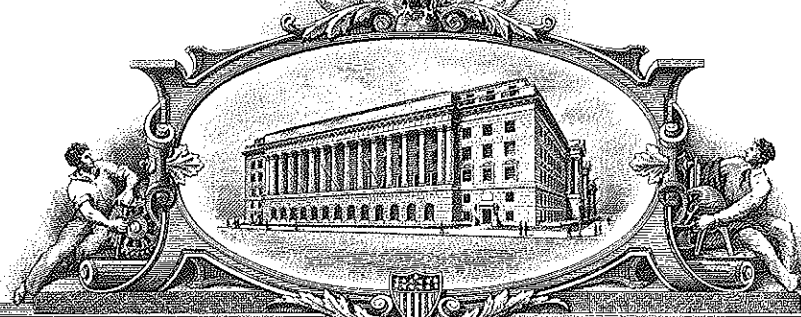


# EXHIBIT 4

U 7608123



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U.S. PATENT: 7,683,509

ISSUE DATE: *March 23, 2010*

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US007683509B2

(12) **United States Patent**  
**Neal**

(10) **Patent No.:** **US 7,683,509 B2**  
(45) **Date of Patent:** **Mar. 23, 2010**

(54) **ELECTROMAGNETIC DEVICE WITH OPEN, NON-LINEAR HEAT TRANSFER SYSTEM**

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(75) Inventor: **Griffith D. Neal**, Alameda, CA (US)

(73) Assignee: **Encap Technologies Inc.**, Alameda, CA (US)

\* cited by examiner

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 661 days.

*Primary Examiner*—Michael C Zarroli  
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(21) Appl. No.: **11/489,914**

(57) **ABSTRACT**

(22) Filed: **Jul. 19, 2006**

Electromagnetic components are provided with a heat exchange mechanism. For example, a fluid-cooled electromagnetic field-functioning device, such as a motor, generator, transformer, solenoid or relay, comprises one or more electrical conductors. A monolithic body of phase change material substantially encapsulates the conductors or an inductor. At least one liquid-tight coolant channel is also substantially encapsulated within the body of phase change material. The coolant channel may be part of a heat pipe or cold plate. The coolant channel may be made by molding a conduit into the body, using a "lost wax" molding process, or injecting gas into the molten phase change material while it is in the mold. The coolant channel may also be formed at the juncture between the body and a cover over the body.

(65) **Prior Publication Data**

US 2008/0017354 A1 Jan. 24, 2008

(51) **Int. Cl.**  
**H02K 11/00** (2006.01)

(52) **U.S. Cl.** ..... 310/54; 310/58; 180/65.1

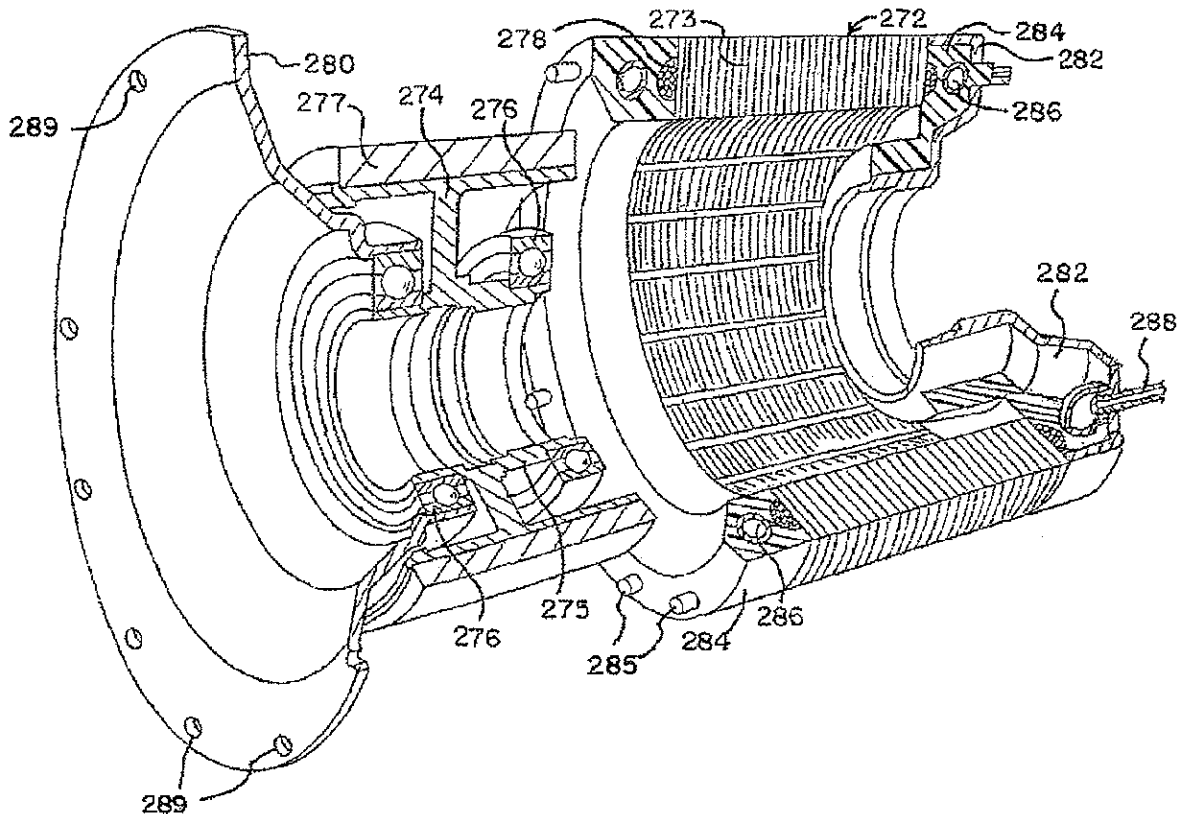
(58) **Field of Classification Search** ..... 310/54, 310/52, 43, 58-59, 64; 180/65.1  
See application file for complete search history.

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**16 Claims, 14 Drawing Sheets**



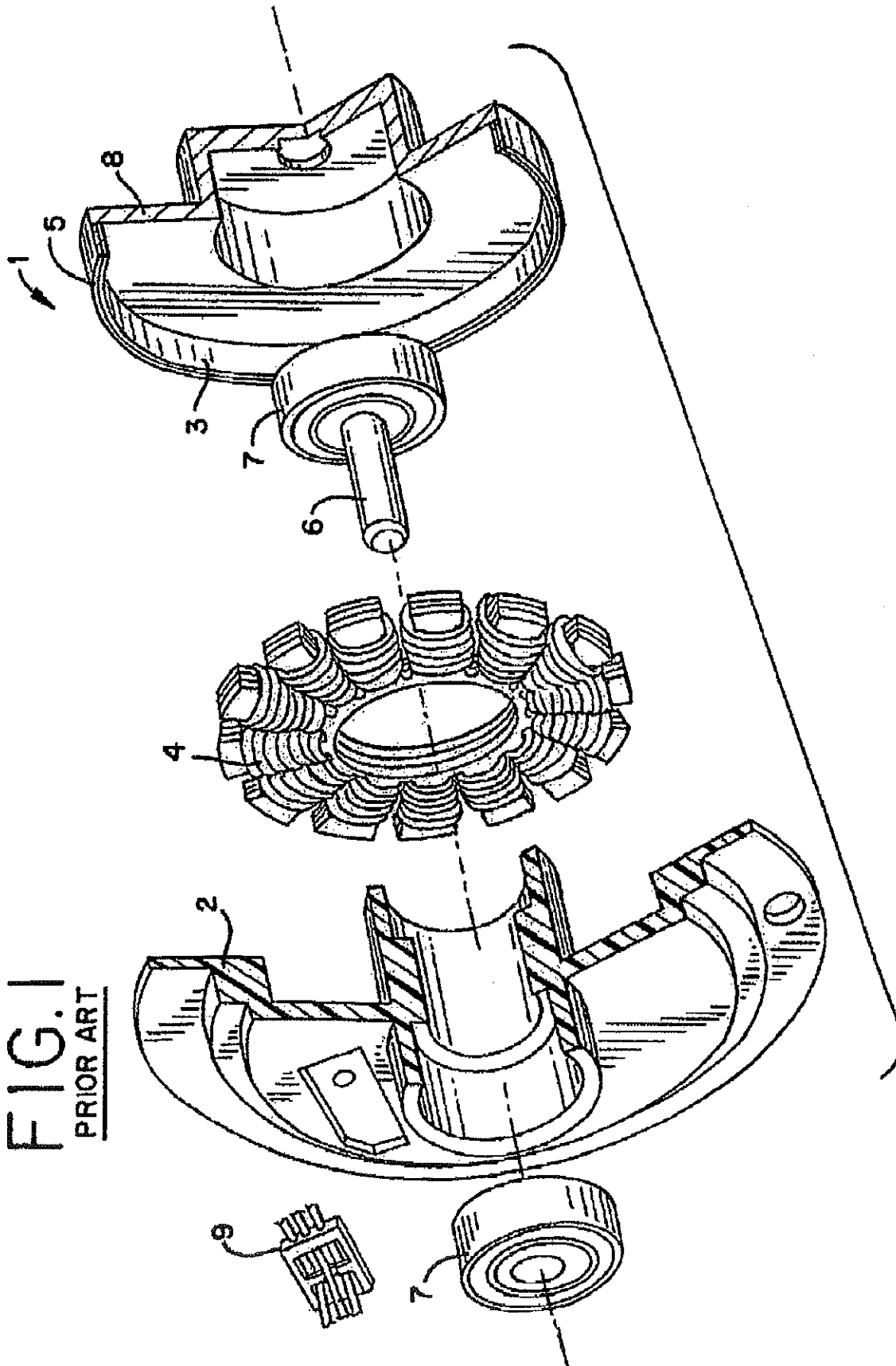


FIG. 1  
PRIOR ART

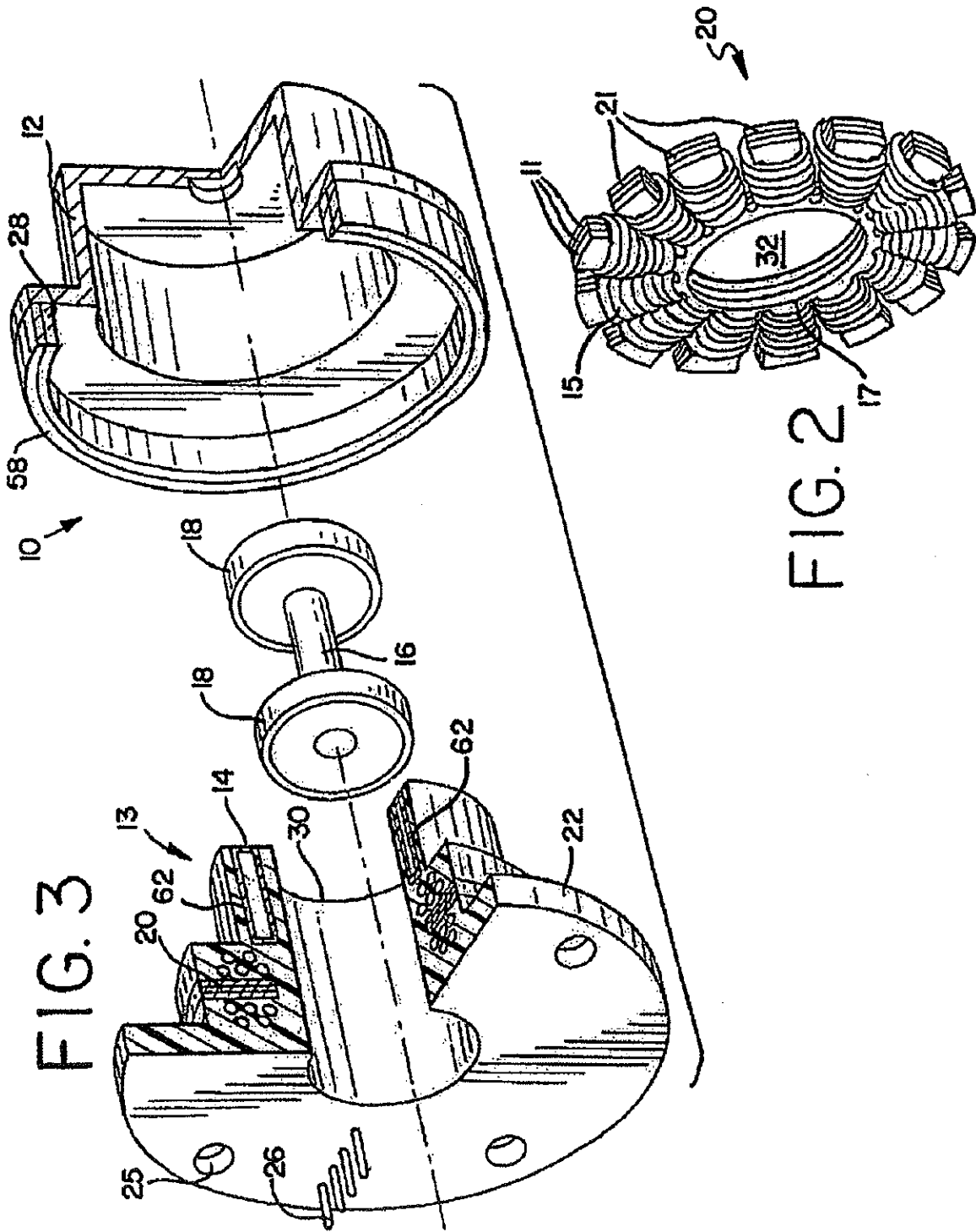


FIG. 3

FIG. 2

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