US 20100117679A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2010/0117679 A1

(43) Pub. Date: May 13, 2010

Piec et al.

(54) TEST APPARATUS, SYSTEM, AND METHOD HAVING A MAGNETIC FEATURE

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(21) Appl. No.: **12/638,708**

(22) Filed: **Dec. 15, 2009**

Related U.S. Application Data

(63) Continuation of application No. 11/549,587, filed on Oct. 13, 2006, now Pat. No. 7,642,806.

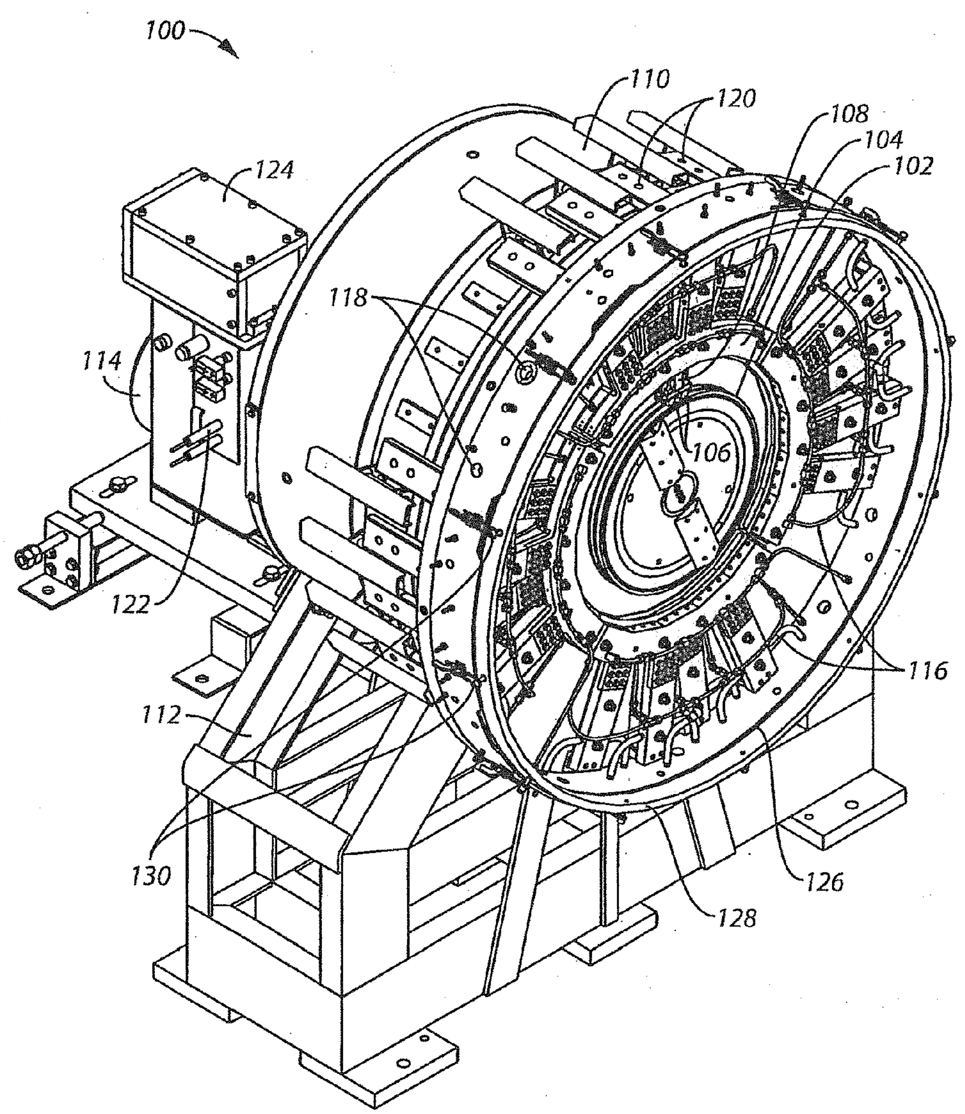
Publication Classification

(51) **Int. Cl.**
G01R 31/34 (2006.01)

(52) **U.S. Cl.** **324/772**

(57) **ABSTRACT**

A test apparatus involving a rotor coupled to a drive shaft, wherein the drive shaft is mechanically coupled to a drive system; a stator coupled to a brush holder; a brush held by the brush holder, wherein the brush is held in contact with the rotor; a housing for supporting the rotor and the stator; and a superconducting magnet for providing a magnetic field in the vicinity of the brush, in accordance with one embodiment.



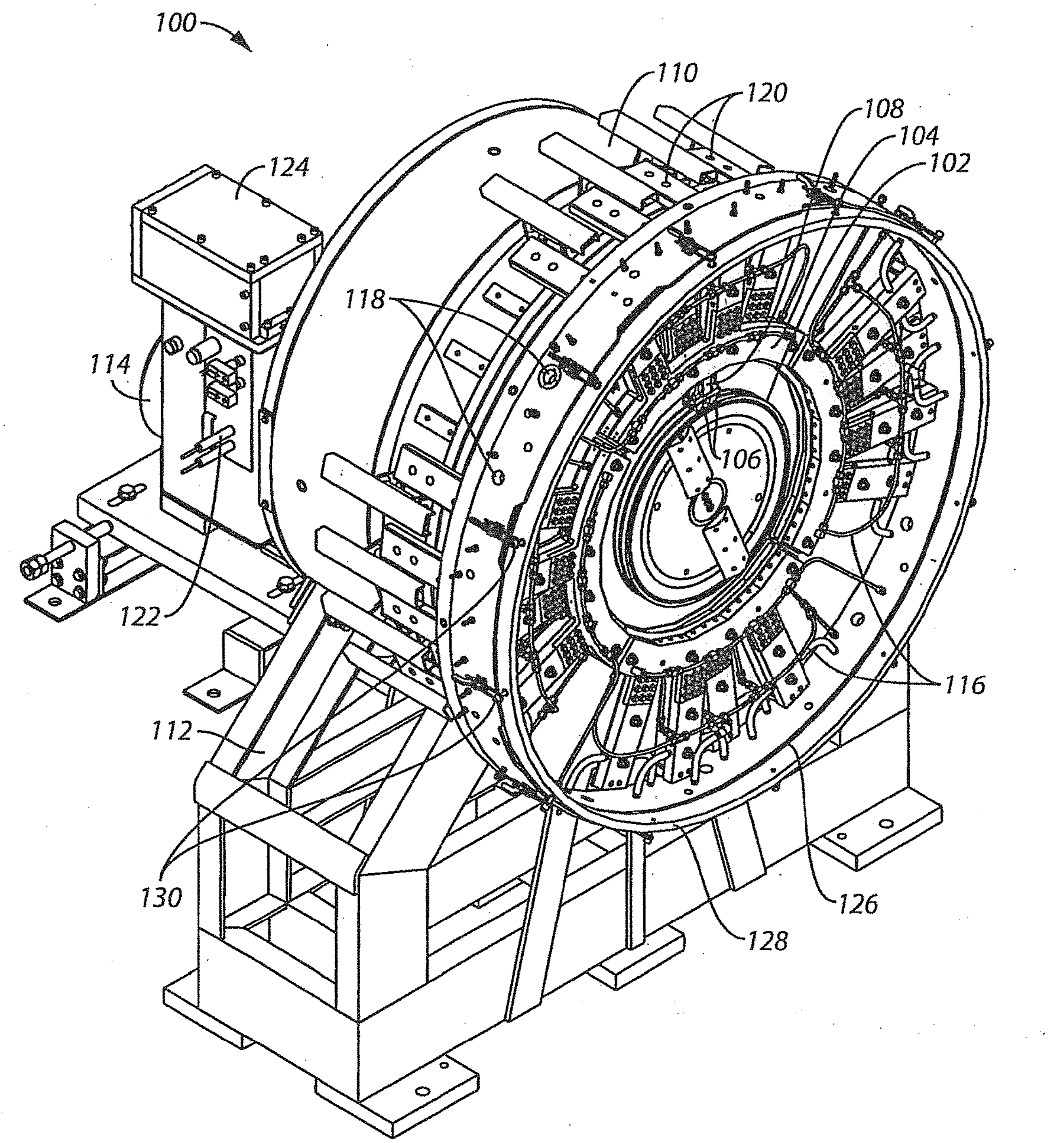


FIG. 1

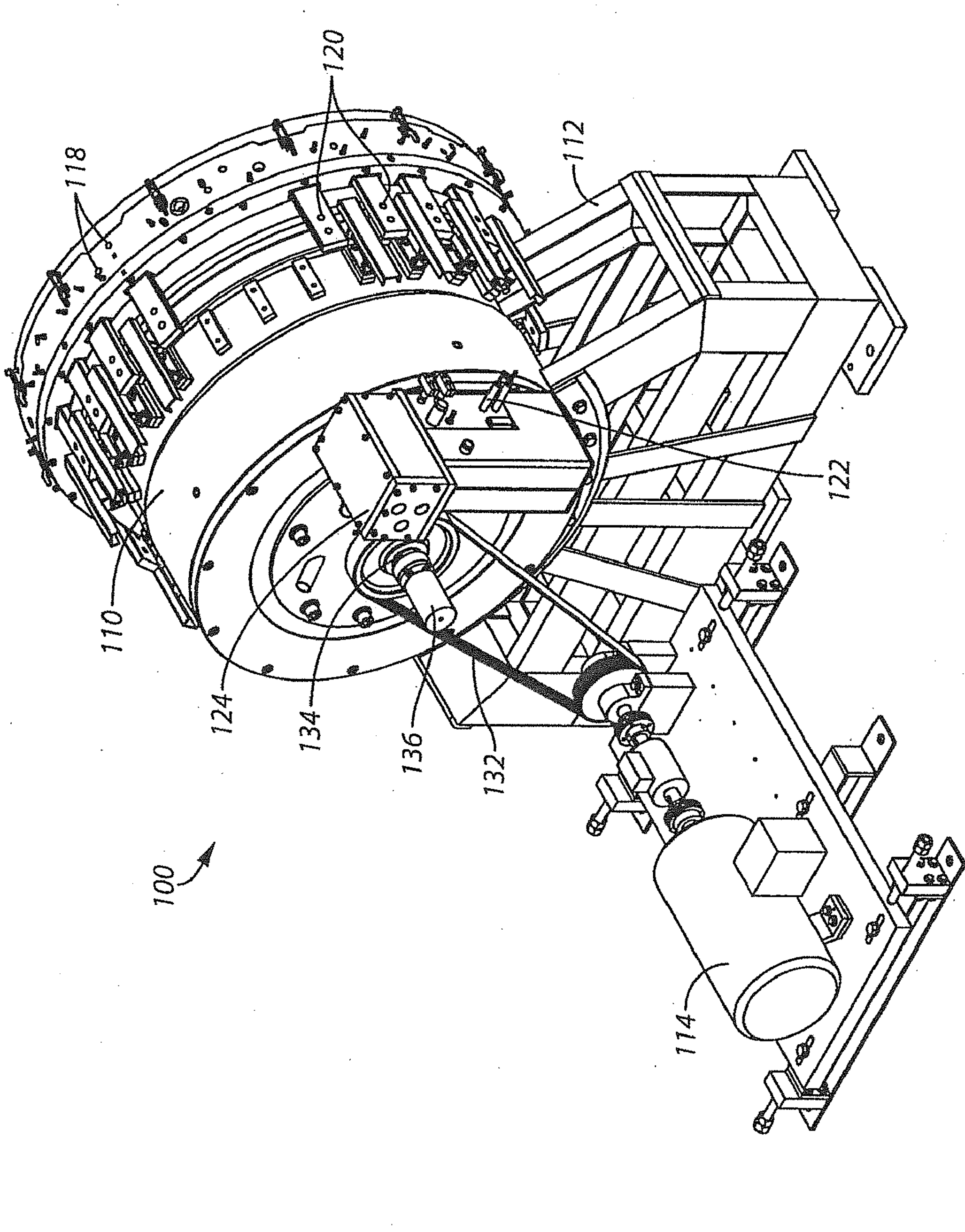


FIG. 2

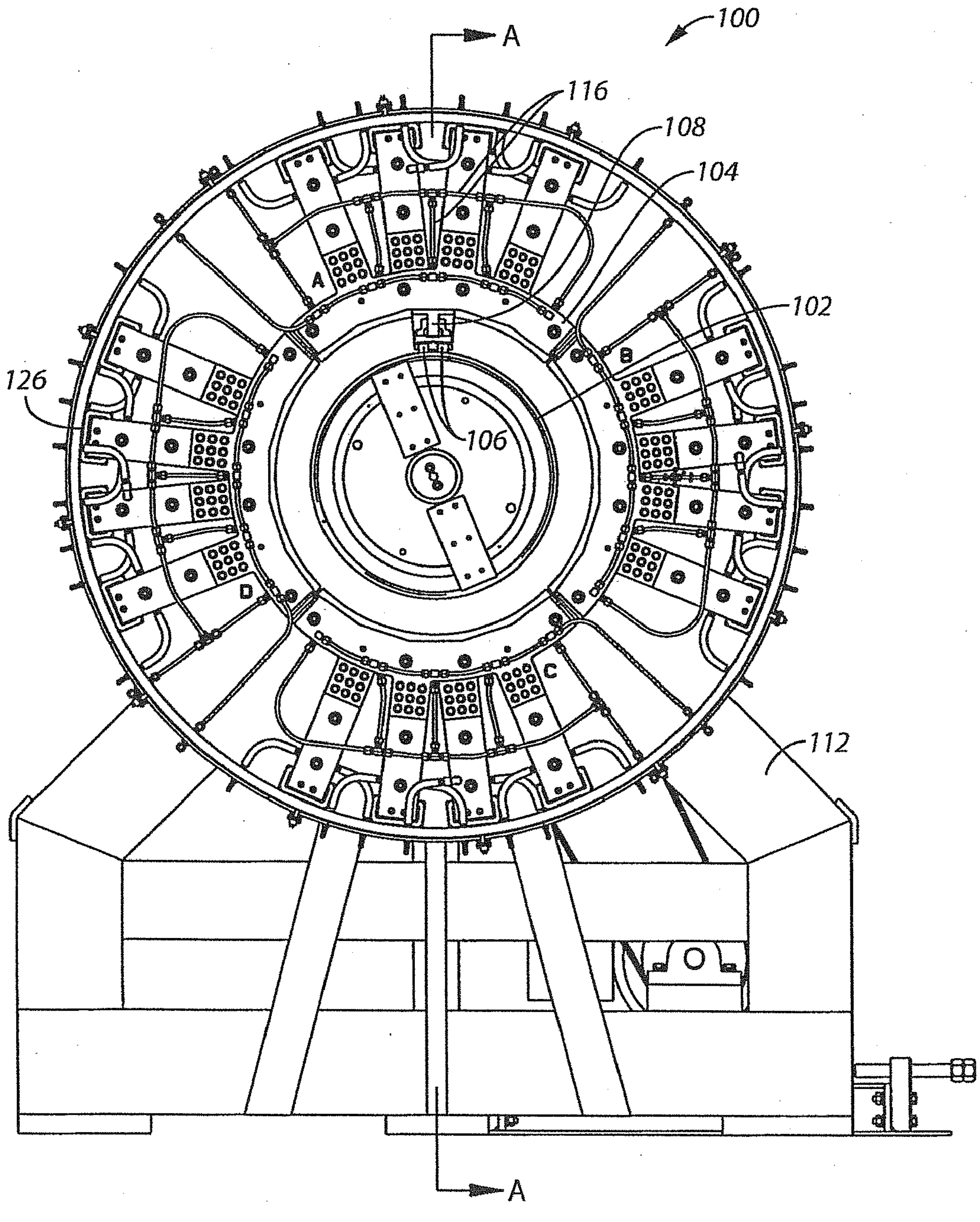
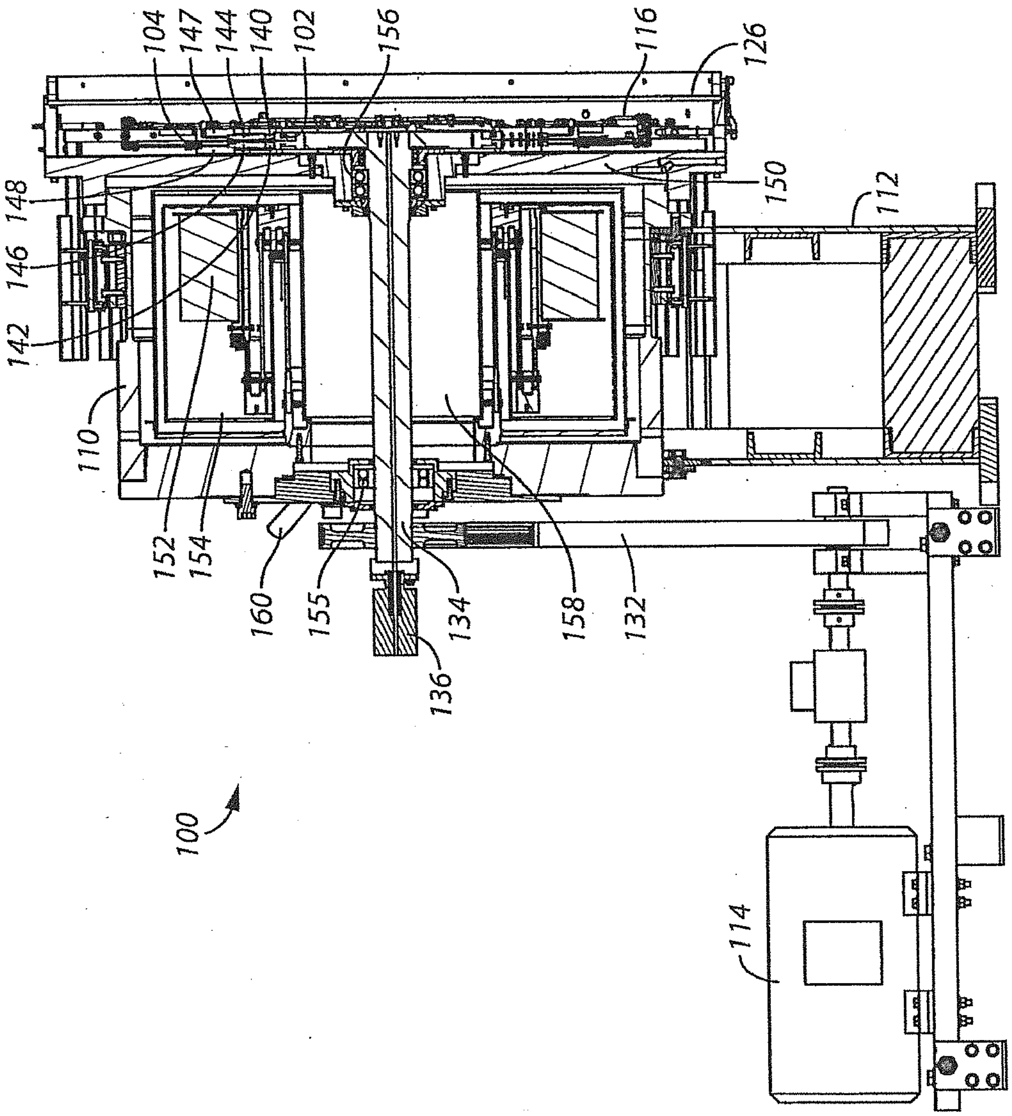


FIG. 3



SECTION A-A
FIG. 4

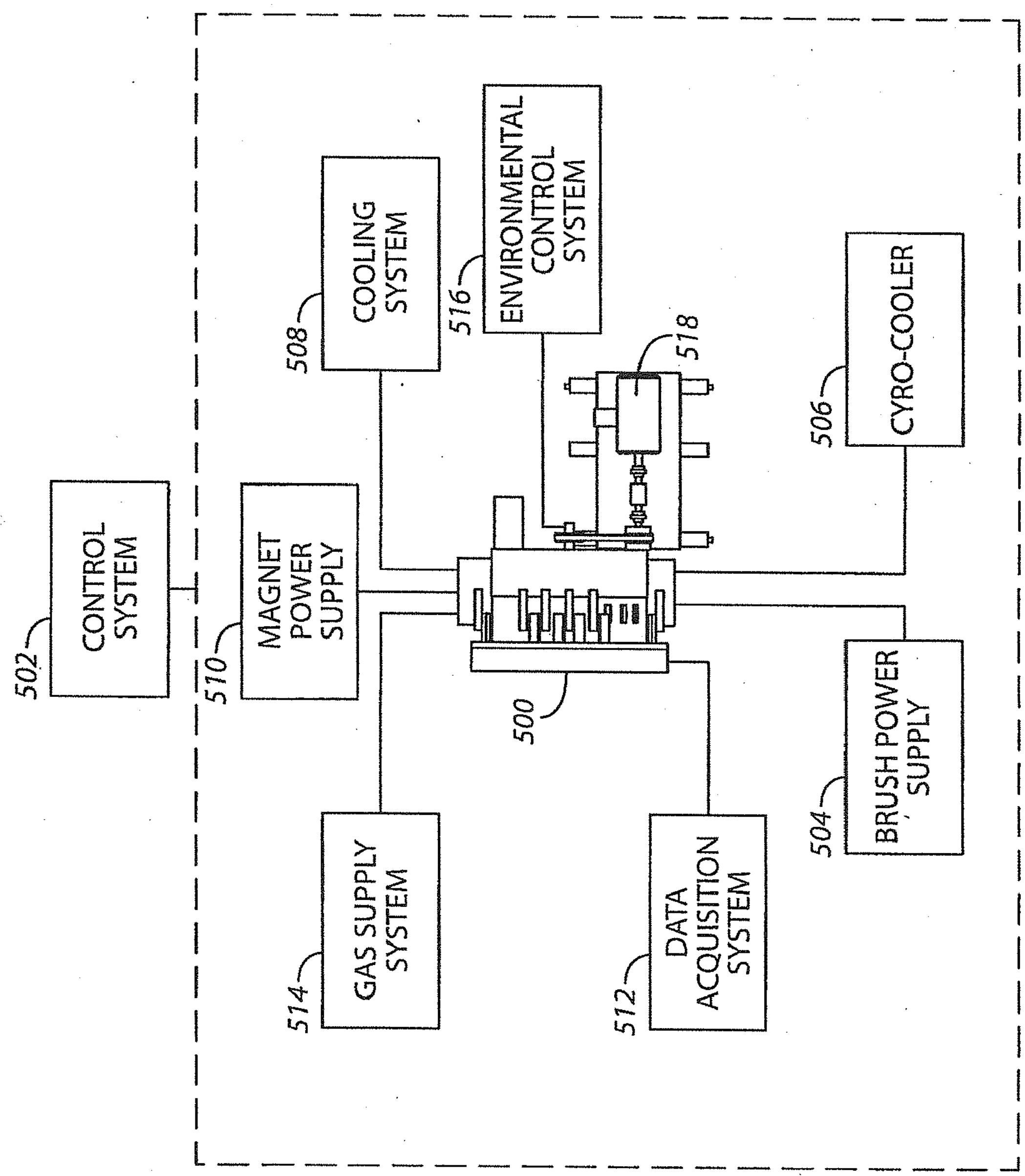

502
CONTROL SYSTEM
510
MAGNET POWER SUPPLY
508
COOLING SYSTEM
516
ENVIRONMENTAL CONTROL SYSTEM
518
506
CYRO-COOLER
500
504
BRUSH POWER SUPPLY
514
GAS SUPPLY SYSTEM
512
DATA ACQUISITION SYSTEM

FIG. 5

TEST APPARATUS, SYSTEM, AND METHOD HAVING A MAGNETIC FEATURE

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This document is a continuation application that is related to, and claims priority from U.S. patent application Ser. No. 11/549,587, entitled "Test Apparatus, System, and Method With a Magnetic Feature," and filed on Oct. 13, 2006, which is commonly owned, and which is hereby incorporated by this reference in its entirety.

GOVERNMENT RIGHTS

[0002] The present invention was made with support of the government under Office of Naval Research, Contract No. N00014-04-C-0618. The Government may have certain rights in the present invention.

BACKGROUND OF THE INVENTION

[0003] 1. Field of the Invention

[0004] The present invention relates to a test apparatus for testing a brush and a brush holder. More specifically, the present invention relates to a test apparatus for testing brushes and brush holders in the presence of a magnetic field.

[0005] 2. Discussion of the Related Art

[0006] Evaluation of multi-conductor metallic brushes for electric propulsion motors and generators is important in assuring reliable operation of the motors, generators, vehicles, or vessels with which they are utilized. The complex operational environment of a large number of brushes can be simulated by a computer program; however, preferable is that the computer results be validated by laboratory testing. Additionally, brushes can be evaluated after being actually used in a motor; however, these brushes are not easily accessible. Furthermore, in many instances, disassembling the motor during use in order to evaluate the brushes is impractical. Previously, brushes have been evaluated using a test apparatus that includes a motor driven rotor. The brushes are held in contact with the rotor; and the wear on the brushes can be evaluated. However, this type of test apparatus lacks many real world applications.

[0007] Motors and generators can be subjected to high magnetic field strengths and varying environmental conditions while in use. These high varying magnetic fields and varying environmental conditions, possibly present in electric propulsion motors and generators, create a need for an apparatus to simulate the conditions of the motors and generators. Thus, a need exists for a measurement apparatus that can test brushes and brush holders under varying magnetic fields as well as varying environmental conditions.

SUMMARY OF THE INVENTION

[0008] The present embodiments provide a test apparatus, system, and method for testing many brushes and brush holders under a varying magnetic field as well as a plurality of varying environmental conditions. The present test apparatus for testing a plurality of brushes and brush holders under a varying magnetic field can be used with measurement instruments to evaluate the performance of the brushes and brush holders within controlled operating conditions.

[0009] One embodiment can be characterized as a test apparatus, comprising a rotor coupled to a drive shaft, wherein the drive shaft is mechanically coupled to a drive system. The apparatus comprises a stator coupled to at least one brush holder and at least one brush held by the at least one brush holder, wherein the at least one brush is held in contact with the rotor. The test apparatus system further comprises a housing for supporting the rotor and the stator as well as a magnet for providing a magnetic field in the vicinity of the at least one brush.

[0010] The present invention also involves a test system, comprising an apparatus for testing a plurality of brushes and a plurality of brush holders under a varying magnetic field. The test apparatus comprises a stator, at least one brush holder coupled to the stator, at least one brush held by the at least one brush holder, a rotor positioned to contact the at least one brush, a drive shaft coupled to the rotor, and a magnet for supplying a magnetic field, wherein the at least one brush contacts the rotor. The test apparatus system further comprises a drive system coupled to the drive shaft, a power supply for providing power to the at least one brush, and a power supply for providing power to the magnet.

[0011] Another subsequent embodiment can be characterized as a method of testing at least one brush and at least one brush holder, the method comprising rotating a rotor of a test apparatus, providing power from a brush power supply to at least one brush in contact with the rotor, providing power from a magnet power supply to a magnet, and generating a magnetic field from the magnet in the vicinity of the at least one brush and the rotor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The above and other aspects, features and advantages of the present invention will be more apparent from the following more particular description thereof, presented in conjunction with the following drawings.

[0013] FIG. **1** is a front perspective diagram of a test apparatus, in accordance with an embodiment of the present invention.

[0014] FIG. **2** is a rear perspective diagram of the test apparatus, as shown in FIG. **1**, in accordance with an embodiment of the present invention.

[0015] FIG. **3** is a front view diagram of the test apparatus, shown in FIG. **1**, in accordance with an embodiment of the present invention.

[0016] FIG. **4** is a side cross-sectional diagram of the test apparatus, as shown in FIG. **1**, in accordance with an embodiment of the present invention.

[0017] FIG. **5** is a schematic diagram of a test system, comprising a test apparatus, in accordance with an embodiment of the present invention.

[0018] Corresponding reference characters indicate corresponding components throughout the several views of the drawings. Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions, sizing, and/or relative placement of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of various embodiments of the present invention. Also, common but well-understood elements that are useful or necessary in a commercially feasible embodiment are often not depicted in order to facilitate a less obstructed view of these various embodiments of the present invention. Also understood is that the terms and expressions used herein have the ordinary meanings as are usually accorded to such terms and expressions by those skilled in the corresponding respective areas of inquiry and study, except where other specific meanings have otherwise been herein set forth.

DETAILED DESCRIPTION

[0019] The following description is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of the invention. The scope of the invention should be determined with reference to the herein appended claims. The present embodiments address the problems described in the background while also addressing other additional problems as will be seen from the following detailed description.

[0020] The embodiments described herein provide an apparatus for testing brushes in a variety of different conditions. The brushes can be subjected to a magnetic field, such as would be present in real-world applications. Because the brushes of homopolar machines can be the greatest source of failure, the capability of testing various brushes under a variety of different conditions is advantageous. Additionally, some embodiments provide the ability to test and measure the brush performance under many different environmental situations. The long term evaluation of brushes under typical motor operating conditions can be monitored in order to improve wear rate, current density, efficiency, and reliability. Additionally, the interactions between the brushes and the rotor contact surface can be evaluated.

[0021] Advantageously, in some embodiments, both magnetic field components (B_r and $\mathbf{13}_z$) can be adjusted in the vicinity of the brushes and brush holders. In various embodiments, the brushes can be evaluated over a large variation in the disc surface speed. Additionally, the brushes can be evaluated with different additives at the interface between the brush and the rotor. The brushes can also be evaluated for losses due to Ohmic heating resulting from transfer and circulating currents, as well as for mechanical losses resulting from friction. The long term performance of the brushes can be evaluated based upon the azimuthal location of the brush and holder as well as the effect of wear due to particle accumulation in long term performance.

[0022] Advantageously, the evaluation of the brushes under different ranges of coverage factors can be performed. Additionally, the thermal limits and operational envelope of the brushes and the brush holders can be evaluated. Different brush designs and the evaluation of brushes under different duty cycles can be evaluated. The validation of parameters from both a microscopic analysis and a macroscopic analysis as well as modeling can be performed. Furthermore, the accumulation of data to support statistical analysis for the projection of a lifetime for the brushes can be accomplished for a large number of brushes. Advantageously, the test apparatus, in some embodiments, can be operated unattended, twenty-four hours per day, for extended periods of time.

[0023] The above features can be accomplished in various embodiments of the apparatus described herein. The following description of a test apparatus, system, and method in accordance with various embodiments will further describe and detail the above features.

[0024] Referring now to FIG. **1**, a front perspective diagram illustrates a test apparatus **100**, in accordance with an embodiment of the present invention. Shown is a rotor **102**, a stator **104**, a set of brushes **106**, a brush holder **108**, a machine housing **110**, a support structure **112**, a drive system **114**, a plurality of gas delivery tubes **116**, a plurality of connectors for a data acquisition system **118**, a plurality of power supply connectors **120**, a magnet power supply connector **122**, a cryo-cooler, e.g., a cryo-compressor **124**, an environmental chamber housing **126**, a support ring **128**, and a plurality of attachment clips **130**, by example only. An environmental delivery system supplies gas to the environmental chamber **126**. The plurality of power supply connectors **120** comprises first and second power supply connectors.

[0025] The brush holder **108** is connected to the stator **104** and holds the brushes **106** in contact with the rotor **102**. The rotor **102** and stator **104** are held in place by the machine housing **110** and the support structure **112**. This embodiment includes only one brush holder **108**; however, a plurality of brush holders can be connected to the stator **104**. The plurality of gas delivery tubes **116** are coupled to the brush holders and supply gas, e.g., carbon dioxide, that controls the pressure that the brushes **106** exert in contacting the rotor **102**. In this embodiment, the apparatus comprises two brushes **106** and one brush holder **108**; however, understood is that many brushes and brush holders may be placed around the stator in other embodiments. Additionally, the brushes and brush holders are placed on both an inner side and an outer side of the stator in some embodiments (see FIG. **4**). The present test apparatus is capable of testing up to one hundred twenty brushes at one time. In order to hold one hundred twenty brushes, twenty brush holders are disposed on the outside of the stator **104**; and twenty brush holders are disposed on the inside of the stator **104** (see FIG. **4**). Each brush holder can be configured to hold a plurality of brushes. Thus, in the embodiment shown, when the test apparatus **100** is fully loaded, **120** brushes are being tested simultaneously.

[0026] The plurality of power supply connectors **120** are generally coupled to a power supply (not shown). The power supply supplies power to the test apparatus and controls the current flowing from the stator, through the brushes, and into the rotor. The drive system **114** (shown in more detail in FIG. **3**) is used to rotate the rotor **102** as current flows through the brushes **106**. Additionally, a magnetic field is produced by a magnet (shown in FIG. **4**) such that the brushes **106** are subjected to a magnetic field. The magnetic field simulates the environment to which the brushes would be subjected in a motor in operation. The magnet, which can produce magnetic fields over a range of strengths, is powered by a magnet power supply. The magnet power supply is coupled to the magnet through the magnet power supply connector **122**. The cryo-cooler, e.g., cryo-compressor **124** cools the magnet. In one embodiment, the magnet is a super-conducting magnet that operates at approximately 4.2 degrees Kelvin. The magnet produces a magnetic field when charged by the power supply. The strength of the field varies depending upon the level of charge of the magnet. In one embodiment, the proportion of the axial and radial portions of the magnetic filed (B_z and B_r) in the brush operating region are controlled by varying the charge of the magnet and by adjusting the axial position of the rotor **102** and brushes **106** relative to the magnet.

[0027] The environmental chamber housing **126** is attached to the front of the machine housing. The environmental chamber housing **126** encloses the rotor **102**, the stator **104**, and the brushes **106** inside of an environmentally controlled chamber. The environmental chamber housing **126** comprises, in the exemplary embodiment, the support ring **128**, the plurality of attachment clips **130**, and a front plate. The front plate is made from, for example, glass or plastic, and is preferably light transmissive, such that the brushes can be viewed during operation. The environmental chamber housing **126** allows for the brushes to be tested under a variety of different environmental conditions, such as with different temperatures and different gasses. Because the front plate is generally made from a transmissive material, it is not shown in the figure; however, the front plate forms a seal on the inside of the support ring.

[0028] Referring to FIG. **2**, a rear perspective diagram illustrates a test apparatus, as shown in FIG. **1**, in accordance with an embodiment of the present invention. Shown is the machine housing **110**, the support structure **112**, the drive system **114**, the plurality of connectors for the data acquisition system **118**, the plurality of power supply connectors **120**, the magnet power supply connector **122**, the cryo-cooler, e.g., a cryo-compressor **124**, a drive belt **132**, a drive shaft **134**, and a water union **136**.

[0029] The drive system **114** is coupled to the drive shaft **134** through the drive belt **132**. The drive system **114** rotates the drive shaft **134** of the test apparatus **100** in a controlled manner. The drive system **114**, in one embodiment, is a variable frequency controlled electric motor and drive belt system that can produce a rotor speed of up to 30 m/s. Because the test apparatus **100** includes the drive shaft **134** and, additionally, the magnet, the test apparatus is not a true motor. As described above, the magnets are charged as the rotor **102** is rotated and current is driven through the brushes **106**. This creates torque which must be compensated by the drive system **114**. Thus, a balance exists between the drive system **114** and the magnet that is taken into account when operating the test apparatus **100**. Generally, in a motor, the rotor has many windings that create a large amount of torque; however, the present embodiment of the test apparatus **100** only includes one winding, thereby reducing the generated torque.

[0030] As described, in one embodiment, the drive system **114** is a variable frequency drive (VFD) that is used to control the speed of the rotor **102**. The VFD controls the speed of the motor that, in turn, drives the rotor **102**. In operation, the VFD will maintain a constant revolutions per minute (RPM) of the rotor. The current passing through the brushes and rotor **102** in the magnetic field generated by the magnet will either add torque or reduce torque on the rotor **102**, i.e., either try to accelerate the rotor or brake the rotor. If the current is trying to accelerate the rotor **102**, the VFD must provide braking torque to maintain a constant RPM of the rotor. If the current is trying to decelerate the rotor, the VFD will provide additional torque to maintain the constant RPM of the rotor. In one embodiment, the VFD is a commercially available unit with an internal chopper to allow dissipation of braking energy. The energy is dissipated into an external, water cooled, braking resistor. The VFD settings may be made at the front panel of the VFD or remotely via an Ethernet port. The Ethernet port also allows for remote monitoring of the status of the VFD.

[0031] A water cooling system is connected to the water union **136**. The water cooling system is a controllable cooling system for the rotor **102** and stator **104**. This allows the brushes to be tested at varying degrees of operation and also prevents the rotor **102** and the stator **104** from overheating. Water is supplied to the water union **136** through water hoses (not shown). The water union **136** is designed such that the drive shaft **134** can rotate while the water union **136** remains in place. In one embodiment, the water union **136** is a hydraulic rotary union mounted to the end of the drive shaft **134** which passes water down holes in the drive shaft **134** and into the slip rings. Supply and return hoses from the cooling water system connect to the hydraulic rotary union and also to plumbing connected to the stator bus bars.

[0032] Referring to FIG. **3**, a front view diagram illustrates the test apparatus, as shown in FIG. **1**, in accordance with an embodiment of the present invention. Shown are the rotor **102**, the stator **104**, the brushes **106**, the brush holder **108**, the support structure **112**, the plurality of gas delivery tubes **116**, and the environmental chamber housing **126**.

[0033] The stator **104** is divided into four sections. Each section can hold up to five brush holders. The plurality of gas delivery tubes **116** supply gases to a respective plurality of brush holders, thereby controlling the pressure that the brushes **106** exert on the rotor **102**. In one embodiment, the rotor **102** is an electrically-shorted double slip ring mounted onto a stainless steal wheel and shaft. Each section of the stator **104** comprises two stacked copper bus bars mounted to a back plate (shown in FIG. **4**).

[0034] Referring to FIG. **4**, a cross-sectional diagram illustrates the test apparatus, as shown in FIG. **1**, in accordance with an embodiment of the present invention. Shown is the rotor **102**, the stator **104**, a first brush **140**, a second brush **142**, a first brush holder **144**, a second brush holder **146**, a first bus bar **147**, a second bus bar **148**, a back plate **150**, the machine housing **110**, the support structure **112**, the drive system **114**, the drive belt **132**, the plurality of gas delivery tubes **116**, a magnet **152**, a magnet housing **154**, the drive shaft **134**, the water union **136**, a first bearing **155**, a second bearing **156**, a center chamber **158**, a gas delivery attachment **150**, and the environmental chamber housing **126**.

[0035] The first brush **140** is held by the first brush holder **144**; and the second brush **142** is held by the second brush holder **146**. The first brush holder **144** is connected to the first bus bar **147** on a front side of the stator **104**; and the second brush holder is connected to the second bus bar **148** on a back side of the stator **104**. As described above, the brush holders **142**, **144** can be attached to either the front side or the back side of the stator **104**, thus allowing for greater capacity to test the brushes **106**.

[0036] The center chamber **158** and the gas delivery attachment **160** allow for the delivery of environmental gases into vicinity of the brushes **106**, the rotor **102**, and the stator **104**. The environmental chamber housing **126** (described above in relation to FIG. **1**), disposed on the front of the test apparatus **100**, maintains the gas at the front of the test apparatus **100**. This allows the brushes **106** to be tested while in the presence of different types of environmental gases and varies pressure within the chamber **158**. The environmental chamber housing **126**, in one embodiment, encloses the stator **104**, the rotor **102**, and the brushes **106**. The environmental chamber housing **126** is sealed and various gaseous atmospheres, as delivered by an environmental control system, can be tested.

[0037] The magnet housing **154**, in one embodiment, is a vacuum-sealed, super-cooling chamber for a superconducting magnet. The superconducting magnet is cooled by the cyro-compressor **124**. The superconducting magnet can generate large magnetic fields in the vicinity of the brushes **106**, thus allowing for the testing of the brushes **106** under conditions that simulate the real operation of motors.

[0038] The drive shaft **134** is supported by the first bearing **154** and the second bearing **156**. In one embodiment, the first bearing **154** and the second bearing **156** are rolling element bearings. The bearings **154**, **156** allow the drive shaft **134** to easily rotate. The drive shaft **134** is coupled to the rotor **102**, thus as the drive motor is on the drive belt **132** rotates the drive shaft **134** which in turn rotates the rotor **102**. Additionally, during operation, the magnet **152** generates a magnetic field in the vicinity of the first brush **140** and the second brush **142**. The rotor **102**, the stator **104**, and the brushes can be adjusted in an axial direction of the shaft by adjusting the position of the drive shaft **134**. That is, the relative axial position of the brushes **106** in relation to the magnet **152** is adjustable. This adjustment allows for control over both the axial and radial components of the magnetic field (B_z and B_r) in the vicinity of the brushes **106**, thus allowing for a more controlled environment for testing.

[0039] The stator **104** is connected to the back plate **150** which is mounted to the machine housing **110**. The first bus bar **147** and the second bus bar **148** can be easily accessed and allow for the relatively simple removal and replacement of the brush holders **144**, **146** and/or brushes **106**. As described above, in one embodiment, the stator **104** comprises four sections where each section includes two stacked bus bars mounted to the back plate **150**. The bus bars line up with the two rings of the double copper slip ring of the rotor **102**. The brush holders **144**, **146** are mounted to the bus bars and the brushes **106** are then in contact with the rotor slip rings. The two bus bars are electrically isolated from each other and from the back plate **150**.

[0040] Referring to FIG. **5**, a schematic diagram illustrates a test system, in accordance with an embodiment of the present invention. Shown is a test apparatus **500**, a control system **502**, a brush power supply **504**, a cyro-cooler **506**, a cooling system or chiller **508**, a magnet power supply **510**, and a data acquisition system **512**, a gas supply system **514**, an environmental control system **516**, and a drive motor **518**.

[0041] The control system **502**, in one embodiment, controls the operation of the entire system, including the test apparatus **500**, the magnet power supply **510**, the brush power supply **504**, the chiller **508**, the environmental control system **516**, the cyro-cooler **506**, the gas supply system **514**, and the data acquisition system **512**. In an alternative embodiment, at least one or more of the individual components of the system are operated independently of the control system **502**. For example, the data acquisition system **512** can be operated independently from the control system **502**. The brush power supply **504** is connected to the test apparatus **500** and supplies current to the brushes **106**. the rotor **102**, and the stator **104** during operation. In one embodiment, the brush power supply **504** is a constant-current supply used to provide the current for testing the brushes **106**. The brush power supply **504** is capable of providing up to 6,000 amps dc at up to 5 volts. The brush supply is a low ripple supply (<1% pk-pk of full current) even at low voltage. The brush power supply **504** consists of two commercial supplies, each rated at 3,000 amps, bused together in parallel. "Freewheeling" diodes provide protection for the brush power supply **504** from the back EMF that can be generated by the movement of the rotor **102** in the magnetic field. The brush power supply **504** utilizes a master-slave configuration where the master settings are used to control both supplies. A DC power supply capable of delivering up to 26,000 Amps at 10 Volts may be connected to the stator bus bars. The current path delivered by the brush power supply **504** is through one stator bus bar, through the brush holders **144**, **146** and brushes **106** into the rotor slip ring, through the rotor **102** into the second slip ring, and out of the second slip ring through brushes **106** and brush holders **144**, **146** mounted to the second bus bar.

[0042] The magnet power supply **510** supplies power to the magnet during operation in order to induce a magnetic field in the vicinity of the brushes **106**. The cyro-cooler **506** cools the magnet during operation. As described above, in one embodiment, the magnet is a superconducting magnet that is cooled to 4.2 degrees Kelvin. The gas supply system **514** provides gas to the brush holders **144**, **146** which, in turn, control the pressure that the brushes **106** exert on the rotor **102**. The chiller **508** provides cooling for the rotor **102** and stator **104** during operation. The drive motor **518** is, for example, a variable frequency motor that is coupled to the shaft through a drive belt. The drive motor **518** turns the shaft which then turns the rotor **102** during operation.

[0043] The environmental control system **516** supplies environmental gases to the environmental chamber of the test apparatus **500**. This allows the brushes **106** to be tested under different pressure and environmental conditions. The data acquisition system **512** is connected to the test apparatus **500** and collects data about the temperature and pressure, e.g., temperature data and pressure data, within the environmental chamber of the test apparatus **500**. The data acquisition system **512**, in one embodiment, is a standard system including sensors and data logging equipment, such as, a computer system. The data acquisition system **512**, in one embodiment, is connected to sensors designed to measure temperature, voltage drop, brush wear, humidity, oxygen concentration, pressure, speed, and many other parameters at various points. In particular, stator bus bar, brush holder **144**, **146**, brush **106**, and rotor slip ring temperatures are measured. In one embodiment, up to 175 channels are allocated for instrumentation with the majority of the measurement signals being recorded on by the data acquisition system **512**.

[0044] Information as herein shown and described in detail is fully capable of attaining the above-described object of the invention, the presently preferred embodiment of the invention, and is, thus, representative of the subject matter which is broadly contemplated by the present invention. The scope of the present invention fully encompasses other embodiments which may become obvious to those skilled in the art, and is to be limited, accordingly, by nothing other than the appended claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." All structural and functional equivalents to the elements of the above-described preferred embodiment and additional embodiments that are known to those of ordinary skill in the art are hereby expressly incorporated by reference and are intended to be encompassed by the present claims.

[0045] Moreover, no requirement exists for a device or method to address each and every problem sought to be resolved by the present invention, for such to be encompassed by the present claims. Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims. However, that various changes and modifications in form, material, and fabrication material detail may be made, without departing from the spirit and scope of the invention as set forth in the appended claims, should be readily apparent to those of ordinary skill in the art.

What is claimed:

1. A test apparatus, comprising:
a rotor coupled to a drive shaft, wherein the drive shaft is mechanically coupled to a drive system;
a stator coupled to at least one brush holder;
at least one brush held by the at least one brush holder, wherein the at least one brush is held in contact with the rotor;
a housing for supporting the rotor and the stator; and
a superconducting magnet for providing a magnetic field in a vicinity of the at least one brush.

2. The apparatus of claim **1**, further comprising at least one gas delivery tube to supplies gas to the at least one brush holder for controlling a pressure that the at least one brush exerts on the rotor.

3. The apparatus of claim **1**, further comprising an environmental chamber enclosing the rotor and the at least one brush.

4. The apparatus of claim **3**, further comprising at least one data acquisition system.

5. The apparatus of claim **1**, further comprising:
a first power supply connector for supplying power to the at least one brush; and
a second power supply connector for supplying power to the superconducting magnet.

6. The apparatus of claim **1**, further comprising a magnet housing for accommodating the superconducting magnet, wherein the magnet housing comprises a vacuum-sealed super-cooling housing.

7. The apparatus of claim **1**, wherein the drive system comprises a motor and drive belt coupled to the drive shaft.

8. The apparatus of claim **1**, further comprising a support structure for supporting the housing, the stator, the rotor, and the drive shaft.

9. A test system, comprising:
a test apparatus, the apparatus comprising:
a stator;
at least one brush holder coupled to the stator;
at least one brush held by the at least one brush holder;
a rotor positioned to contact the at least one brush;
a drive shaft coupled to the rotor; and
a superconducting magnet for supplying a magnetic field to a location at which the at least one brush contacts the rotor;
a drive system coupled to the drive shaft;
a power supply for providing power to the at least one brush; and
a power supply for providing power to the superconducting magnet.

10. The system of claim **9**, further comprising an environmental chamber enclosing the rotor and the at least one brush.

11. The system of claim **10**, further comprising a data acquisition system coupled to the test apparatus.

12. The system of claim **10**, further comprising an environmental delivery system for supplying gas to the environmental chamber.

13. The system of claim **9**, further comprising a gas delivery system for supplying gas to the at least one brush holder.

14. The system of claim **9**, further comprising a chiller coupled to the test apparatus for controlling a temperature of the rotor and the at least one brush.

15. The system of claim **9**, further comprising a magnet housing, wherein the magnet housing is a vacuum-sealed super-cooling housing for the superconducting magnet.

16. The system of claim **15**, further comprising a cryocooler for cooling the superconducting magnet.

17. A method of testing at least one brush, comprising:
rotating a rotor of a test apparatus;
providing power from a brush power supply to at least one brush in contact with the rotor;
providing power from a magnet power supply to a superconducting magnet; and
generating a magnetic field from the superconducting magnet in a vicinity of the at least one brush and the rotor.

18. The method of claim **17**, further comprising acquiring data related to an operation of the at least one brush.

19. The method of claim **18**, further comprising providing gas to an environmental chamber enclosing the rotor and the at least one brush.

20. The method of claim **19**, further comprising acquiring at least one of temperature data and pressure data within the environmental chamber.

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