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(56) Documents Cited:
US 6109042 A **US 4719938 A**
US 20060064989 A1 **US 20050198973 A1**
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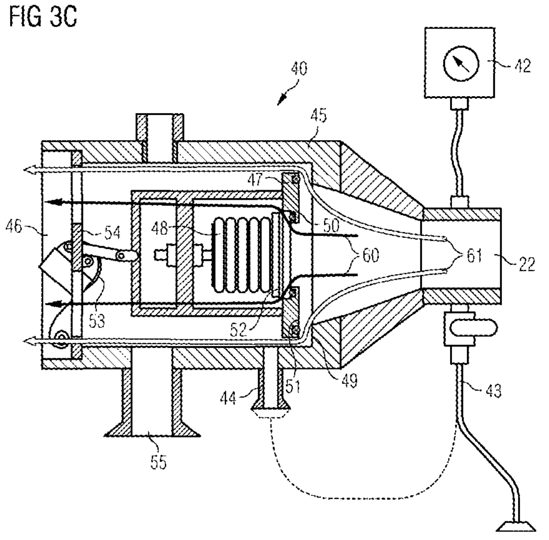
(54) Title of the Invention: **Cryostat vent valve**
Abstract Title: **Cryostat Vent Valve**

(57) A cryostat vent valve 40 comprises a housing 45 having an inlet 22 and an outlet 46 defining a gas flow path 60,61 therebetween, a quench valve 47; and a relief valve 48. The quench valve and relief valve are biased to close the gas flow path. The relief valve 48 opens at a lower gas pressure than the quench valve 47 and the relief valve lies within the housing 45 in the same gas flow path 60,61 as the quench valve.

FIG 3C



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG 1

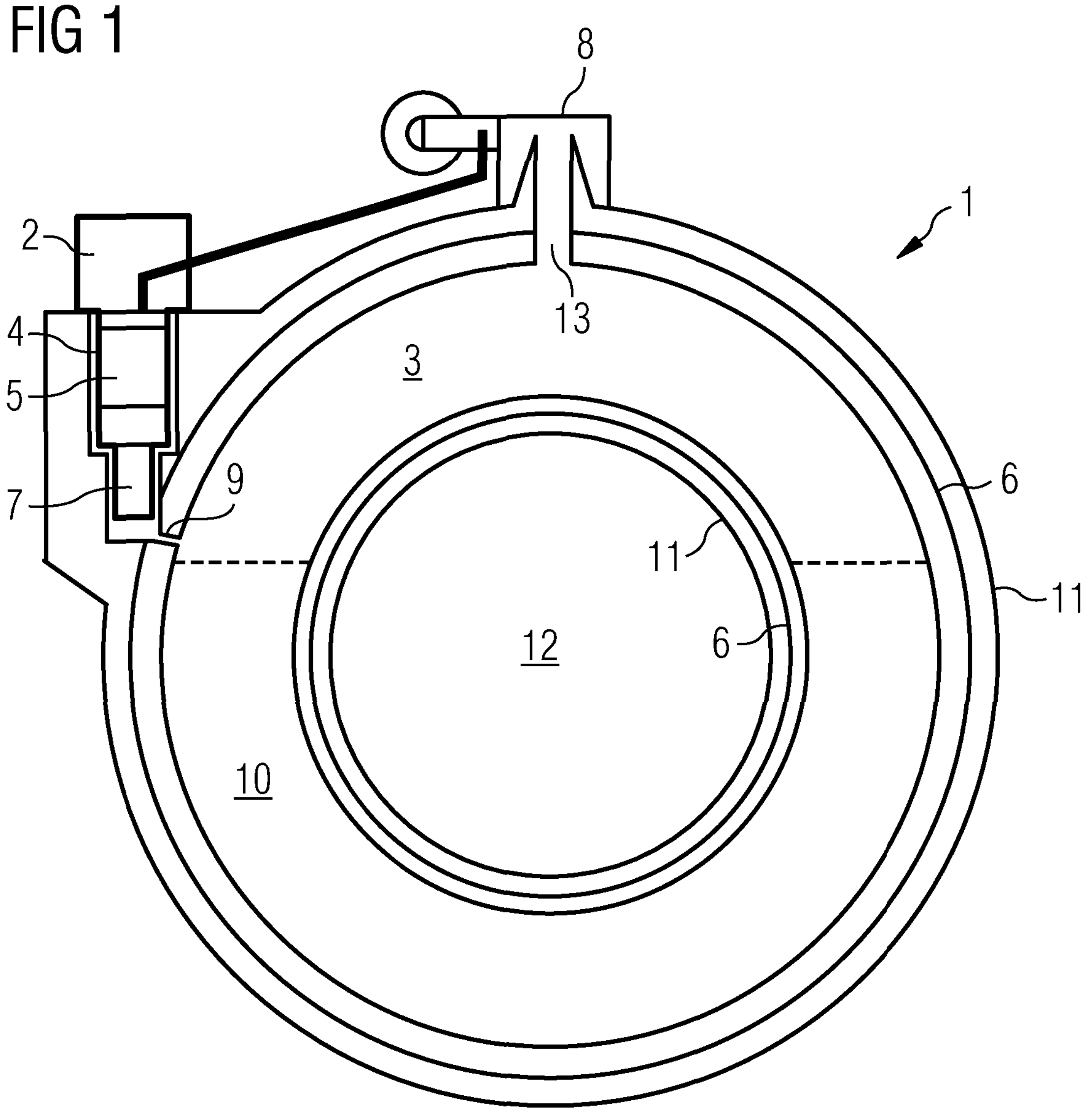

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FIG 2

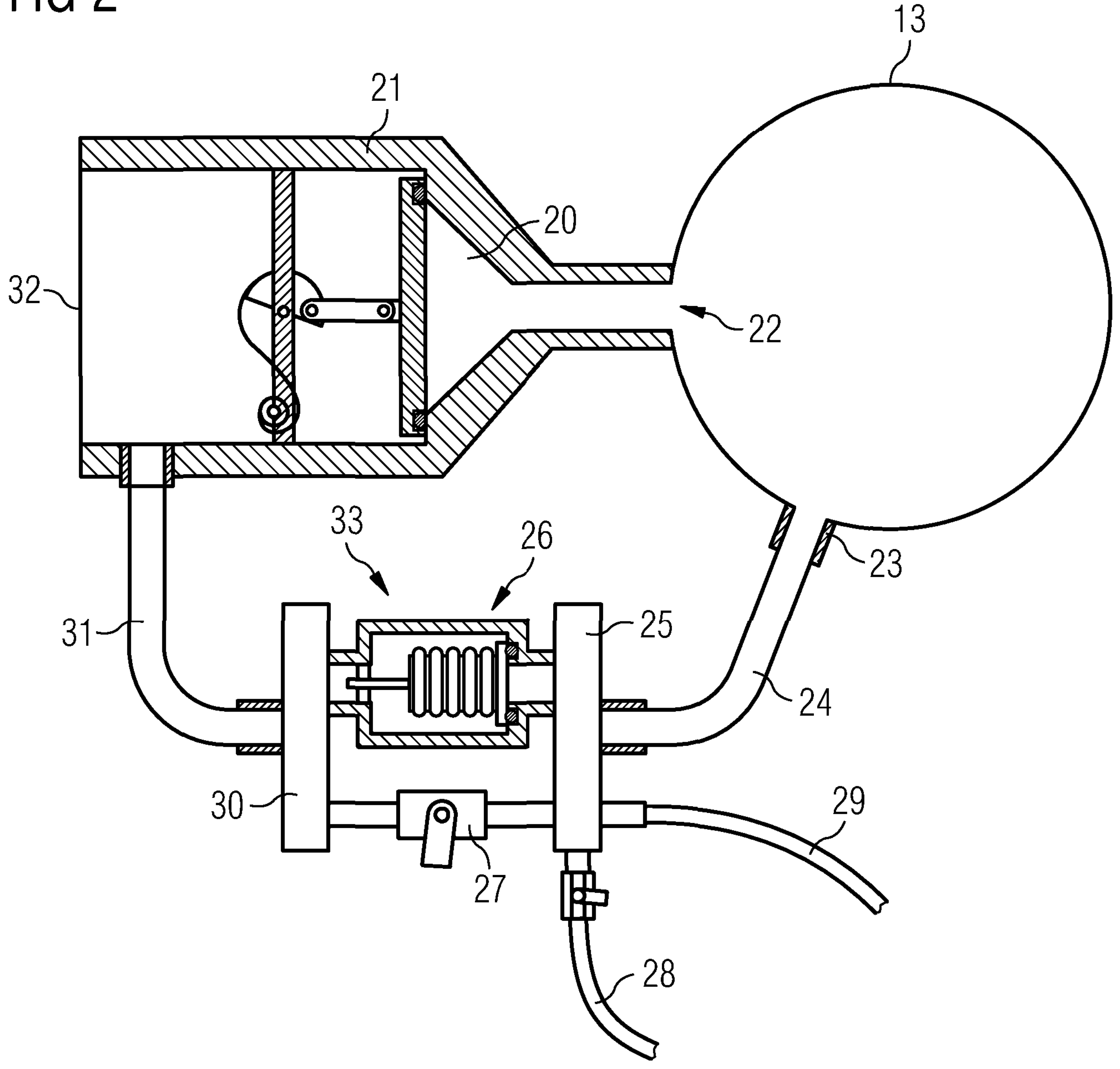

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FIG 3A

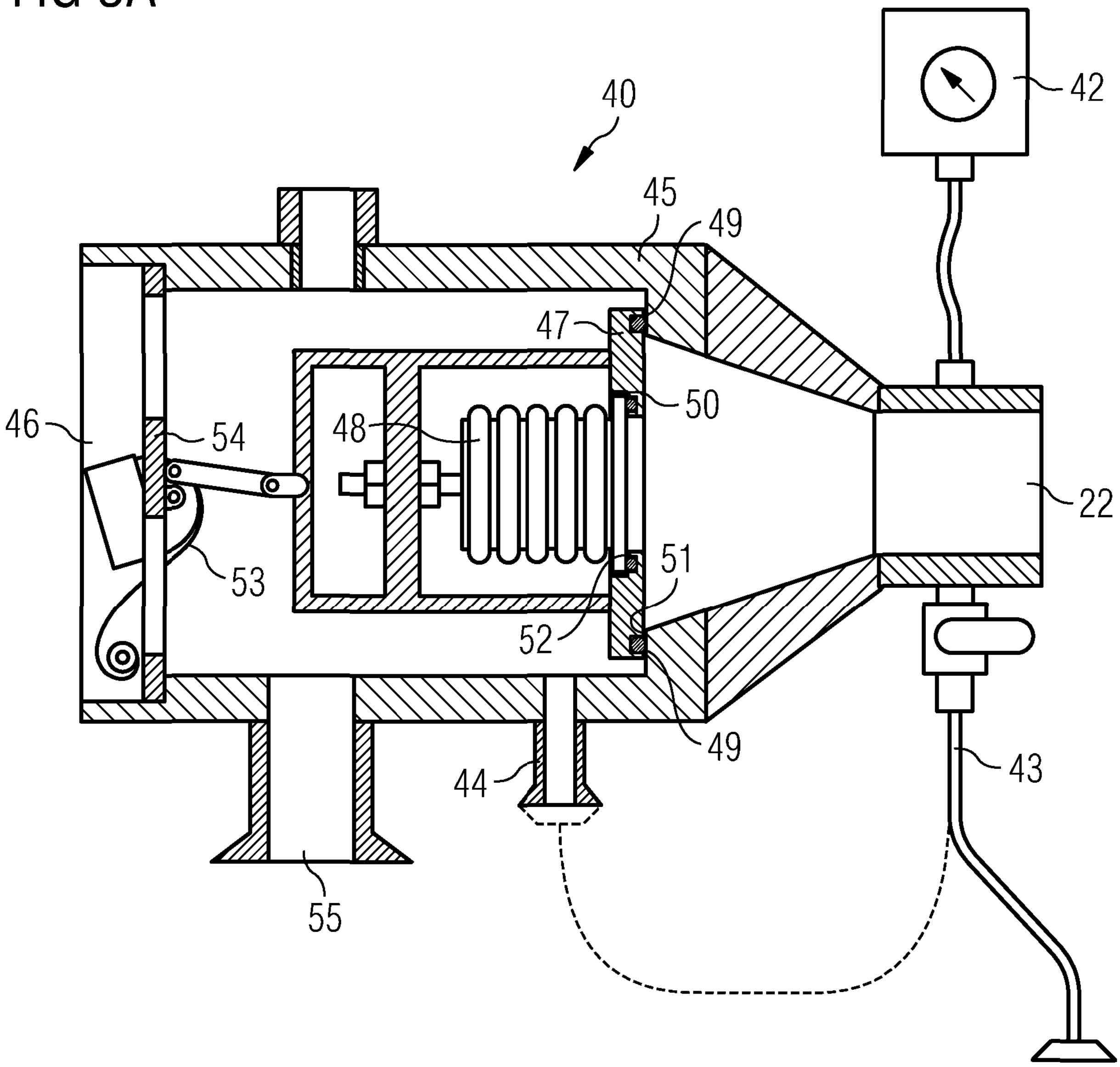

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FIG 3B

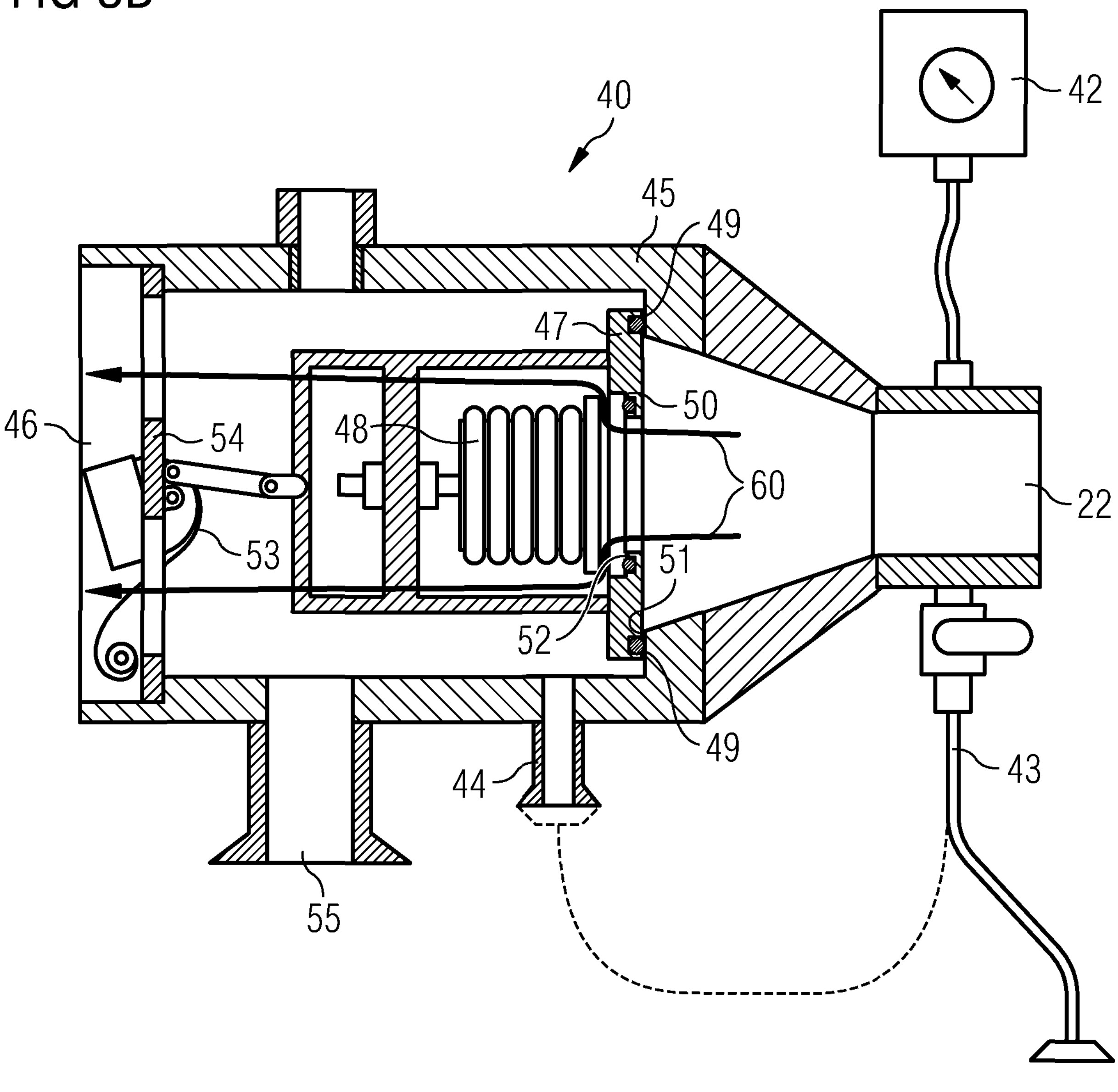

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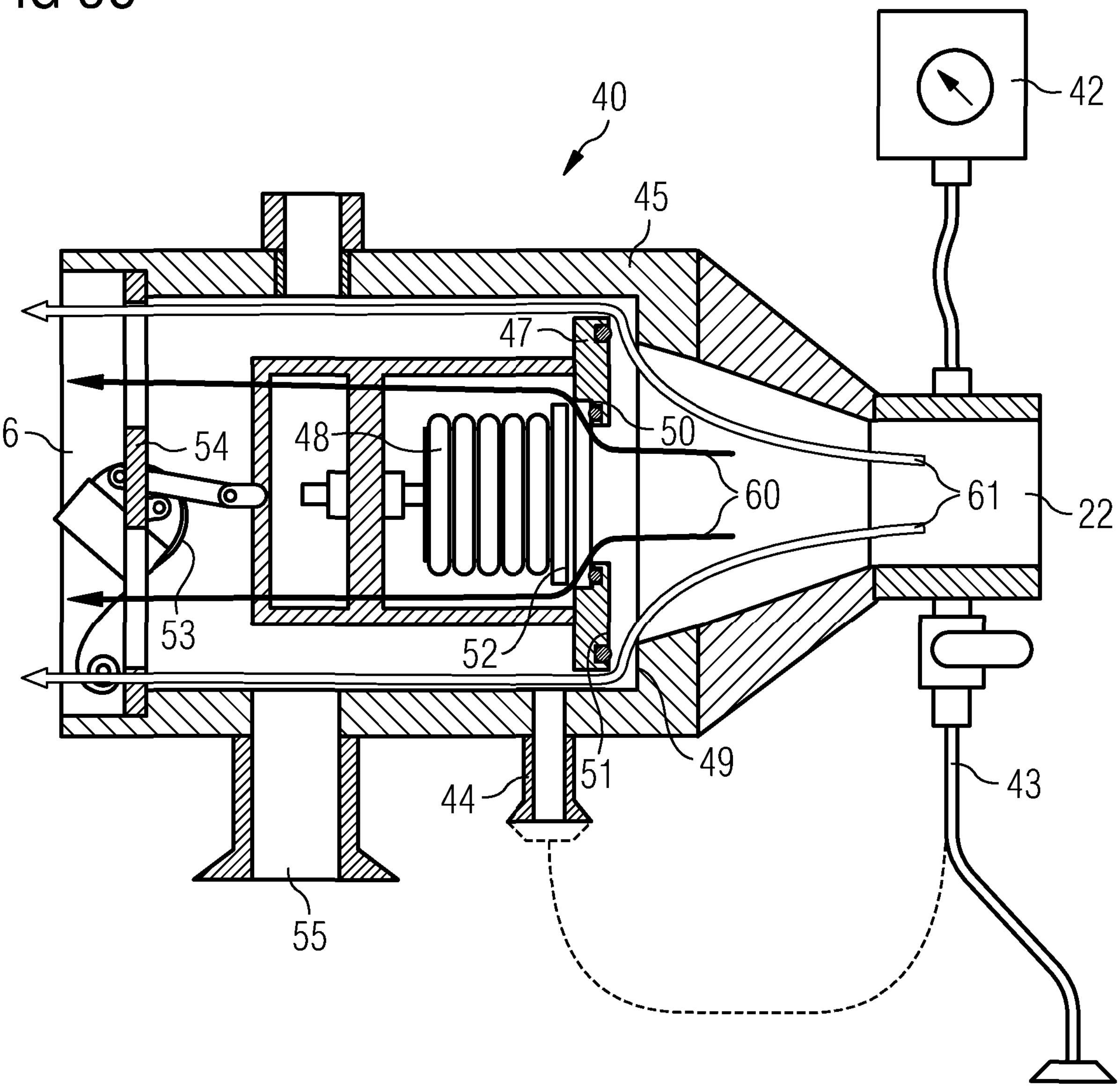
FIG 3C



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CRYOSTAT VENT VALVE

This invention relates to a cryostat vent valve, in particular for use in a cryostat of a magnetic resonance imaging (MRI) system.

Superconducting magnets are typically cooled by a liquid cryogen, such as liquid helium, within a cryostat. Superconducting magnets are susceptible to quench events, in which, for one of a number of reasons, part of the superconducting magnet ceases to be superconducting. The resulting resistance in part of the magnet causes heat due to the current flowing through it. This rapidly causes further parts of the superconducting magnet to cease superconducting. The result is that all of the energy which was stored in the magnetic field of the magnet is suddenly released as heat. In a superconducting magnet cooled by a liquid cryogen, this typically results in rapid boiloff of a large volume of the cryogen, with gaseous and liquid cryogen being expelled from the cryostat at high speed.

During a quench, it is essential that the escaping cryogen gas is allowed to exit the cryostat in a safe manner into an associated conduit, and be routed safely out of the building housing the magnet.

The exit point from the cryostat must allow the gas to exit with the minimum of restriction, yet the exit point from the cryostat must remain leak tight until the point of failure i.e. quench. The exit point typically opens by responding to an increase in the pressure within the cryostat.

Currently, it is known to provide a re-sealable quench valve to control the exit point. The quench valve is closed until a certain pressure is reached within the cryostat. Once the cryostat pressure reaches the certain value, the quench valve is opened by the pressure acting upon it. Once the quench event is over, the quench valve will reseal itself, and should be undamaged. In such arrangements, however, the valve mechanism is directly in the exit flow path, which reduces the available cross sectional area for the gas flow, which in turn increases the cryostat pressure during a quench This has a direct relationship on the design of the helium vessel.

The present invention provides apparatus and a method as defined in the appended claims.

An example of a cryostat vent valve arrangement according to the present invention will now be described with reference to the accompanying drawings in which:

Figure 1 shows an example of a conventional arrangement of a refrigerator on a superconducting magnet system;

Figure 2 illustrates a conventional quench valve arrangement for use in the system of Fig.1; and,

Figure 2 illustrates schematically an example of a vent valve arrangement according to the present invention for use with the cryostat of Fig. 1.

Figure 1 shows a cross-section of a conventional superconducting magnet system 1 for use in an MRI system. A two-stage cryogenic refrigerator 2 is removably connected to the magnet system 1 by an interface sock 4, such that a first stage 5 of the refrigerator 2 is thermally linked to a thermal shield 6, in order to cool the thermal shield and a second stage 7 of the refrigerator cools a cryogen vessel 3. The refrigerator is preferably, but not necessarily, arranged as a recondensing refrigerator. A heat exchanger, cooled by the second stage 7 of the refrigerator 2, is exposed to the interior of the cryogen vessel 3, for example by a tube 9. The refrigerator is, in operation, thereby enabled to reduce the consumption of cryogen by recondensation of evaporated cryogen back into its liquid state.

Superconductive magnet coils (not shown) are provided in the cryogen vessel. The coils are immersed in a liquid cryogen 10. The thermal shield 6 completely surrounds the cryogen vessel 3. An outer vacuum chamber (OVC) vacuum casing 11 completely encloses the cryogen vessel and the shield in a vacuum. A central bore 12 is provided, to accommodate a patient for examination. An access neck 13 is provided in a turret 8 to allow access to the cryogen vessel 3. The access neck 13 is thermally linked to the thermal shield 6.

Magnet venting design aims to fulfil a number of diverse criteria. During operation, the magnet must remain sealed against air ingress; during ramping, a controlled release of cold gas is required to cool the current leads; and during quench, huge volumes of gas must be vented safely. Since 1500 litres of liquid helium equates to a gas volume of more than 1 million litres at room temperature, arranging for this to be rapidly and safely removed at quench is a significant consideration. As much as 10^6 litres of gas is vented in a minute, so the quench valve is typically a gauge device and must react rapidly, as well as being reliable and repeatable, but the exact opening pressure is of less significance. There are various shipping regulations for air and sea freight which have to be met and the risk of failure in transit minimised.

Conventionally, one option for sealing the magnet, whilst allowing rapid gas removal during quench, has been to use a burst disc, positioned across the access neck 13. When the pressure within the cryogen vessel 3 increases significantly due to quench, the burst disc is broken and so allows the helium gas to escape. An alternative has been to provide an emergency valve 20 in a discharge pipe 21 connected to an end of the access neck 13, which opens when quench occurs, as illustrated in Fig. 2.

Fig.2 illustrates a conventional venting arrangement used with a magnet system such as that shown in Fig.1. The discharge pipe 21 is provided at an outlet 22 of the access neck 13 and the emergency quench valve 20 is mounted in the discharge pipe. The valve 20 opens into a quench line 32 to atmosphere. During normal operation, the quench valve remains closed and any venting occurs through a bypass path 33. The bypass path 33 is formed by a line 24 from an outlet 23 of the access neck, which line 24 feeds into a high pressure manifold 25. From the high pressure manifold 25 to a low pressure manifold 30, there are two paths, one through a 16 pounds per square inch absolute (PSIA) valve assembly 26 (110,316.16Pa) and the other path through a by-pass valve 27. A pressure switch (not shown) is connected to the high pressure manifold 25 by a line 29. A path to the high pressure manifold 25 via a transit line 28 from the refrigerator 2 completes a circuit to allow cryogen from the cryostat to be used to cool the refrigerator, when the refrigerator is not operational, e.g. in transit, so as to reduce the heat transfer into the cryogen vessel from the refrigerator. The low pressure manifold 30 has an outlet 31 to atmosphere, via the quench line 32.

For the controlled release of gas during ramping, the separate absolute pressure relief valve in the valve assembly 26 is provided, which can also be used for venting during shipping. The ramping gas flow is relatively modest, but needs to be repeatable, reliable and well controlled. However, these conventional arrangements tend to be expensive, bulky and prone to condensation problems.

Although it might seem that a single valve could be used in place of all these components, a single valve which is large enough to deal with the requirements of quench is unable to operate smoothly enough to deal with the small leaks for which the relief valve is designed, or to provide reliable cooling, due to the variable gas flows in the quench valve.

Thus, the present invention aims to address the problems of these conventional quench valve arrangements.

Fig. 3 illustrates schematically the functions of a valve according to the present invention. In Fig. 3a, the valve is fully closed; in Fig. 3b, the valve is partially open; and in Fig. 3c, the valve is fully open. A vent valve arrangement 40 according to the invention is positioned in a path from the outlet 22 of the access neck and the pressure at the outlet is measured by a pressure gauge 42. A pipeline 43 from the outlet allows circulation of cryogen to cool the refrigerator 2, as described above when not operational, or connects to a bypass 44 in operation. The bypass enables manual depressurising, e.g. for dismantling of the equipment for servicing. The vent valve arrangement of the present invention comprises a housing 45 and a two part quench valve opening into a quench line 46, the valve having two valve elements 47, 48 mounted on respective seats 49, 50, the seat 49 being formed in the housing 45. Each element 47, 48 comprises a sealing surface 51, 52 which seals against its respective seat 49, 50. The quench valve element 47 is arranged to respond to pressures at typical levels occurring during quench and the secondary relief, or regulator valve element 48 is also provided which is arranged to open at lower pressures than the quench valve. A resilient member, in this example, a spring 53 on a quench valve support 54, remote from the cryostat is set such that the quench valve is generally closed.

As shown in Fig. 3b, for small pressure leaks, such as for controlled venting or cooling, an alternative path is formed by the secondary relief valve 48 having a seal, in this example formed as a bellows, which seals 52 against sealing seat 50. Gas flow 60 through the alternative path may then escape to atmosphere. As illustrated in Fig. 3c, when quench occurs, the entire vent valve, including the quench element 47 and secondary relief valve 48, moves out of the way of the gas flow 60, 61. The whole quench valve assembly lifts off its seats 49, 50 allowing gas to escape via the quench line 46. An auxiliary vent may be provided in the casing of the cryostat, which vents 55 into the quench line 46.

The secondary relief valve 48 may be a 16 psi (110KPa) absolute valve, 1.5psi (10.34KPa) above typical atmosphere with reference pressure in the set of bellows in a vacuum and the spring 53 on the upper quench valve section setting a bias to fix the pressure, or alternatively, a 0.5 psi (3.44KPa) gauge valve may be used for the relief valve. In the gauge example, the quench valve may be set to open at a value between

2psi (13.79KPa) and 6 psi (41.4KPa) gauge, typically 6 psi (41.4KPa). At an altitude of 3000m, the ambient atmospheric pressure is typically 11 psi (75.8KPa). Typically, the cryostat is controlled to be at 15.3psi absolute (105.5KPa). When operating, or transporting the cryostat at high altitudes, e.g. in mountainous regions, there can be problems with the quench valve opening in response to a non-quench event, because the pressure difference between the valve opening setting and the actual ambient pressure is quite small, perhaps only 1.7psi (11.7KPa).

In a preferred embodiment, one or both of the central relief valve 48 and the quench valve 47 is absolute, not gauge, which gives a number of operational advantages. During ramping, the gas flow through the absolute relief valve 48 is repeatable regardless of altitude of the installation, thereby maximising cooling of fixed current leads, which tend to heat up during ramping, and also providing an optimum thermal environment for the coils. During magnet operation, the relief for gradient induced boil off is through an absolute valve. Therefore, the increase in the permissible pressure rise before helium loss occurs is known and repeatable. Working in absolute pressure is considered more reliable and a requirement for shipping.

During shipping, when the refrigerator is not working, an absolute quench valve negates the need for additional valves to be fitted, greatly simplifying the shipping kits and reducing risk of errors in preparation for shipping, a significant business level risk. For mobile and high altitude use, during which the refrigerator is operating, an absolute quench valve addresses the problem of valve opening in response to non-quench events. Generally, recondensing systems have absolute values, as absolute pressure is controlled in the cryogen vessel when in operation.

Integration leads to fewer components, so reducing weight, complexity and joints. The present invention reduces the number of components, space envelope, weight and cost of the venting assembly by combining gas paths, by mounting the relief valve within the quench valve, so that integrated venting is achieved. This is done by arranging for the functionality of the manifold, relief valve and quench valve to all be contained within the quench valve body, with a single gas path and a sufficiently large quench valve with an absolute pressure valve trapdoor.

The invention combines the functionality of the regulator valve with the quench valve and manifold, in order that the cryostat valve system is cheaper and less complex. The design of the present invention reduces the cost of the vent assembly. The design also reduces risk during shipping, due to ease of assembly and leak testing and simplifies service replacement. As the valve is more compact, there are reduced condensation problems.

CLAIMS

1. A cryostat vent valve, the valve comprising a housing having an inlet and an outlet defining a gas flow path therebetween; a quench valve; and a relief valve; wherein the quench valve and relief valve are biased to close the gas flow path; wherein the relief valve opens at a lower gas pressure than the quench valve; and, wherein the relief valve lies within the housing in the same gas flow path as the quench valve.

2. A valve according to claim 1, wherein the quench valve comprises a first sealing surface and a first sealing seat; wherein the relief valve comprises a second sealing surface and a second sealing seat; and wherein the sealing surfaces are held against their respective sealing seats by the bias of a first resilient member.

3. A valve according to claim 2, wherein the first sealing surface is adjacent to the inlet.

4. A valve according to claim 2 or claim 3, wherein the second sealing surface comprises a surface of a bellows.

5. A valve according to any of claims 2 to 4, wherein the relief valve further comprises a second resilient member biasing the bellows against the second sealing seat.

6. A valve according to claim 5, wherein the first and second resilient members comprise springs.

7. A valve according to any preceding claim, wherein the relief valve is co-axial with the quench valve.

8. A valve according to any preceding claim, wherein the relief valve comprises a 16 psi absolute valve.

Application No: GB0904037.9 **Examiner:** Thomas Britland

Claims searched: 1-8 **Date of search:** 10 June 2009

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	US2005/088266 A1 (MANGANO) See figs. 2 & 3. Paragraphs [0019] to [0023].
A	-	US4719938 A (HELIX) See figs. 2 - 4. Col. 4, line 15 to col. 6, line 45.
A	-	US2006/064989 A1 (BRUKER BIOSPIN) See fig. 3. Paragraph [0043].
A	-	US6109042 A (GEN ELECTRIC) See fig. 1 and all text.
A	-	US2005/198973 A1 (GEN ELECTRIC) See whole document.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

N0T

Worldwide search of patent documents classified in the following areas of the IPC

F17C; H01F

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, TXTE

International Classification:

Subclass	Subgroup	Valid From
F17C	0013/00	01/01/2006

Subclass	Subgroup	Valid From
F17C	0013/12	01/01/2006
H01F	0006/02	01/01/2006