on both sides of the wall of the enclosure. One or bolts 903 tightened in threaded blind holes in the internal part 802 are used to squeeze the internal part 802 and external part 803 towards each other, so that the copper gaskets 901 and 902 deform against the knife edges of the respective sealing surfaces. In the embodiment of fig. 9 the thermally conductive connection to a further structural part of the cryostat is to the right where only a part of a corresponding extension of the external part 803 is shown.

[0069] Fig. 10 illustrates a detail of a cabling subsystem according to an embodiment. This detail is related to embodiments of the so-called "custom wire harness" type. The parts shown in fig. 10 include the base temperature flange 111, the lower end of the enclosure 405, the mechanical interface 407 at the inner end of the enclosure 405, and the mating surface 409 to which the mechanical interface 407 is joined in gastight manner. Also shown, as examples, are the temperature sensor 415 and the heater 416 that may be available for a thermally conductive coupling at the inner end of the enclosure 405.

[0070] An internal wired device 1001 is shown attached to the base temperature flange 111. The internal wired device 1001 may be any device that is meant for use in a scientific experiment, a quantum computing process, and/or other task that is to be performed in the cryogenically cooled environment and that requires a wired connection to and/or from the surrounding room temperature environment. It is also possible that the wired connection goes between the internal wired device 1001 and another internal wired device that is located at some other thermal stage of the cryostat. As an illustrative example, the internal wired device 1001 may be a quantum processing circuit and the wired connection may be one through which an operator may pass control signals, excitation signals, bias signals, readout signals, and/or the like. Some of such signals may be oscillating signals at extremely high frequencies, so terms like "wire" and "wired" used here must be understood in the general sense, covering e.g. coaxial transmission lines in addition to simpler wires and cables.

[0071] According to the principle illustrated in fig. 10, the wired connection to and/or from the internal wired device 1001 comprises a stub wire 1002 between the internal wired device 1001 and the exposed end of an UHV-compliant feedthrough 1003 in the mating surface 409. Additionally, said wired connection comprises a further wire 1004 that goes inside the enclosure 405, between the internal end of the UHV-compliant feedthrough 1003 and some further device, which may be e.g. a connector box of the kind shown earlier in fig. 4. Thermally

conductive couplings to internal parts (not shown) inside the enclosure 405 may be used to ensure that the further wire 1004 does not cause thermal loading of the coldest stages of the cryostat.

[0072] The versatile possibilities of making wired connections this way explains why embodiments of the kind shown in fig. 10 are referred to as providing a custom wire harness. At the time when a cryostat is originally designed, manufactured, and delivered to its user it may not be completely known, what kind of wired connections will be needed. Using wired connections that go at least partly inside the enclosure 405 it is possible to later add functionalities for which there is no originally designated wiring possibilities in other parts of the cryostat.

[0073] One important thing to note is that while the UHV-compliant feedthrough 1003 is shown in the mating surface 409 in fig. 10, there could be one or more corresponding UHV-compliant feedthroughs elsewhere in the walls of the enclosure 405. The principle shown in fig. 10 can thus be widened to cover wired connections to devices located anywhere inside the cryostat.

[0074] Another important thing to note is that the principle shown in fig. 10 is applicable regardless of whether the cabling subsystem comprises any temperature sensors or heaters. In other words, it is possible to provide an embodiment in which the "instrument" referred to above is the inner end of an UHV-compliant feedthrough, said inner end being located inside the enclosure 405 or being available for connections at the place where the inner end of the enclosure 405 comes in the cryostat. In such a case it is not necessary to even have any thermally conductive connection for the purposes of signal transfer between the inside and outside of the enclosure 405. It is advantageous, though, to have such thermally conductive connections at locations where thermalization of the further wire 1004 inside the enclosure with a particular thermal stage of the cryostat should be accomplished.

[0075] Fig. 11 illustrates an embodiment in which one of the instruments is a wired connector 1101 at the inner end of an UHV-compliant feedthrough 1103 in the wall of the enclosure 405. A wired coupling 1102 comes to the wired connector 1101 inside the enclosure 405. The wired coupling 1102 is attached to the internal part 410 inside the enclosure 405 for thermalizing it with the appropriate structure of the cryostat, which in this example is the 50 K flange 105 to which the external part (clamp 412) is attached. By making wired connections of this kind at any intermediate location along the length of the elongate enclosure 405 it is possible to tailor the cabling subsystem to many kind of specific needs that may necessitate wired connections to components not only at the target region but also at some intermediate stages of the cryostat.

[0076] It is obvious to a person skilled in the art that with the advancement of technology, the basic idea of the invention may be implemented in various ways. The invention and its embodiments are thus not limited to the examples described above, instead they may vary within

the scope of the claims.

Claims

1. Cabling subsystem for a cryostat, comprising:

- an instrument (401, 402, 417, 418, 801, 805, 1003) that comprises at least one of: a temperature sensor (401, 417, 801), a heater (402, 418, 805), a wired connector (1101), and
- a wired coupling (403, 404, 1004, 1102) to or from said instrument,

characterized in that the cabling subsystem comprises:

- an elongate enclosure (405) made of a gastight material of low thermal conductivity,
- at or close to both ends of said enclosure (405), mechanical interfaces (406, 407) for joining said enclosure to corresponding further structures (408, 409) of the cryostat in a gastight manner,
- inside said enclosure (405), at an intermediate location between the ends of the enclosure, an internal part (410, 411, 419, 420, 802, 806) comprising material of high thermal conductivity,
- outside said enclosure (405), at said intermediate location, an external part (412, 413, 421, 422, 803, 807) comprising material of high thermal conductivity, and
- a thermally conductive connection between said internal part (410, 411, 419, 420, 802, 806) and said external part (412, 413, 421, 422, 803, 807);

wherein at least one of said instrument (401, 402, 417, 418, 801, 805) and said wired coupling (403, 404, 1004, 1102) is attached to said internal part (410, 411, 419, 420, 802, 806) inside the enclosure (405).

2. A cabling subsystem according to claim 1, comprising a bridge (804, 808) of material of high thermal conductivity connecting said internal part (802, 806) to said external part (803, 807) through a wall of said enclosure (405).

3. A cabling subsystem according to claim 1, wherein:

- said internal part is an insert (410, 411, 419, 420) inside said enclosure, and
- said external part is a clamp (412, 413, 421, 422) squeezed against said insert (410, 411, 419, 420) with a wall of said enclosure (405) therebetween.

4. A cabling subsystem according to any of claims 1 to

3, wherein:

- said instrument comprises a temperature sensor (401, 417, 801), and
- said external part (412, 421, 803) comprises a mechanical interface for making a thermally conductive coupling (501) between the external part (412, 421, 803) and a part (105, 108) of the cryostat the temperature of which is to be measured with said temperature sensor (401, 417, 801).

5. A cabling subsystem according to any of the preceding claims, wherein:

- said instrument comprises a heater (402, 418, 805), and
- said external part (413, 422, 807) comprises a mechanical interface for making a thermally conductive coupling (414) between the external part (413, 422, 807) and a part (310, 108) of the cryostat that is to be heated with said heater (402, 418, 805).

6. A cabling subsystem according to any of the preceding claims, wherein:

- one of the ends of the elongate enclosure (405) is an inner end, so that the mechanical interface (407) at said inner end is configured for connecting to a base temperature region (409, 111) inside the cryostat in a gastight manner, and
- the cabling subsystem comprises a temperature sensor (415) available for a thermally conductive coupling at said inner end of the enclosure (405).

7. A cabling subsystem according to claim 6, wherein:

- the cabling subsystem comprises a heater (416) available for a thermally conductive coupling at said inner end of the enclosure (405).

8. A cabling subsystem according to any of claims 6 or 7, wherein:

- said inner end of the elongate enclosure (405) is open, making at least said temperature sensor (415) available for directly connecting to the base temperature region (409, 111) of the cryostat to which said mechanical interface (407) at said inner end is configured to be connected.

9. A cabling subsystem according to any of the preceding claims, wherein:

- one of the ends of the enclosure (405) is an outer end and comprises a flange (406, 601,

- 701) for joining the enclosure (405) to a fixed flange (408, 602, 702) inside or outside the cryostat.
10. A cabling subsystem according to claim 9, wherein: 5
- the outer end of the enclosure extends beyond said flange (601, 701), and
 - the outer end of the enclosure (405) comprises a further flange (603) for joining the enclosure to an external device (604, 314). 10
11. A cabling subsystem according to claim 10, wherein the further flange (603) is configured to make a less gastight joint than said flange (406, 601, 701) that is provided for joining the enclosure (405) to a fixed flange (408, 602, 702) inside or outside the cryostat. 15
12. A cabling subsystem according to any of the preceding claims, wherein the internal part (410, 411, 419, 420, 802, 806) is configured to block the propagation of thermal radiation in the longitudinal direction of the enclosure (405) inside the enclosure (405). 20
13. A cabling subsystem according to any of the preceding claims, wherein the instrument comprises a wired connector at an inner end of an UHV-compliant feedthrough (1003, 1103). 25
14. A cabling subsystem according to claim 13, wherein said inner end of said UHV-compliant feedthrough (1003, 1103) is located inside the enclosure (405) or is available for connections at a place where the inner end of the enclosure (405) comes at in the cryostat. 30
15. A cryostat, comprising a vacuum can, **characterized in that** the cryostat comprises a cabling subsystem according to any of claims 1 to 13 located at least partly inside said vacuum can. 35
16. A cryostat according to claim 14, wherein: 40
- the cryostat comprises an adsorption pump (310), the adsorbing effect of which depends on its temperature, 45
 - the instrument in the cabling subsystem comprises a heater (402, 805), and
 - the external part (413, 807) in said cabling subsystem comprises a mechanical interface for making a thermally conductive coupling (414) between the external part (413, 807) and the adsorption pump (310). 50
17. A cryostat according to any of claims 14 or 15, wherein: 55
- the cryostat comprises a thermal stage (108),
 - the instrument in the cabling subsystem com-

prises a temperature sensor (401, 417, 801), and

- the external part (421, 803) in said cabling subsystem comprises a mechanical interface for making a thermally conductive coupling between the external part (421, 803) and the thermal stage (108).

18. A cryostat according to claim 16, wherein:

- the internal part in the cabling subsystem is a first insert (419) located at a first intermediate location between the ends of the enclosure (405) that is on a first side of said thermal stage (108),
- the external part in said cabling subsystem is a first clamp (421) and comprises a mechanical interface for making a thermally conductive coupling between the first clamp (421) and the thermal stage (108) on a first side of the thermal stage (108),
- the cabling subsystem comprises a second insert (420) inside said enclosure at a second intermediate location between the ends of the enclosure (405) that is on the other side of said thermal stage (108), the second insert (420) comprising material of high thermal conductivity,

- the cabling subsystem comprises a heater (418) attached to said second insert (420) inside the enclosure (405),
- the cabling subsystem comprises a second clamp (422) outside said enclosure (405) at said second intermediate location, said second clamp (422) comprising material of high thermal conductivity and being squeezed against said second insert (420) with a wall of said enclosure (405) therebetween,
- the second clamp (422) comprises a second mechanical interface for making a thermally conductive coupling between the second clamp (422) and the thermal stage (108) on a second side of the thermal stage (108).

19. Method for assembling a cabling subsystem to a cryostat, comprising:

- attaching an instrument or its wired coupling (403, 404, 1004, 1102) to an internal part (410, 411, 419, 420, 802, 806) comprising material of high thermal conductivity, said instrument comprising at least one of: a temperature sensor (401, 417, 801), a heater (402, 418, 805), a wired connector (1101),
- placing said internal part (410, 411, 419, 420, 802, 806) inside an elongate enclosure (405) made of a gastight material of low thermal conductivity,
- making a wired coupling to said instrument inside the enclosure (405),

- placing an external part (412, 413, 421, 422, 803, 807) comprising material of high thermal conductivity outside said enclosure (405) at the same location between the ends of the enclosure where the insert (410, 411, 419, 420) is located, and 5
- making a thermally conductive connection between said internal part (410, 411, 419, 420, 802, 806) and said external part (412, 413, 421, 422, 803, 807) through a wall of said enclosure (405). 10

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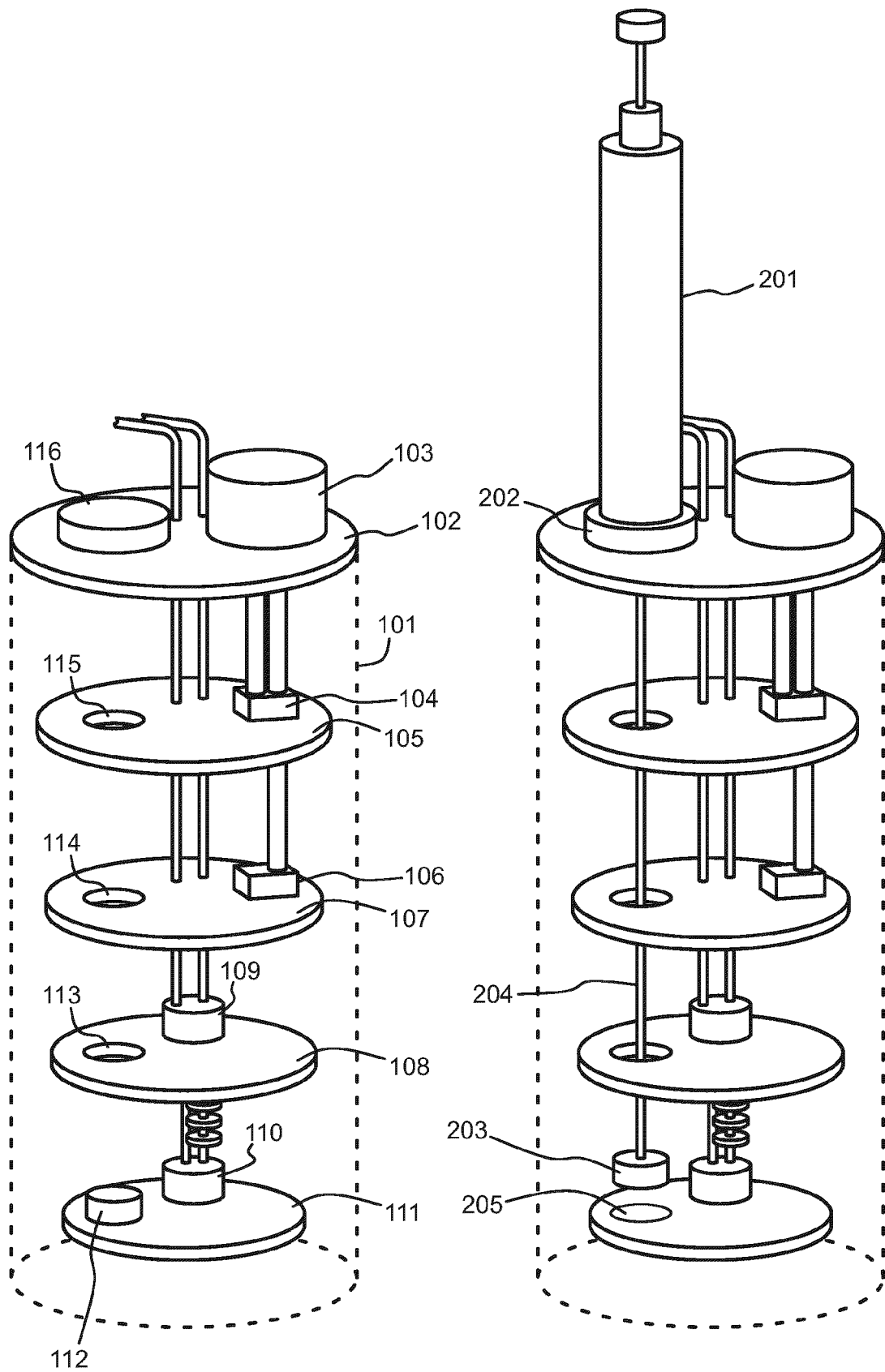
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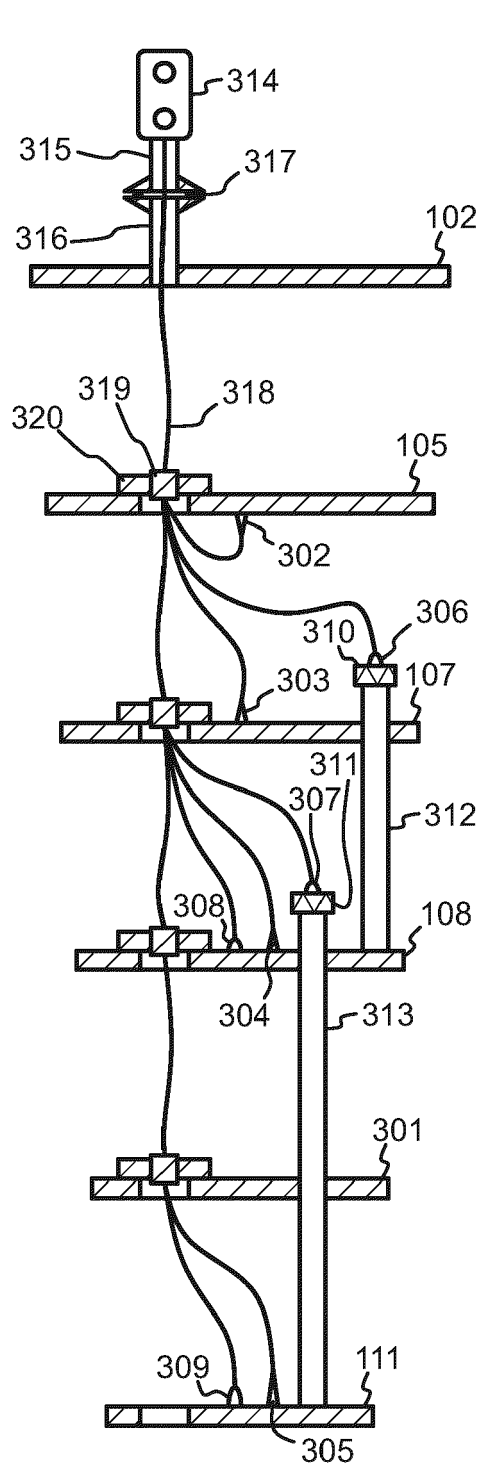


Fig. 3
PRIOR ART

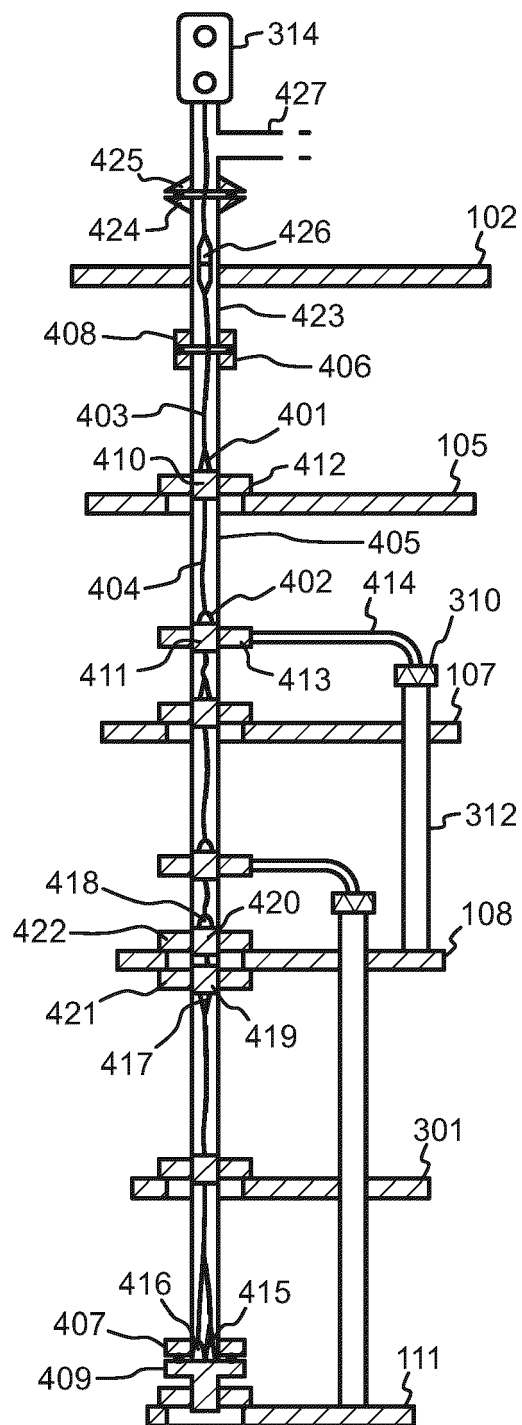


Fig. 4

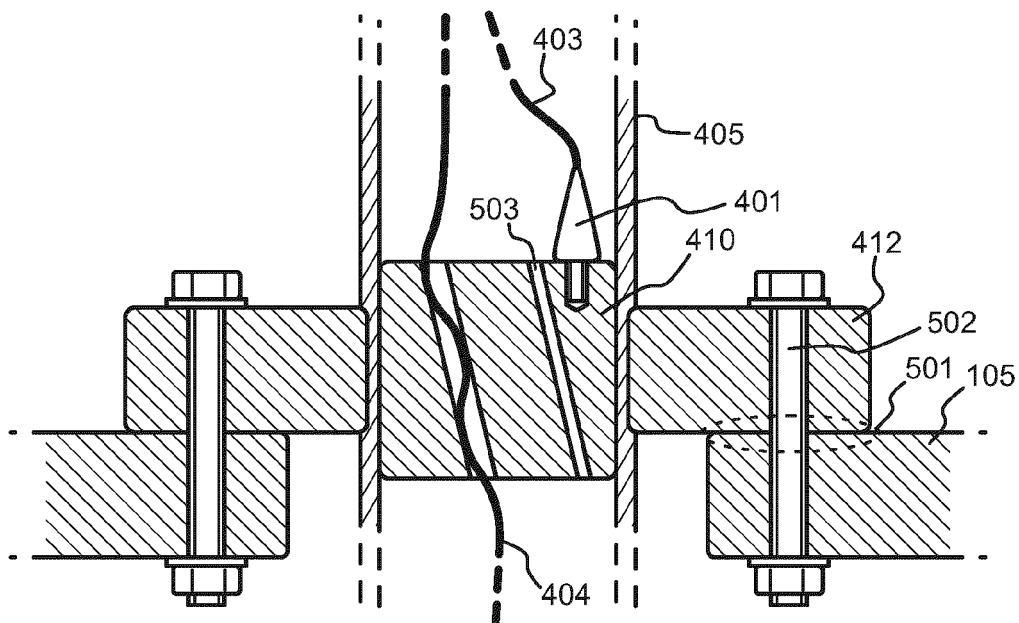


Fig. 5

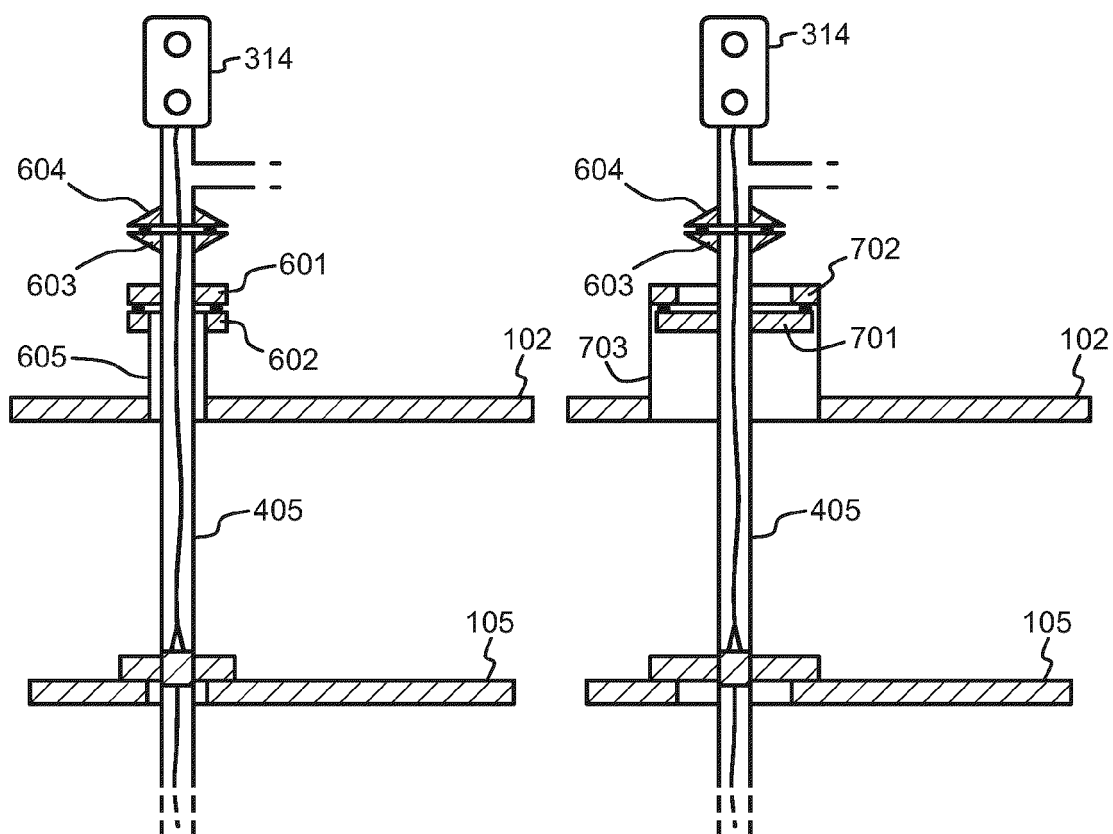


Fig. 6

Fig. 7

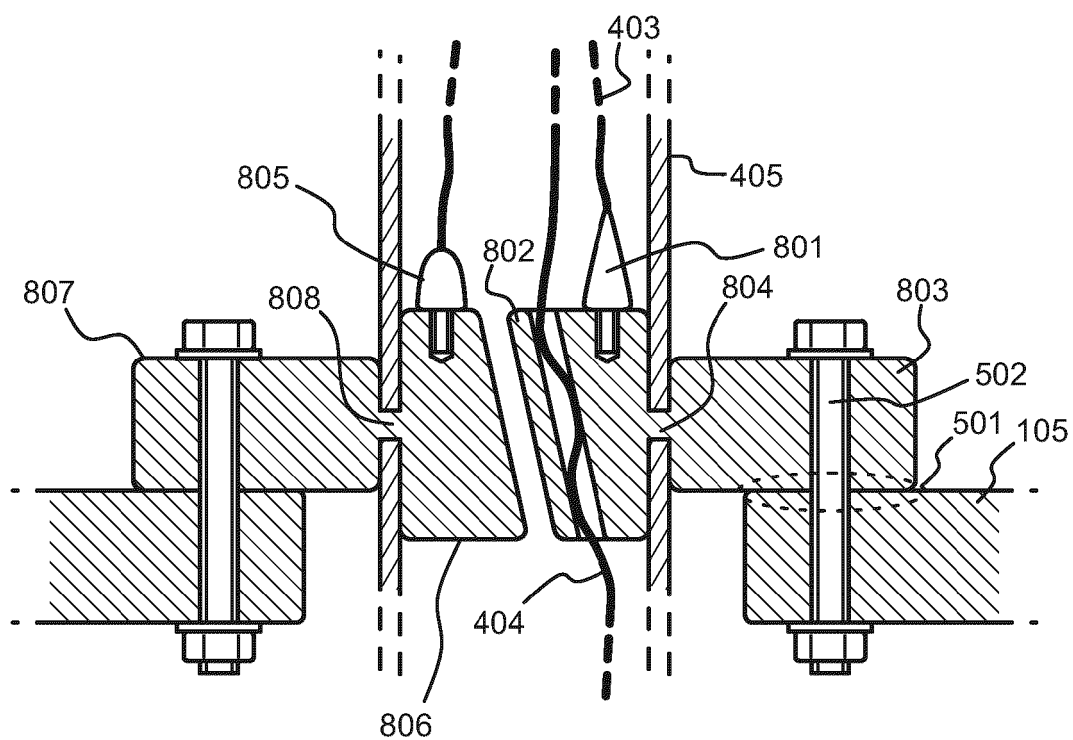


Fig. 8

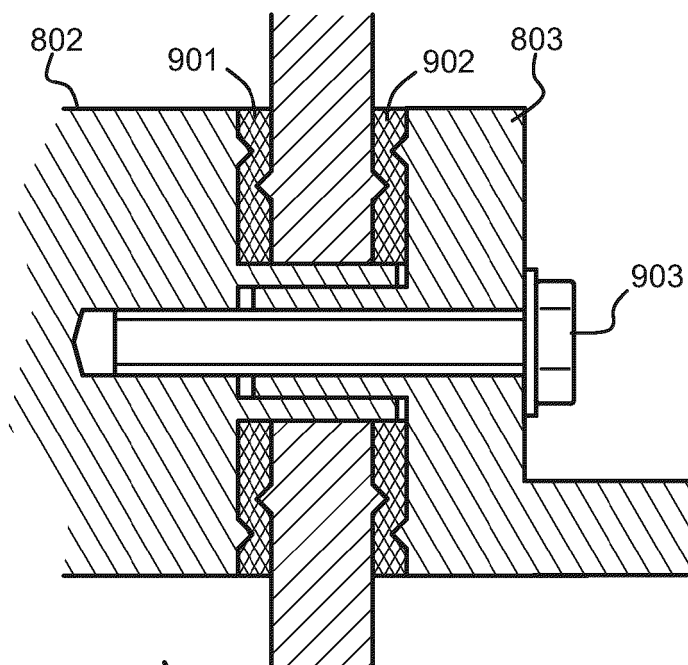


Fig. 9

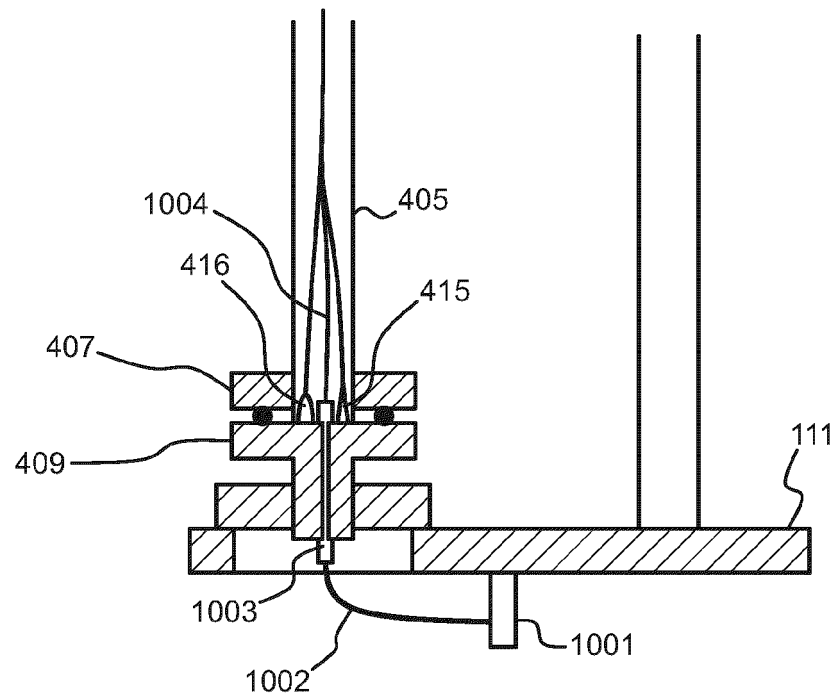


Fig. 10

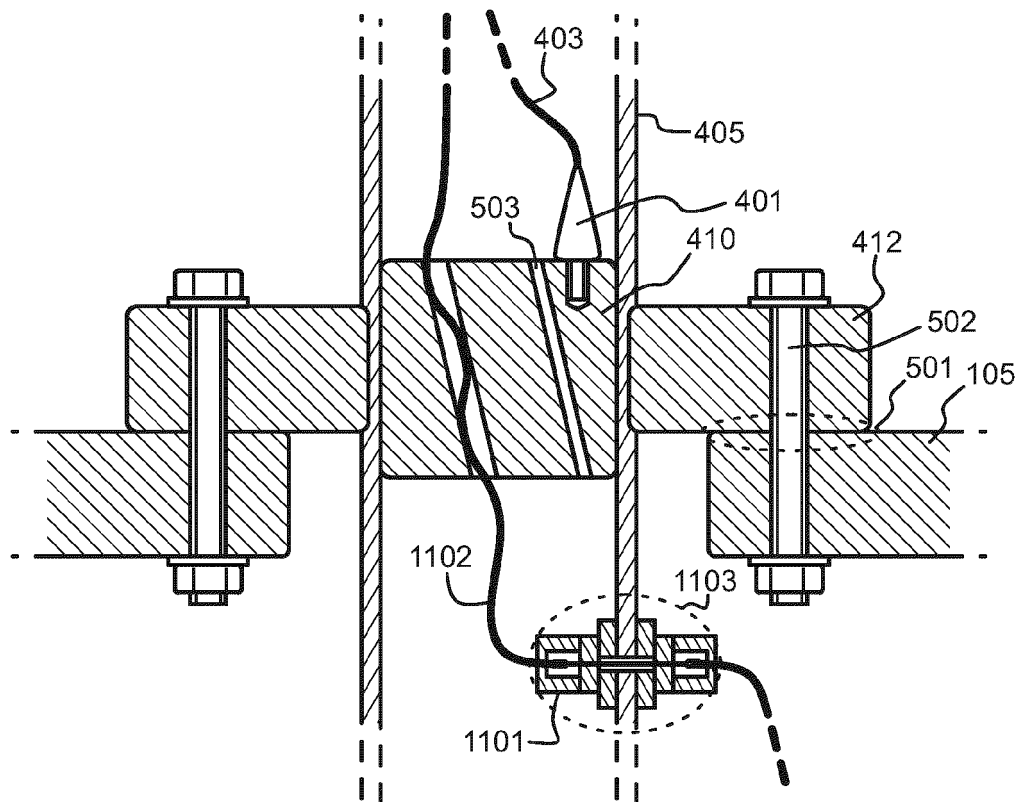


Fig. 11



EUROPEAN SEARCH REPORT

Application Number
EP 20 21 3816

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EPO FORM 1503 03.82 (P04C01)

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	SEBASTIAN KRINNER ET AL: "Engineering cryogenic setups for 100-qubit scale superconducting circuit systems", ARXIV.ORG, CORNELL UNIVERSITY LIBRARY, 201 OLIN LIBRARY CORNELL UNIVERSITY ITHACA, NY 14853, 20 June 2018 (2018-06-20), XP081562741, DOI: 10.1140/EPJQT/S40507-019-0072-0 * abstract; figures 3,4 * * page 18; figure 7 *	1-19	INV. F25D19/00 F17C3/08 F25D29/00
A	Bluefors: "LD dilution refrigerator - Bluefors", 11 August 2020 (2020-08-11), XP055808257, Retrieved from the Internet: URL:https://web.archive.org/web/20200811104837/https://bluefors.com/products/ld-dilution-refrigerator/ [retrieved on 2021-05-27] * the whole document *	1-19	TECHNICAL FIELDS SEARCHED (IPC)
A	EP 0 023 850 A1 (SCHLUMBERGER LTD [US]; SCHLUMBERGER PROSPECTION [US]) 11 February 1981 (1981-02-11) * figure 1 *	1-19	F25D F17C H05K
A	JP H07 302934 A (HITACHI LTD) 14 November 1995 (1995-11-14) * figures 1-5 *	1-19	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 28 May 2021	Examiner Kuljis, Bruno
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 20 21 3816

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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ORM P0459

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0023850 A1	11-02-1981	AR 229914 A1	30-12-1983
		AT 9407 T	15-09-1984
		AU 533206 B2	10-11-1983
		BR 8003868 A	13-01-1981
		CA 1138127 A	21-12-1982
		CA 1138128 A	21-12-1982
		CA 1138129 A	21-12-1982
		EG 14570 A	30-09-1984
		EP 0023850 A1	11-02-1981
		ES 8102265 A1	16-12-1980
		GR 69277 B	13-05-1982
		IE 49489 B1	16-10-1985
		IN 152457 B	21-01-1984
		JP S5644874 A	24-04-1981
		JP S6359543 B2	21-11-1988
		MX 148778 A	14-06-1983
		NO 157717 B	25-01-1988
		OA 06551 A	31-07-1981
		SU 1281182 A3	30-12-1986
		TR 21161 A	25-11-1983
		US 4312192 A	26-01-1982
		US 4313317 A	02-02-1982
		US 4315417 A	16-02-1982

JP H07302934 A	14-11-1995	NONE	
