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JOULE-THOMSON EFFECT COOLING SYSTEM

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Fig. 1.

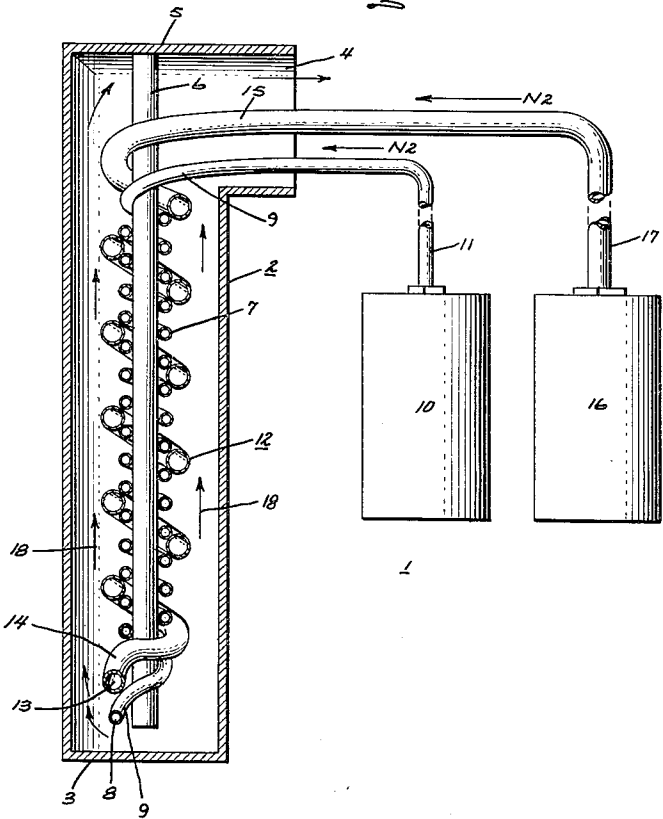


Fig. 2.

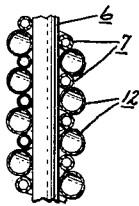


Fig. 3.

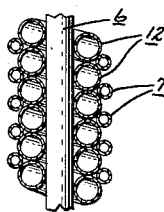
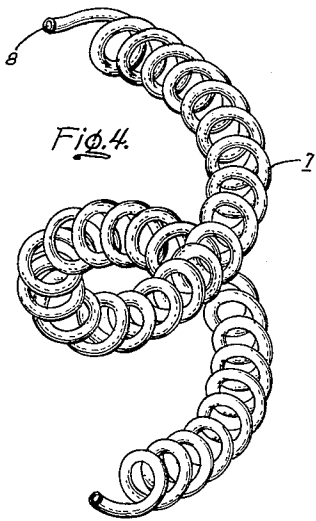


Fig. 4.



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JOULE-THOMSON EFFECT COOLING SYSTEM
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This invention relates to Joule-Thomson effect cooling apparatus and more particularly to a Joule-Thomson effect cooling system providing fast initial cool-down to a reduced temperature and subsequent maintenance of such reduced temperature with minimum gas consumption.

Joule-Thomson effect cooling devices are well known in the art and are employed where it is desired to obtain extremely low temperatures; Joule-Thomson effect cooling devices are capable of producing temperatures as low as -196°C . Such a device conventionally includes a thin wall tube or jacket having a closed lower end and a low pressure gas discharge opening adjacent its other end, the jacket being formed of suitable material having good heat transfer properties, such as stainless steel. Entering the jacket is a small elongated capillary tube extending downwardly, typically in a "coiled coil" configuration and terminating in a small nozzle. Gas, having a Joule-Thomson coefficient which is positive (2NS, 2/15/58) at room temperature, such as nitrogen, is supplied under high pressure to the capillary tube and expands through the nozzle. This expansion of the gas to the nozzle causes initial cooling, and the gas then flows upwardly over the convolutions of the tubing thus extracting further heat from the tubing in the nature of a heat exchanger, the gas being finally exhausted to the atmosphere through the low pressure discharge opening of the jacket.

In installations in which size and weight are not a factor and with a large supply of gas available, the capillary tubing of the Joule-Thomson effect device is made sufficiently large to provide a sufficiently fast gas flow so that initial cool-down to the desired temperature is accomplished in the desired length of time, with the gas flow thereafter being reduced by means of suitable valves in order to maintain the desired reduced temperature. However, in certain self-contained systems in which minimum size and weight are essential, it is necessary that the gas flow be small in order to limit the gas supply tanks or compressor to a correspondingly small size. For such small flows, however, the initial cool-down time is substantially increased. This lengthened cool-down time may not be of any particular disadvantage in certain installations, however there are other applications for Joule-Thomson effect devices in which it is desired that the initial cool-down time be as short as possible with a further requirement that the reduced temperature obtained after the initial cool-down be maintained for a substantial period of time. In such systems, with size and weight being critical, the use of automatic devices such as thermally responsive valves to reduce the gas flow from that which will provide fast initial cool-down to a lower level to maintain the required temperature, is prohibited. It is thus seen that an apparently irreconcilable conflict in requirements is present, i.e., if a capillary tube is provided of sufficient size to provide a sufficiently fast gas flow to secure the desired rapid temperature drop, continuance of this fast gas flow in order to maintain the reduced temperature for the desired period of time would require a gas supply tank of prohibitive size. On the other hand, if a capillary tube of smaller size is provided, thereby to permit the use of a smaller gas storage tank, the initial cool-down time of the device is prohibitively long.

In accordance with the broader aspects of my invention therefore, I provide a Joule-Thomson effect cooling system having two gas conduit means connected respec-

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tively to two gas supplying means. One of the gas conduit means is arranged for substantially faster gas flow than the other gas conduit means thereby providing fast initial cool-down of the device to the desired reduced temperature responsive to the faster gas flow, with maintenance of the reduced temperature thereafter being provided by the slower gas flow through the other gas conduit means. More specifically, I provide two elongated tubes respectively in close proximity within an enclosing jacket, each of the tubes having a gas discharge opening at one end thereof adjacent the closed end of the jacket and having their other ends extending out of the jacket and respectively connected to two gas reservoir means for supplying gas at high pressure thereto. One of the elongated tubes is arranged for substantially faster gas flow than the other and the gas reservoir means connected to said one tube has a gas capacity to supply the one tube for a first predetermined period thereby to supply fast initial cool-down of the device to the desired reduced temperature. The other gas reservoir means has a gas capacity sufficient to supply the other tube with the slower gas flow for a predetermined period substantially longer than the initial cool-down period thereby to maintain the reduced temperature responsive to the slower gas flow in the other elongated tube. With this arrangement, both gas reservoirs may be relatively small, one emptying in a relatively short period, i.e., for example fifteen (15) seconds or less, to provide the fast initial cool-down, and the other emptying in a substantially longer period, i.e., for example, fifteen (15) minutes to one-half ($\frac{1}{2}$) hour, in order to maintain the reduced temperature.

It is accordingly an object of my invention to provide an improved Joule-Thomson effect cooling system.

Another object of my invention is to provide an improved Joule-Thomson effect cooling system providing fast initial cool-down and maintenance of the reduced temperature for a substantial period thereafter with minimum gas consumption.

A further object of my invention is to provide an improved Joule-Thomson effect cooling system in which fast gas flow is provided for a short period to secure initial cool-down and slow gas flow is thereafter provided for a substantially longer period to maintain the reduced temperature, the system occupying minimum size and weight and not incorporating valve means or other control devices.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a side elevational view, partly in section and partly broken away, showing one embodiment of my improved Joule-Thomson effect cooling system;

FIG. 2 is a fragmentary cross-sectional view showing a modified form of the Joule-Thomson effect cooling device of FIG. 1;

FIG. 3 is a fragmentary cross-sectional view showing yet another modified form of my invention; and

FIG. 4 is a fragmentary view showing the actual configuration of the coiled coil capillary tubes of the embodiments of FIGS. 1, 2 and 3.

Referring now to FIG. 1, my improved Joule-Thomson effect cooling system, generally identified as 1, includes an elongated thin wall tube or jacket 2 formed of material having good heat conduction properties, such as stainless steel, and having a closed end 3 and a low pressure gas discharge opening 4 adjacent its other end 5. Disposed within the jacket 2 is a central mandril 6 having a first elongated capillary tube 7 wound thereon; the capillary

tube 7 preferably has a "coiled coil" configuration as best shown in FIG. 4. Capillary tube 7 has a gas discharge opening or nozzle 8 at its end 9 adjacent the closed end 3 of the jacket 2, and has its other end 9 extending out of the jacket 2, for example through the low pressure gas discharge opening 4. End 9 of capillary tube 7 is connected to a high pressure gas supply tank 10 by means of line 11 for supplying a suitable gas, such as nitrogen, at high pressure thereto.

In accordance with my invention, I provide a second capillary tube 12 wound over the first capillary tube 7 and also preferably having a coiled coil configuration, as shown in FIG. 4. The second capillary tube 12 has a gas discharge opening 13 at its end 14 adjacent closed end 3 of jacket 2 and has its other end 15 extending out of jacket 2, as through low pressure gas discharge opening 4. End 15 of the second capillary tube 12 is connected to a second gas supply tank 16 by a line 17 for supplying a suitable gas, such as nitrogen, at high pressure thereto.

It will be seen that the second elongated capillary tube 12 has its inside diameter and its gas discharge opening 13 substantially larger, respectively, than the inside diameter and gas discharge opening 8 of the first capillary tube 7, thereby providing substantially faster gas flow thereto. Thus, the second elongated capillary tube 12 may have an inside diameter of .040 inch and a gas discharge opening 13 .040 inch in diameter to provide a gas flow of 200 liters per minute with the tank 16 supplying a suitable gas, such as nitrogen, under a pressure of 2,000 pounds per square inch. With this fast rate of gas flow, the jacket 2 should cool down to its low temperature of -196°C . in approximately fifteen (15) seconds and thus gas supply tank 16 need only have such capacity as to supply gas for such fifteen (15) second period; a gas supply tank 16 accommodating approximately one-half ($\frac{1}{2}$) liter of gas should therefore suffice for this purpose. Once the device has been initially cooled down to the desired lower temperature, the -196°C . can be maintained by a much slower gas flow. Therefore, the inner elongated convolute tube 7 may have an inside diameter of 0.010 inch and a gas discharge opening 8 having a diameter of 0.010 inch to supply a flow of three (3) liters per minute with gas supply tank 10 supplying the suitable gas, again such as nitrogen, at 2,000 pounds per square inch. If it is desired that the reduced temperature be maintained for on the order of fifteen (15) minutes, the volume of the tank 10 would be on the order of three-fourths ($\frac{3}{4}$) liters.

It will be readily understood that the size of the gas discharge opening 13 of the capillary tube 12 and the volume of gas supply tank 16 depends upon the permissible duration of the initial cool-down period and that the volume of the other gas supply tank 10 depends upon the required period for maintenance of the reduced temperature after the initial cool-down period. In any event, the gas supply tank 16 supplying the larger capillary tube 12 need only be of sufficient size to supply gas during the initial cool down period; since the initial cool-down period will be very short with the fast gas flow provided by the larger capillary tube 12, the size of the gas supply tank 16 may nevertheless be relatively small with the other gas supply tank 10 supplying the smaller capillary tube 7 being also relatively small since the gas flow provided thereby through the smaller capillary tube 7 is very slow compared with that provided by the larger capillary tube 12. It will be readily understood that the gas discharge through the gas discharge openings 8 and 13 of the capillary tubes 7 and 12 respectively flows upwardly, as indicated by the arrows 18 over the convolutions of the coiled coil tubes 7 and 12 providing the heat exchanging action to secure the extremely cold lower temperature, the gas finally being exhausted to the atmosphere through the low pressure gas discharge opening 4.

Referring now to FIGS. 2 and 3, it will be seen that whereas in the embodiment of FIG. 1, the larger elon-

gated capillary tube 12 is wound or coiled over the smaller capillary tube 7, the two capillary tubes 7 and 12 may be wound side by side as shown in FIG. 2, or with the smaller capillary tube 7 wound or coiled over the larger capillary tube 12 as shown in FIG. 3.

It will now be seen that I have provided an improved Joule-Thomson effect cooling system in which fast initial cool-down is provided together with subsequent maintenance of the reduced temperature for a predetermined additional period with minimum gas consumption and thus minimum size and weight of the accompanying gas supply tanks.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention.

What is claimed is:

1. A Joule-Thomson effect cooling system comprising: a cooling device having first and second elongated tubes each having a gas discharge opening at one end thereof, an enclosure member having a closed end and a low pressure gas discharge opening adjacent the other end, said first and second tubes being arranged in said enclosure with their gas discharge ends adjacent said closed end and with their other ends extending out of said enclosure adjacent said other end thereof; and first and second gas storage tanks respectively connected to said other ends of said tubes for respectively supplying gas at high pressure thereto; said first tube gas discharge opening being substantially larger than said second tube gas discharge opening thereby providing substantially faster gas flow therethrough; said first gas storage tank having a gas capacity to supply said faster gas flow for a first predetermined relatively short period thereby to provide fast initial cool-down of said device to a reduced temperature; said second gas storage tank having a gas capacity to supply the slower gas flow in said second tube gas discharge opening for a predetermined period substantially longer than said first period thereby to maintain said reduced temperature.

2. A Joule-Thomson effect cooling system comprising: a cooling device having first and second elongated convolute tubes each having a gas discharge opening at one end thereof, and a thin wall elongated jacket formed of material having good heat transfer properties having a closed end and a low pressure gas discharge opening adjacent its other end, said first and second tubes being arranged respectively in close proximity within said jacket with their gas discharge opening ends adjacent said closed end and with their other ends extending out of said jacket adjacent said other end thereof; and first and second gas storage tanks respectively connected to said other ends of said tubes for respectively supplying gas at high pressure thereto; said first tube having its inside diameter and gas discharge opening respectively substantially larger than the inside diameter and gas discharge opening of said second tube thereby providing substantially faster gas flow therethrough; said first gas storage tank having a gas capacity to supply said faster gas flow for a first predetermined relatively short period thereby to provide fast initial cool-down of said device to a reduced temperature; said second gas storage tank having a gas capacity to supply the slower gas flow in said second tube gas discharge opening for a predetermined period substantially longer than said first period thereby to maintain said reduced temperature.

3. A Joule-Thomson effect cooling system comprising: a cooling device having a first elongated coiled tube with a gas discharge opening at one end thereof, a second elongated coiled tube arranged in engagement with said first tube and having a gas discharge opening at one end thereof, and a thin wall elongated jacket formed of material having good heat transfer properties and having a closed end and a low pressure gas discharge open-

ing adjacent its other end, said first and second tubes being arranged in said jacket with their gas discharge opening ends adjacent said closed end and with their other ends extending out of said jacket adjacent said other end thereof; and first and second gas storage tanks respectively connected to said other ends of said tubes for respectively supplying gas at high pressure thereto; said first tube having its inside diameter and gas discharge opening respectively substantially larger than the inside diameter and gas discharge opening of said second tube thereby providing substantially faster gas flow therethrough; said first gas storage tank having a gas capacity to supply said faster gas flow for a first predetermined relatively short period thereby to provide fast initial cool-down of said device to a reduced temperature; said second gas storage tank having a gas capacity to supply the slower gas flow in said second tube gas discharge opening for a predetermined period substantially longer than said first period thereby to maintain said reduced temperature.

4. A Joule-Thomson effect cooling system comprising: a cooling device having first and second elongated tubes coiled on a common mandril and each having a gas discharge opening at one end, and a thin wall elongated jacket formed of material having good heat transfer properties and having a closed end and a low pressure gas discharge opening adjacent its other end, said mandril with said first and second tubes coiled thereon being arranged in said jacket with said gas discharge ends of said tubes being adjacent said closed end and with their other ends extending out of said jacket adjacent said other end thereof; and first and second gas storage tanks respectively connected to said other ends of said tubes for respectively supplying gas at high pressure thereto; said first tube having its inside diameter and gas discharge opening respectively substantially larger than the inside diameter and gas discharge opening of said second tube thereby providing substantially faster gas flow therethrough; said first gas storage tank having a gas capacity to supply said faster gas flow for a first predetermined relatively short period thereby to provide fast initial cool-down of said device to a reduced temperature; said second gas storage tank having a gas capacity to supply the slower gas flow in said second tube gas discharge opening for a predetermined period substantially longer than said first period thereby to maintain said reduced temperature.

5. A Joule-Thomson effect cooling system comprising: a cooling device having a first elongated coiled tube coiled on a mandril and having a gas discharge opening at one end thereof, a second elongated coiled tube coiled over said first tube and having a gas discharge opening adjacent one end thereof, and a thin wall jacket formed of material having good heat transfer properties and having a closed end and a low pressure gas discharge opening adjacent its other end, said mandril with said first and second tubes coiled thereon being arranged in said jacket with said gas discharge ends of said tubes being adjacent said closed end and with their other ends extending out of said jacket adjacent said other end thereof; and first and second gas storage tanks respectively connected to said other ends of said tubes for respectively supplying gas at high pressure thereto; said first tube having its inside diameter and gas discharge opening respectively substantially larger than the inside diameter and gas discharge opening of said second tube thereby providing substantially faster gas flow therethrough; said first gas storage tank having a gas capacity to supply said faster gas flow for a first predetermined relatively short period thereby to provide fast initial cool-down of said device to a reduced temperature; said second gas storage tank having a gas capacity to supply the slower gas flow in said second tube gas discharge opening for a predetermined period substantially longer than said

first period thereby to maintain said reduced temperature.

6. A Joule-Thomson effect cooling system comprising: a cooling device having a first elongated coiled tube coiled on a mandril and having a gas discharge opening at one end thereof, a second elongated coiled tube coiled over said first tube and having a gas discharge opening adjacent one end thereof, and a thin wall jacket formed of material having good heat transfer properties and having a closed end and a low pressure gas discharge opening adjacent its other end, said mandril with said first and second tubes coiled thereon being arranged in said jacket with said gas discharge ends of said tubes being adjacent said closed end and with their other ends extending out of said jacket adjacent said other end thereof; and first and second gas storage tanks respectively connected to said other ends of said tubes for respectively supplying gas at high pressure thereto; said second tube having its inside diameter and gas discharge opening respectively substantially larger than the inside diameter and gas discharge opening of said first tube thereby providing substantially faster gas flow therethrough; said second gas storage tank having a gas capacity to supply said faster gas flow in said second tube discharge opening for a first predetermined relatively short period thereby to provide fast initial cool-down of said device to a reduced temperature; said first gas storage tank having a gas capacity to supply the slower gas flow in said first tube gas discharge opening for a predetermined period substantially longer than said first period thereby to maintain said reduced temperature.

7. A Joule-Thomson effect cooling system comprising: a cooling device having first and second elongated coiled tubes coiled side-by-side on a common mandril and each having a gas discharge opening at one end, and a thin wall elongated jacket formed of material having good heat transfer properties and having a closed end and a low pressure gas discharge opening adjacent its other end, said mandril with said first and second tubes coiled thereon being arranged in said jacket with said gas discharge ends of said tubes being adjacent said closed end and with their other ends extending out of said jacket adjacent said other end thereof; and first and second gas storage tanks respectively connected to said other ends of said tubes for respectively supplying gas at high pressure thereto; said first tube having its inside diameter and gas discharge opening respectively larger than the inside diameter and gas discharge opening of said second tube thereby providing substantially faster gas flow therethrough; said first gas storage tank having a gas capacity to supply said faster gas flow in said first tube gas discharge opening for a first predetermined relatively short period thereby to provide fast initial cool-down of said device to a reduced temperature; said second gas storage tank having a gas capacity to supply the slower gas flow in said second tube gas discharge opening for a predetermined period substantially longer than said first period thereby to maintain said reduced temperature.

8. In a Joule-Thomson effect cooling device having an enclosure member with an open end and a closed end: first and second elongated convolute tubes respectively in engagement substantially throughout their lengths and respectively having gas discharge openings at one end and having their other ends adapted respectively to be connected to first and second high pressure gas supply means, said tubes being adapted to be disposed in said enclosure member with their gas discharge openings adjacent said closed end thereof, one of said tubes having a gas discharge opening substantially larger than the gas discharge opening of the other tube thereby providing substantially faster gas flow therethrough.

9. In a Joule-Thomson effect cooling device having an enclosure member with an open end and a closed end: first and second elongated coiled tubes coiled on a common mandril and respectively having gas discharge open-

ings at one end and having their other ends adapted respectively to be connected to first and second high pressure gas supply means, said tubes being adapted to be disposed in said enclosure member with their gas discharge openings adjacent said closed end thereof, one of said tubes having its inside diameter and gas discharge openings respectively substantially larger than the inside diameter and gas discharge opening of the other tube thereby providing substantially faster gas flow therethrough.

10. In a Joule-Thomson effect cooling device having an enclosure member with an open end and a closed end: a first elongated coiled tube coiled on a mandril and having a gas discharge opening at one end; and a second elongated coiled tube coiled over said first tube and having a gas discharge opening at one end; said tubes having their other ends adapted respectively to be connected to first and second high pressure gas supply means, said tubes being adapted to be disposed in said enclosure member with their gas discharge openings adjacent said closed end thereof, one of said tubes having its inside diameter and gas discharge openings respectively substantially larger than the inside diameter and gas discharge opening of the other tube thereby providing substantially faster gas flow therethrough.

11. In a Joule-Thomson effect cooling device having an enclosure member with an open end and a closed end:

first and second elongated coiled tubes coiled side-by-side on a common mandril and respectively having gas discharge openings at one end and having their other ends adapted respectively to be connected to first and second high pressure gas supply means, said tubes being adapted to be disposed in said enclosure member with their gas discharge openings adjacent said closed end thereof, one of said tubes having its inside diameter and gas discharge opening respectively substantially larger than the inside diameter and gas discharge opening of the other tube thereby providing substantially faster gas flow therethrough.

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