

relatively high magnetic permeabilities. For example, in the subsea oil and gas production industry, electrically powered devices such as sensors, transmitters and actuators are sometimes positioned inside the production equipment components, such as wellhead housings, christmas tree flow lines and valve actuators, in order to monitor and control the flow of fluids through the components. Although power for these electrically powered devices may be provided by internal batteries or external power supplies, batteries lose charge over time and external power supplies require the drilling of holes through the components to accommodate pass-through connectors, and such holes are undesirable when the pressure integrity of the components must be assured.

Therefore, a wireless induction power transfer system for powering devices positioned inside subsea hydrocarbon production equipment components would be beneficial. However, many of the common materials used to manufacture these components, such as 4130, X65, Super Duplex and 1010 steel, have relative permeabilities near 1000. Consequently, the power transfer efficiencies for an induction power transfer system for use with these components would likely be only a small fraction of a percent. As a result, induction power transfer systems are not practical for use with such components.

In other applications in which wireless induction power transfer systems are currently employed, the power transfer efficiencies are less than ideal because the barriers are made from very low magnetic permeability materials. For example, cordless charging stations employing wireless induction power transfer systems have been developed to recharge a number of portable devices, such as cell phones, personal media players and cameras. However, these devices commonly comprise housings made of very low magnetic permeability materials, such as plastic. As a result, the power transfer efficiency of the charging station is relatively low. Consequently, a relatively long time is required to fully charge the device and the charging efficiency is substantially lowered.

SUMMARY OF THE INVENTION

~~In accordance with the present invention, these and other limitations in the prior art are addressed by providing a method for increasing the power transfer efficiency of a wireless induction power and/or data transfer system comprising a magnetic field transmitter which is positioned on a first side of a barrier and a magnetic field receiver which is positioned on a second side of the barrier~~

~~barrier. Thus, the flux flow member increases the amount of magnetic flux generated by the transmitter which is coupled through the barrier and into the receiver.~~

According to a first aspect of the invention, there is provided a method for increasing the power transfer efficiency of a wireless induction power and/or data transfer system comprising a magnetic field transmitter which is positioned on a first side of a barrier and a magnetic field receiver which is positioned on a second side of the barrier opposite the first side, the method comprising: disposing at least one flux flow member in the barrier at least partially between the transmitter and the receiver, the flux flow member comprising a magnetic permeability different from a magnetic permeability of the barrier; wherein the flux flow member is a separate member from the transmitter and the receiver; and wherein the flux flow member increases the amount of magnetic flux generated by the transmitter which is coupled through the barrier and into the receiver.

According to a second aspect of the invention, there is provided a method for increasing the power transfer efficiency of a wireless induction power and/or data transfer system comprising a magnetic field transmitter which is positioned on a first side of a barrier and a magnetic field receiver which is positioned on a second side of the barrier opposite the first side, the method comprising: disposing at least one flux flow member in the barrier at least partially between the transmitter and the receiver, the flux flow member comprising a magnetic permeability different from a magnetic permeability of the barrier; wherein the flux flow member increases the amount of magnetic flux generated by the transmitter which is coupled through the barrier and into the receiver, wherein the at least one flux flow member comprises a magnetic permeability lower than the magnetic permeability of the barrier, the transmitter comprises two transmitter poles, and the step of disposing at least one flux flow member in the barrier comprises: incorporating the flux flow member into the barrier such that at least a portion of the flux flow member is positioned between the transmitter poles; wherein the flux flow member inhibits the magnetic flux generated by the transmitter from shorting through the barrier between the transmitter poles.

According to a third aspect of the invention, there is provided a wireless induction power and/or data transfer system which comprises: a magnetic field transmitter which is positioned on a first side of a barrier; a magnetic field receiver which is positioned on a second side of the barrier opposite the first side; and at least one flux flow member which is disposed in the barrier at least partially between the transmitter and the receiver, the flux flow member comprising a

magnetic permeability different from a magnetic permeability of the barrier; wherein the flux flow member is a separate member from the transmitter and the receiver; and wherein the flux flow member increases the amount of magnetic flux generated by the transmitter which is coupled through the barrier and into the receiver.

According to a fourth aspect of the invention, there is provided a wireless induction power and/or data transfer system which comprises: a magnetic field transmitter which is positioned on a first side of a barrier; a magnetic field receiver which is positioned on a second side of the barrier opposite the first side; and at least one flux flow member which is disposed in the barrier at least partially between the transmitter and the receiver, the flux flow member comprising a magnetic permeability different from a magnetic permeability of the barrier; wherein the flux flow member increases the amount of magnetic flux generated by the transmitter which is coupled through the barrier and into the receiver, wherein the at least one flux flow member comprises a magnetic permeability lower than the magnetic permeability of the barrier, the transmitter comprises two transmitter poles, and at least a portion of the flux flow member is positioned between the transmitter poles.

In accordance with one embodiment of the invention, the at least one flux flow member comprises a magnetic permeability lower than the magnetic permeability of the barrier, the transmitter comprises two transmitter poles, and the step of disposing at least one flux flow member in or adjacent the barrier comprises incorporating the flux flow member into the barrier such that at least a portion of the flux flow member is positioned between the transmitter poles. In this manner, the flux flow member inhibits the magnetic flux generated by the transmitter from shorting through the barrier between the transmitter poles.

In this embodiment, the flux flow member may comprise a thickness which is approximately the same as a thickness of the barrier at an interface between the barrier and the flux flow member.

In accordance with another embodiment of the invention, the flux flow member comprises an elongated member which is positioned between the transmitter poles. In this embodiment, the flux flow member may extend through the barrier generally perpendicular to the transmitter poles. In addition, the flux flow member may comprise a length which is sufficient to prevent the magnetic flux generated by the transmitter from shorting through the barrier around the ends of the flux flow member. Furthermore, the flux flow member may conform to the shape of the barrier. Also, the flux flow member may conform to the cross sectional configuration of the barrier.

In accordance with yet another embodiment of the invention, the flux flow member comprises at least a generally straight first portion which is positioned between the transmitter poles. In this embodiment, the flux flow member may also comprise at least a second portion which is positioned around the first portion and both of the transmitter poles.

In accordance with a further embodiment of the invention, the at least one flux flow member comprises a first flux flow member which is positioned around one of the transmitter poles. In this embodiment, the at least one flux flow

and second flux flow members into the barrier comprises attaching the flux flow members to at least one of the housings.

~~The present invention is also directed to~~Disclosed herein is a barrier which is manufactured or modified in accordance with the methods described above in order to increase the power transfer efficiency of a wireless induction power and/or data transfer system that is installed across the barrier. ~~The invention is further directed to~~Disclosed herein is a wireless induction power and/or data transfer system which includes a barrier that is manufactured or modified in accordance with the methods described above in order to increase the power transfer efficiency of the system.

~~Thus, Embodiments of~~ the present invention provides an effective method and apparatus for increasing the power transfer efficiency of wireless induction power and/or data transfer systems which are installed across barriers made of relatively high or very low magnetic permeability materials. ~~Thus, Embodiments of~~ the invention enables wireless induction power and/or data transfer systems to be used to power devices which previously could not be practicably powered in this manner.

These and other ~~object embodiments~~ and advantages of the present invention will be made apparent from the following detailed description, with reference to the accompanying drawings. In the drawings, the same reference numbers may be used to denote similar components in the various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic representation of an illustrative prior art wireless induction power and/or data transfer system shown positioned across a exemplary barrier;

Figure 2 is a representation of the induction power/data transfer system of Figure 1 showing the flow of magnetic flux through a barrier made of a material comprising a relative magnetic permeability of around 10;

Figure 3 is a representation of the induction power/data transfer system of Figure 1 showing the flow of magnetic flux through a barrier made of a material comprising a relative magnetic permeability of around 100;

Figure 4 is a representation of the induction power/data transfer system of Figure 1 showing the flow of magnetic flux through a barrier made of a material comprising a relative magnetic permeability of around 1;

Figure 5 is a graph of power transfer efficiency versus relative magnetic permeability for a representative induction power transfer system;