NASA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF: GP

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for
Patent Matters

SUBJECT: Announcement of NASA-Owned U. S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code USI, the attached NASA-owned U. S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U. S. Patent No. : 3,564,866

Government or Corporate Employee : Calif. Inst. of Tech. Pasadena, Calif

Supplementary Corporate Source (if applicable) : JPL

NASA Patent Case No. : NPO-10467

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:
Yes ☒ No ☐

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of . . ."

Elizabeth A. Carter

Elizabeth A. Carter
Enclosure
Copy of Patent cited above

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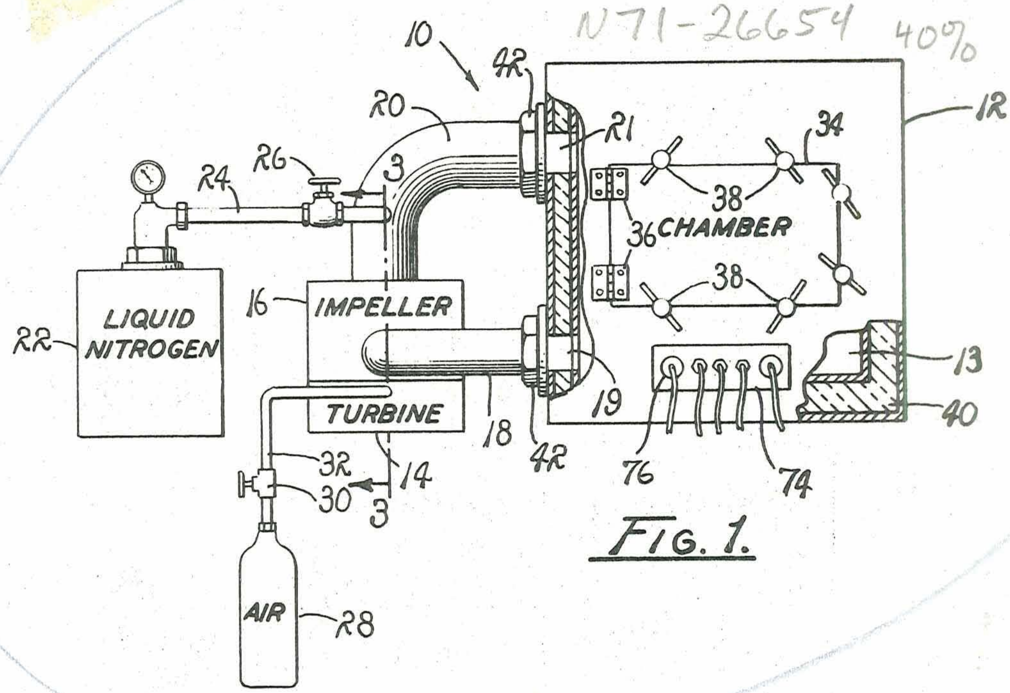

FIG. 1.

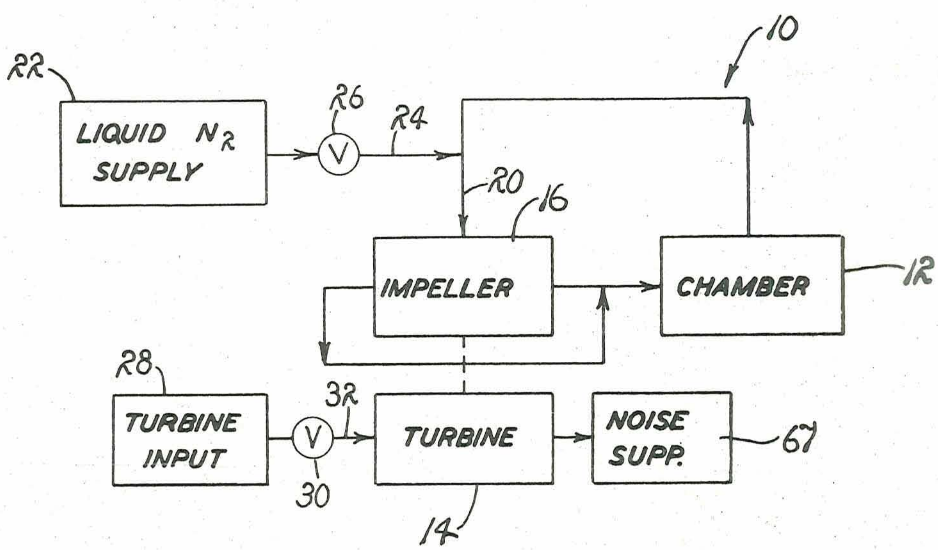

FIG. 2.

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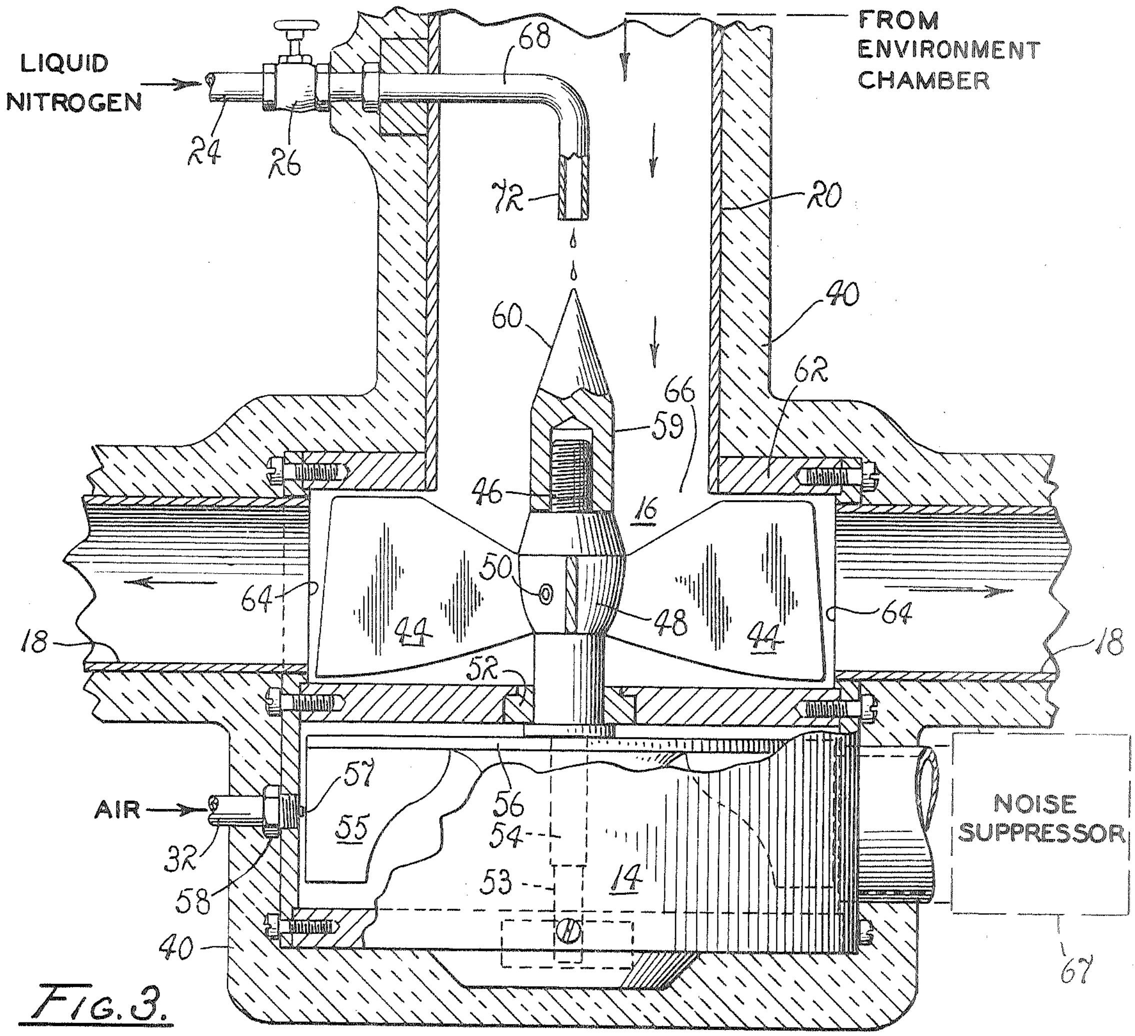

FIG. 3.

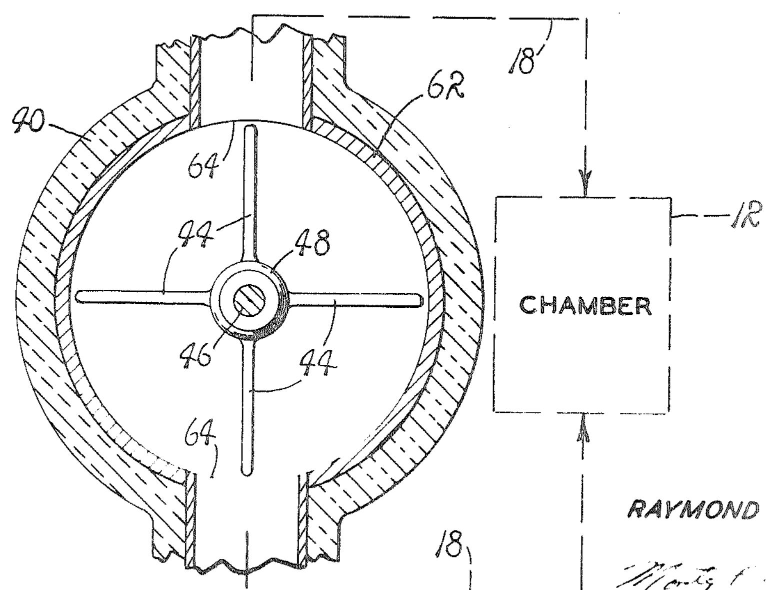

FIG. 4.

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United States Patent Office

3,564,866

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3,564,866

CRYOGENIC COOLING SYSTEM

T. O. Paine, Acting Administrator of the National Aeronautics and Space Administration, with respect to an invention of Raymond E. Fraze, La Crescenta, Calif.

Filed Feb. 11, 1969, Ser. No. 798,277
Int. Cl. F25b *19/00*
U.S. Cl. 62—514 8 Claims

ABSTRACT OF THE DISCLOSURE

A cryogenic cooling system, of general utility, adapted to achieve a high rate of cooling and characterized by a closed circuit including a cooling chamber through which there is established a circulating flow of cryogen, such as vaporized nitrogen, an impeller having an air-driven turbine connected therewith adapted to impart to the impeller selected rates of rotation for accelerating the flow of cryogen to selected flow rates as the cryogen is circulated through the chamber, an injector for injecting liquid cryogen into the established flow, and an atomizer for atomizing the injected cryogen, whereby the cryogenic liquid may be atomized and vaporized as it is introduced into the established flow of cryogen as it is circulated through the cooling chamber.

ORIGIN OF INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

(1) Field of the invention

This invention relates to a portable cryogenic cooling system adapted to be employed for rapidly cooling materials through the use of circulating cryogenic fluids.

(2) Description of the prior art

The prior art includes numerous systems which can be employed in the cooling of materials of various types, ranging between agricultural produce, chilled to prevent spoilage to devices, cooled to cryogenic or space simulated temperatures for test and experimental purposes.

Where cryogenic cooling systems are employed, they frequently are constructed at fixed installations and include complex and expensive cryogenic pumps, heat exchangers, Joule Thompson valves, computer servo-control systems and numerous similar complex and expensive devices designed to achieve selected pressures and temperature ranges over selected periods of time. Normally, the existing systems are not readily made available to all possible users, due to the costs involved in developing and maintaining such systems and the extensive demands made thereon. Hence, difficulty has been experienced in fully exploiting the field of cryogenic cooling for commercial purposes, even though such systems are widely employed in the aero-space field.

OBJECTS AND SUMMARY OF THE INVENTION

This invention overcomes the aforementioned difficulties through the use of a simplified and economic system which includes a closed circuit for vaporizing a liquid cryogen and then circulating the cryogen, as a gas, through a cooling chamber at predetermined rates of flow.

An object of the instant invention is to provide a portable, economical cooling system adapted to be employed at cryogenic temperatures.

Another object is to provide an improved economical, portable cooling system for recycling vaporized cryogen through a cooling chamber.

Another object is to provide an improved portable cooling chamber particularly adapted for use in the lowering of temperatures of materials of general utility to temperatures classed as cryogenic.

Another object is to provide an improved, economic and totally portable system including a cooling chamber, a cryogen impeller and a cryogen atomizer for converting a cryogenic liquid to a vaporized cryogen, and for continuously recycling the cryogen through the system at velocities dictated by desired rates of cooling to be achieved.

These together with other objects and advantages will become more readily apparent by reference to the following description and claims in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a system embodying the principles of the present invention, illustrating a cooling chamber connected with a cryogen injector and impeller, and an air-driven turbine for achieving a desired rate of rotation for the impeller.

FIG. 2 is a flow diagram for the system illustrated in FIG. 1.

FIG. 3 is a partially sectioned view on an enlarged scale of the turbine, impeller and injector illustrated in FIG. 1, taken on line 3—3 of FIG. 1.

FIG. 4 is a partially sectioned plan view of the impeller and a partial flow diagram for the coolant discharged by the impeller.

DESCRIPTION OF THE INVENTION

Turning to FIG. 1, the system **10** of the present invention includes a chamber unit **12**, provided with a sealable cooling chamber **13**, an air-driven turbine **14**, and an impeller **16** adapted to be driven by the turbine **14** and associated with the unit **12**. A cryogen inlet conduit **18** is connected with an inlet port **19**, provided for the chamber **13**, while a cryogen outlet conduit **20** is provided between the impeller **16** and an outlet port **21**, provided for the chamber **13**, so that a flow of cryogen is caused to be circulated through the chamber **13** upon an activation of the impeller **16**.

The cryogen, or coolant, employed in lowering the temperatures of the chamber **13**, preferably is liquid nitrogen provided in its liquid state from a suitable source **22**. The source **22** is, in practice, a pressurized bottle which is connected through a conduit **24** and an "on-off" valve **26** to the conduit **20** adjacent to the impeller **16**. The turbine **14** operatively is driven by a high velocity stream of pressurized air delivered under suitable pressures from a pressurized source **28** through an adjustable "on-off" valve **30** disposed in a conduit **32** connected between the source **28** and the turbine **14**.

The chamber unit **12** is formed of any suitable material which may, as a practical matter, be a readily available sheet metal material welded into a desired configuration. The chamber unit is intended to receive within its cooling chamber **13** an article or articles to be cooled or reduced in temperature to a temperature classed as a cryogenic temperature. Consequently, a hinged, sealable access door **34** is provided for achieving access to the cooling chamber **13**. The door **34** is mounted by hinges **36** and secured by pivoted dogs **38** which serve releasably to seal the door **34** to the housing of the unit. Normally, the housing of the chamber unit **12** is insulated at **40**. While numerous insulating materials could be employed, fiber glass and the like has served quite satisfactorily for this purpose. However, the insulation **40** may be deleted, if desired, as in those instances wherein it is feasible to attain desired temperatures without the use of insulation. That extremely low temperatures may readily be achieved without the use of insulation can be appreciated when it is understood that the flow of cryogen circulated through the chamber 13 may readily be accelerated to and maintained at preselected velocities.

In order to achieve and maintain a desired rate of flow of cryogen through the cooling chamber 13, the impeller 16 drives the cryogen through the conduits 18 and 20. The conduits 18 and 20 are coupled to the openings or ports 19 and 21 of the chamber unit 12 by means of screw-threaded couplings 42. The couplings 42 are of any suitable design which, as a practical matter, may be union couplings which include screw-threaded sleeves particularly suited for joining the conduits 18 and 20 with screw-threaded lips provided for the chamber unit. Hence, the impeller 16, in effect, is connected by the couplings 42 to, and interposed between, the ports 19 and 21, whereby communication between the impeller and the chamber 13 is established. Further, the unions 42 permit the chamber 13 readily to be disassociated or uncoupled from the conduits 18 and 20 and sealed by suitable caps, not shown, if desired.

The impeller 16, as employed, includes a plurality of extended aluminum impeller blades 44 mounted on a common drive shaft 46 by means of a collar 48 fixed to the shaft. The collar 48 is coupled with the shaft 46 by any suitable means, including setscrews 50. The collar 48 and blades 44 may be formed as a unitary member through machining, casting, welding or any other technique, whereby the collar 48 is caused to serve as a hub from which extend the blades 44. The shaft 46 is fabricated from stainless steel or the like and is supported in a vertical attitude through means including suitable Teflon bearings 52. Therefore, it is to be understood that in operation the impeller 16 is driven by imposing a unidirectional rate of rotation on the drive shaft 46 as it is operatively supported in the bearings 52.

In order to impart rotation to the shaft 46, the shaft 46 is coupled to a turbine powered output shaft 53, FIG. 3, through a sleeve coupling 54, as normally is provided for the turbine 14. The turbine 14 is of any suitable design. However, a standard industrial air-driven turbine including radially disposed blades 55 coupled to the shaft 53 through a support plate 56 has been satisfactorily employed. The turbine, in practice, utilizes a stream of high velocity air tangentially directed against the blades 55 to impart selected rates of rotation to the shaft 53, and thence to the shaft 46 coupled therewith.

The pressurized source of air 28 serves to supply the required high-velocity stream through the "on-off" valve 30, and the conduit 32. The conduit 32 is coupled with a jet 57 connected to the turbine 14 through a suitable coupling 58. Therefore, when the valve 30 is opened and suitably adjusted for regulating the air being delivered, a desired high-velocity stream is directed through the conduit 32 and the jet 57 to impinge upon the turbine blades 55. The blades of the turbine are thus caused to be displaced so as to rotate the shaft 53 and drive the shaft 46 coupled therewith. As the shaft 46 is caused to rotate, the impeller blades 44 fixed thereto through the collar 48, are rotated for drawing or displacing gas from the conduit 20 and subsequently expelling the gas so as to accelerate the flow of cryogen through the conduits 18 and 20 and the ports 19 and 21 of the chamber unit 12. Consequently, the velocity of the air delivered from the pressurized source 28 effectively serves to control the rate of flow of cryogen through the chamber 13 of the chamber unit 12, and thereby serves to dictate the rate of cooling imposed on materials deposited within the chamber 13.

To the uppermost end of the shaft 46, there is fixed a cryogen atomizer 59. The atomizer 59 includes a surface conforming to the frusto-conical surface 60 and is screw-threaded to the uppermost end of the drive shaft 46 to be fixedly coupled to and rotated with the shaft as it is rotated in response to the stream of air provided to the turbine 14. Therefore, the surface 60 is, in practice, rotated at a high rate of rotation, in unison with the impeller shaft, and liquid deposited thereon is caused radially to be accelerated and consequently rapidly broken into very fine droplets as it is delivered to the conduit 20.

The impeller also includes a suitable housing 62 which, as a matter of convenience, includes chamber walls defining a housing for the turbine 14 as well as for the blade of the impeller. The housing 62 is of a generally circular configuration and is provided with an impeller exhaust or output side including a pair of diametrically opposed output ports 64 through which the cryogen is delivered to diametrically opposed portions of the conduit 18. An impeller intake or input side for the housing 62 is provided with an input port or opening 66 through which is drawn the atomized and vaporized cryogen from the conduit 20.

Therefore, it is to be understood that the chamber 13 of the chamber unit 12, the conduits 18 and 20 and the housing 62 of the impeller, in effect, establish a closed loop or fluid circuit through which vaporized cryogenic fluid is cycled and accelerated for cooling the chamber 13. Furthermore, it is preferred that the diametrically opposed portions of the conduits 18 be joined by means not shown but as diagrammatically illustrated in FIG. 2. However, if desired, multiple inlet ports 19 could be provided for accommodating a coupling of multiple conduits 18 therewith.

The particular configuration provided for the blades 44 is a matter of convenience. However, the blades must be of a configuration such as to serve to effect an intake or displacement of the cryogen from the conduit 20 and a discharge thereof. As shown, the blades are such as to effect an axial intake and a radial discharge of the cryogen through the ports 64 of the impeller exhaust into the diametrically opposed portions of the conduit 18. It should readily be apparent that the turbine 14 serves to drive the impeller 16 at selected rates suitable for achieving desired axial and radial displacements of the fluid, and that these rates may be varied to values dictated by rates at which the turbine 14 is driven. In practice, the rate achievable for the turbine 14 may be varied upwardly to 15,000 revolutions per minute. Hence, the rate of the impeller may be varied upwardly to 15,000 r.p.m. since the drive shafts are directly coupled in a 1:1 ratio driving relationship.

Where high rates of rotation are to be employed, the turbine may develop a high-pitched noise which is undesirable. Therefore, in practice, a baffled noise suppressor 67 is coupled at the air-discharge portion of the housing 62 in order to reduce the noise level of the turbine 14. While not absolutely required for efficient performance, the suppressor 67 serves to depress the high-level noise output of the turbine, whereby an operator may not be subject to audible discomfort from the utilization of the system. The particular design of the suppressor 67 may be varied as desired. However, a simple, insulated, baffled structure has been found to function quite satisfactorily for this purpose.

In order to introduce the cryogen from the source 22, a tubular injector 68 is extended from the "on-off" valve 26 through the wall of the conduit 20, adjacent to the input port 66 of the impeller 16. The injector 68, in effect, is an extension of the conduit 24 and extends in a sealed relationship through the wall of the conduit 20 by means including a suitable packing or seal 70.

The terminal portion of the injector 68 includes a right-angle segment 72, aligned in concentric alignment with the conduit 20. The opening of the injector is aligned in coaxial alignment with the tip of conical surface 60 and is slightly spaced therefrom. Therefore, it is to be understood that as liquid cryogen is introduced from the valve

26, via the injector 68, the liquid is caused to pour or drip onto and strike the rotating surface 60 near the tip of the surface. As the liquid strikes the surface 60, it is atomized or broken into small droplets due to the effect of the rotating surface 60. Hence, it will be appreciated that liquid cryogen is delivered under expelling pressures existing within the source 22 and that the cryogen injected through the injector 68 is atomized at the surface of the atomizer 59 and introduced into the flow of vaporized cryogen as it is displaced into the impeller blades 44 of the impeller 16. The atomized cryogen is then vaporized within the circuit and mixed with the gas being cycled, and recycled, through the chamber 13 of the chamber unit 12 for effecting the desired cooling.

Since the rate of flow of the cryogen or liquid nitrogen to the impeller 16 is controlled through the manipulation of the valve 26, and the rate at which the impeller blades 44 are driven for accelerating the flow through the chamber 13, is controlled through manipulation of the air valve 30, the rate at which the chamber 13 is cooled may be readily controlled. As a practical matter, temperatures in the range of —300° F. have been achieved while employing an injection rate for the liquid cryogen of 500 milliliters per hour, and an impeller rate of rotation of approximately 10,000 r.p.m. over a period of approximately six hours. Of course, it is preferable to employ increased rates during the initial cooling phases and subsequently to decrease the rates employed for achieving economy in operation.

While the system 10 has been described as utilizing liquid nitrogen, other cryogens can be employed equally well, particularly since sintered metal provides an excellent source of material for fabricating those system components which are, in practice, subjected to extreme temperatures encountered in the handling of the various cryogenic materials. However, since the temperatures to be achieved with the system 10 normally are within a temperature range above —300° F., the impeller blades and shaft are formed of materials suitable for withstanding such temperature. In practice, the shaft 46 is made of 300-stainless steel while the blades 44 and the housing 62 are formed of cast aluminum of a commercial grade normally employed in the fabrication of turbine blades. An examination of the metals thus employed indicated no discernible damage was encountered in the operation of the system. The supporting Teflon bearings employed appear to function quite satisfactorily, even under extensive use at relatively low or cryogenic temperatures.

While not critical, it is desirable, in order to avoid an introduction of ambient heat, to encase the impeller 16 and the conduits 18 and 20 in a suitable insulating material, such as the insulation 40 which is disposed in surrounding relationship with the chamber unit 12.

Additionally, it may be found desirable to provide external circuit coupling leads for coupling articles or devices disposed within the chamber 13 with external sources of electrical power, or with maintaining devices and/or convenient instrumentation as normally employed in similar operations. Therefore, as illustrated, a suitable external terminal plate 74 is mounted on the unit 12 and provided with a plurality of electrical connector 76. Such connectors include clamps, binding posts and the like interconnected with suitable circuit coupling leads extended from the chamber 13, whereby materials and articles may be inserted into the chamber and connected with electrical leads through connectors 76.

OPERATION

With the system 10 disassembled, that is, with the chamber unit 12 disconnected from the conduits 18 and 20, at the unions 42, and with the impeller 16 and turbine 14 being disconnected from the pressurized source of liquid nitrogen 22, and the pressurized source of air 28, the disassembled system may be transported to a location of use. The system subsequently is assembled by con-

necting the conduits 18 and 20 to the chamber 12, through the unions 42, and connecting the source of liquid nitrogen to the impeller 16, through the conduit 24, and the pressurized source of air 28, through the conduit 32, to the turbine 14.

With the system 10 thus assembled, the dogs 38 of the unit 12 are pivotally removed from a sealing engagement with the door 34 so that the door may be opened to provide access to the cooling chamber 13. Selected materials, articles or devices to be cooled are deposited within the chamber 13. If desired, the contents of the chamber 13 may be connected through suitable leads to the electrical connections 76, as provided for by the plate 74. The door 34 now is closed and secured in place through manipulation of the dogs 38, whereupon the chamber unit 12 operatively is sealed.

Once the chamber unit 12 has been sealed, the valve 30 is opened a selected amount for directing the stream of air, at controlled pressures, against the blades 55 of the turbine 14. The blades are thus caused to be displaced for driving the associated shafts 46 and 53 in rotation. A selected rate of rotation is operatively imposed by the shaft 46 on the collar 48, and consequently upon blades 44 of the impeller 16. As the blades 44 are driven in rotation, a stream of air, or gas, is displaced or drawn from the chamber 13, via the conduit 20, and dispelled from the turbine 14 back into the chamber 13 through the ports 64, the conduit 18 and the port 19.

With the impeller blades 44 of the impeller 16 being thus driven, the valve 26 for the liquid cryogen is "cracked" a suitable extent for accommodating passage of liquid cryogen from the source 22 through the downwardly directed segment 72 of the injector 68 so that the nitrogen is caused to be delivered from the source 22. As the liquid nitrogen exists the lowermost end of the segment 72, it is caused to impact on the rotating frusto-conical surface 60 of the rotating atomizer 59, whereupon the liquid is caused to be atomized or broken into fine droplets and drawn into the impeller 16 through the port 66 of the impeller intake. As the atomized cryogen is drawn into the impeller, it is vaporized and ejected radially from the impeller 16 through ports 64 of the impeller exhaust and into the conduit portions of the conduit 18, for circulation along with the gas drawn from the chamber 13 through the conduit 20.

Hence, it will be appreciated that a high-velocity flow or stream of vaporized cryogenic fluid is established through the chamber unit 12, by the impeller 16 acting thereon, and the velocity of the stream, as it is caused to be accelerated by the impeller 16, is determined by the rate at which the shaft 46 is driven in response to the velocity of the stream of air acting against the turbine blades 55 of the turbine 14. The rate at which the chamber 13 of the chamber unit 12 is cooled accordingly is readily controlled simply by controlling the rate at which the liquid cryogen is introduced through the injector 68 and the rate at which the impeller 16 is driven.

In view of the foregoing, it should be apparent that the disclosed embodiment of the instant invention provides a simple solution to a perplexing problem of providing an economical, practical and completely portable cooling system adapted to be employed at cryogenic temperatures, whereby various materials, including agricultural produce, articles and devices of various types may be readily and rapidly cooled to selected temperatures, including cryogenic and space simulated temperatures.

Although the invention has been herein shown and described in what is conceived to be the most practical and preferred embodiment, it is recognized that departures may be made therefrom within the scope of the invention, which is not to be limited to the details disclosed herein but is to be accorded the full scope of the claims so as to embrace any and all equivalent devices and apparatus.

What is claimed is:

1. A system adapted to be cooled by a vaporized cryogen comprising:

(a) means defining a sealable chamber adapted to receive and retain materials to be cooled;

(b) means defining a chamber inlet adapted to direct a flow of vaporized cryogen into said chamber;

(c) means defining a chamber outlet adapted to effect a discharge of vaporized cryogen from said chamber;

(d) conduit means external of the chamber defining a closed circuit between the chamber inlet and the chamber outlet;

(e) a driven impeller including means defining an impeller intake and an impeller exhaust interposed and connected within said closed circuit between the inlet and the outlet of the chamber for effecting an accelerated flow of cryogen through the chamber inlet and the chamber outlet, whereby a continuous recycling of the cryogen through the test chamber is achieved;

(f) drive means connected with said impeller adapted operatively to drive said impeller at a predetermined rate for controlling the rate at which cryogen is caused to flow through the inlet and outlet of the chamber;

(g) means including a source of liquid cryogen operatively associated with the impeller adapted to inject a liquid cryogen into said impeller, whereby the liquid cryogen rapidly is convered from a liquid to a gas and caused to flow through said test chamber for cooling test specimens retained therewithin; and

(h) an atomizer operatively associated with said impeller adapted to break the liquid cryogen into small droplets as it is injected into the impeller, whereby conversion of the cryogen from a liquid to a gas is accelerated.

2. The chamber of claim 1 wherein said impeller further includes:

(a) a plurality of radially connected impeller blades adapted to be rotated for effecting an accelerated flow of the cryogen through the impeller;

(b) a driven turbine adapted to be rotated at an imparted rate of rotation;

(c) drive means including a drive shaft interconnecting said driven turbine and said impeller blades, whereby the impeller blades are caused to be driven at a rate of rotation dictated by the rate of rotation operatively imparted to said turbine; and

(d) means including a source of air maintained under elevated pressure and a discharge jet connected with the source of air adapted to direct a high-velocity stream of air into said turbine for imparting a rate of rotation thereto.

3. In a cooling system for converting a liquid cryogen to a vaporized cryogen and cycling the vaporized cryogen through a closed-circuit, the combination comprising:

(a) a tubular conduit;

(b) a source of liquid cryogen;

(c) means defining a liquid cryogen injector extending from the source of cryogen into said conduit adapted to inject cryogen in a liquid state into said conduit;

(d) an atomizer disposed within said conduit adapted to atomize the liquid cryogen;

(e) an impeller including an impeller intake and an impeller exhaust operatively associated with the conduit and adapted to be driven for extracting vaporized cryogen and atomized liquid cryogen from said conduit through said intake, vaporizing the atomized liquid, and discharging the vaporized cryogen from the impeller through said impeller exhaust; and

(f) means for establishing a selected rate of discharge of said impeller, whereby a predetermined flow of vaporized cryogen is established from the impeller.

4. The combination of claim 3 wherein the impeller includes a rotatable drive shaft and a plurality of radially extended impeller blades mounted on the shaft.

5. The combination of claim 4 wherein the means for establishing a selected rate of discharge from said impeller comprises means defining a turbine drive connected with the drive shaft including a source of air under elevated pressure and an air injector communicating with turbine blades adapted to establish a high-velocity stream of air directed against the turbine blades, whereby a rate of rotation is imparted to said drive shaft as a stream of air is caused to impart a rate of rotation to said power output shaft.

6. The combination of claim 5 further comprising:

(a) a sealable test chamber including means defining a chamber inlet and a chamber outlet adapted to direct a flow of vaporized cryogen through the chamber;

(b) coupling means connecting the chamber outlet with the tubular conduit in a manner such that the outlet operatively is associated with the impeller intake; and

(c) coupling means conecting the chamber inlet with the tubular conduit in a manner such that the inlet operatively is associated with the impeller exhaust, whereby vaporized cryogen is caused to be circulated through said chamber as a rate of rotation is imparted to said drive shaft.

7. The combination of claim 6 wherein said coupling means includes a plurality of quick-disconnect unions interposed in said conduit between said impeller and said chamber.

8. The combination of claim 5 wherein the atomizer includes an impact surface of a frusto-conical configuration suported for rotation by said drive shaft and disposed in the path of the liquid cryogen as it is injected into said conduit.

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ALBERT W. DAVIS, Jr., Primary Examiner

U.S. Cl. X.R.

60—57; 62—52, 388; 230—116