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[54] **MAGNETIC FLUX CONCENTRATOR SHIELD FOR USE IN OVERLOAD RELAY**

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[52] **U.S. Cl.** **335/6**; 335/8; 335/155; 335/177; 335/174; 335/202; 361/42; 361/44; 361/46; 361/102; 324/127; 336/175

[58] **Field of Search** .... 335/6–10, 21–23, 335/35–42, 155, 172–176, 202, 236, 237; 361/78–93, 102, 42–50; 336/175, 176; 324/126–129, 117 R, 117 H; 310/42, 216–218, 254, 258, 259, 261

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Assistant Examiner—Ray Barrera
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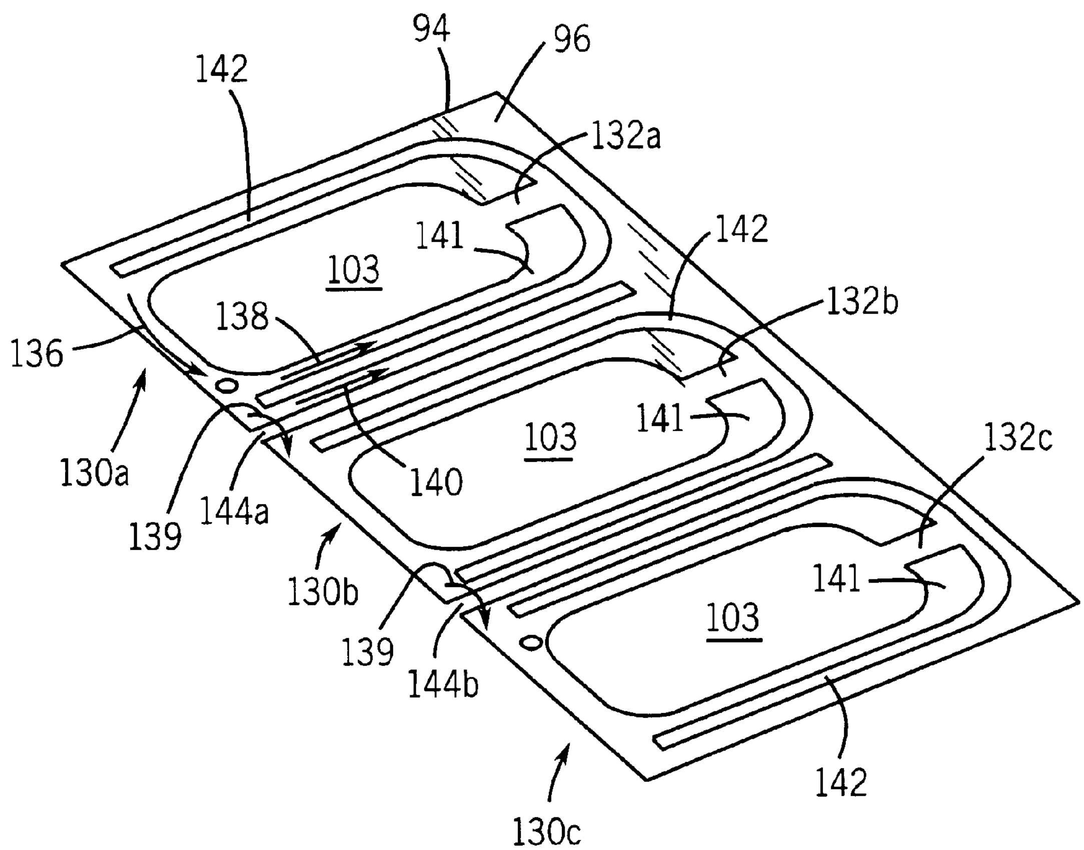
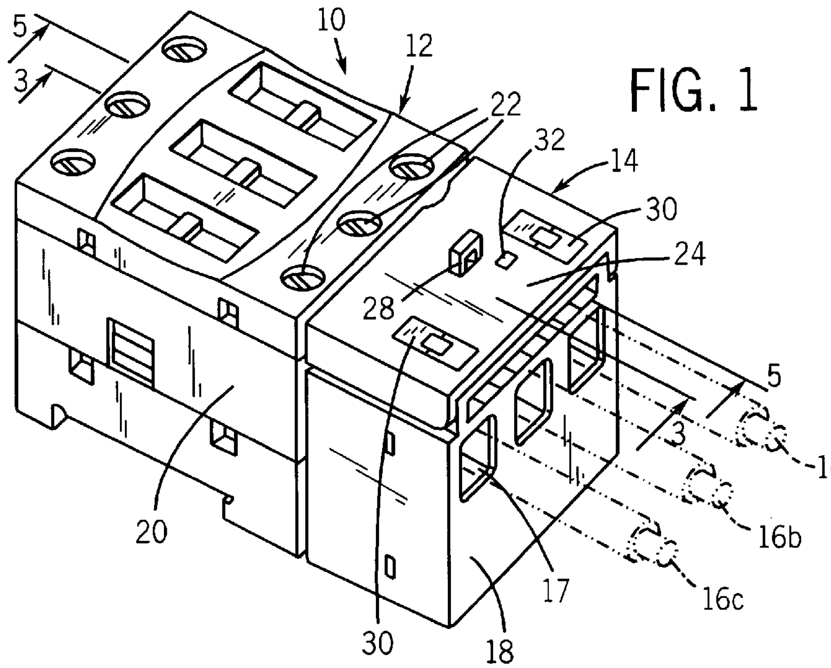
[57] **ABSTRACT**

A magnetic flux concentrator shield is disclosed for use with magnetic flux sensors in an overload relay for multiple pole electromagnetic contactor applications. The magnetic flux concentrating shield has slotted layers of laminated members. The layers have a series of pole shielding slots which concentrate magnetic flux generated by conductors carrying current through conductor apertures in each layer. Magnetic flux sensors are positioned within air gaps within each pole of the shield. By shielding the generated magnetic flux from reaching the magnetic flux sensor of another pole, the pole shielding slots minimize cross pole magnetic flux sensor interference.

26 Claims, 4 Drawing Sheets

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3
10
12
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16a
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16c
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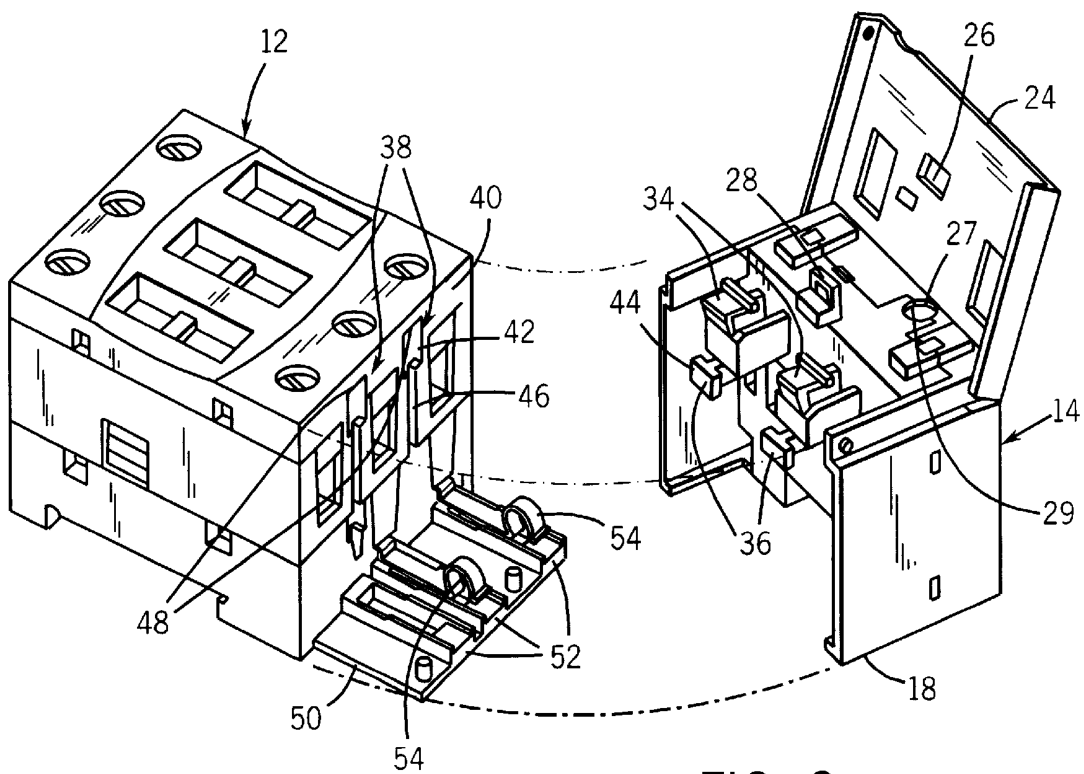
30
18

FIG. 1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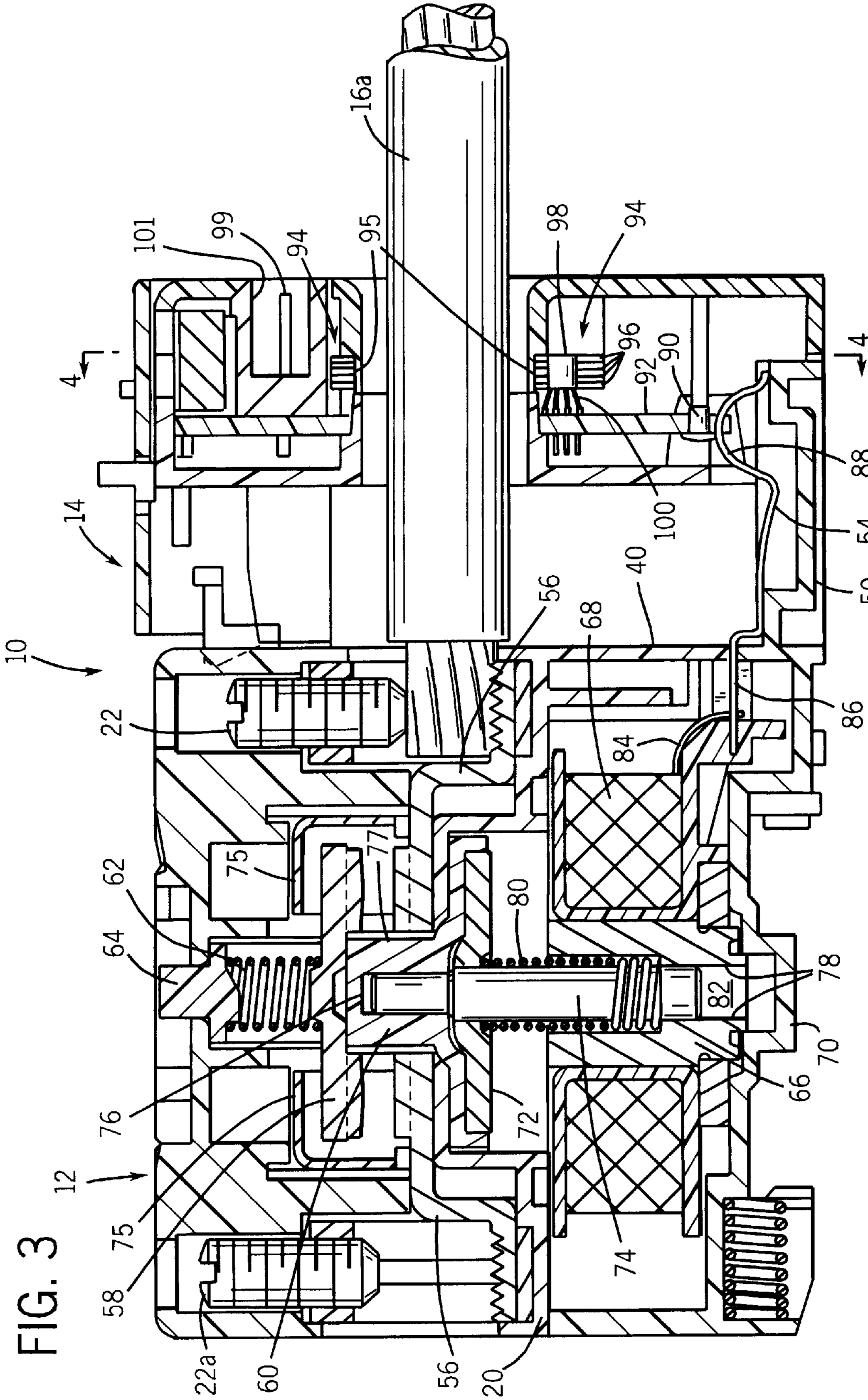
18

FIG. 2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101
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94
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98
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100
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10
22
86
84
62
64
75
77
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76
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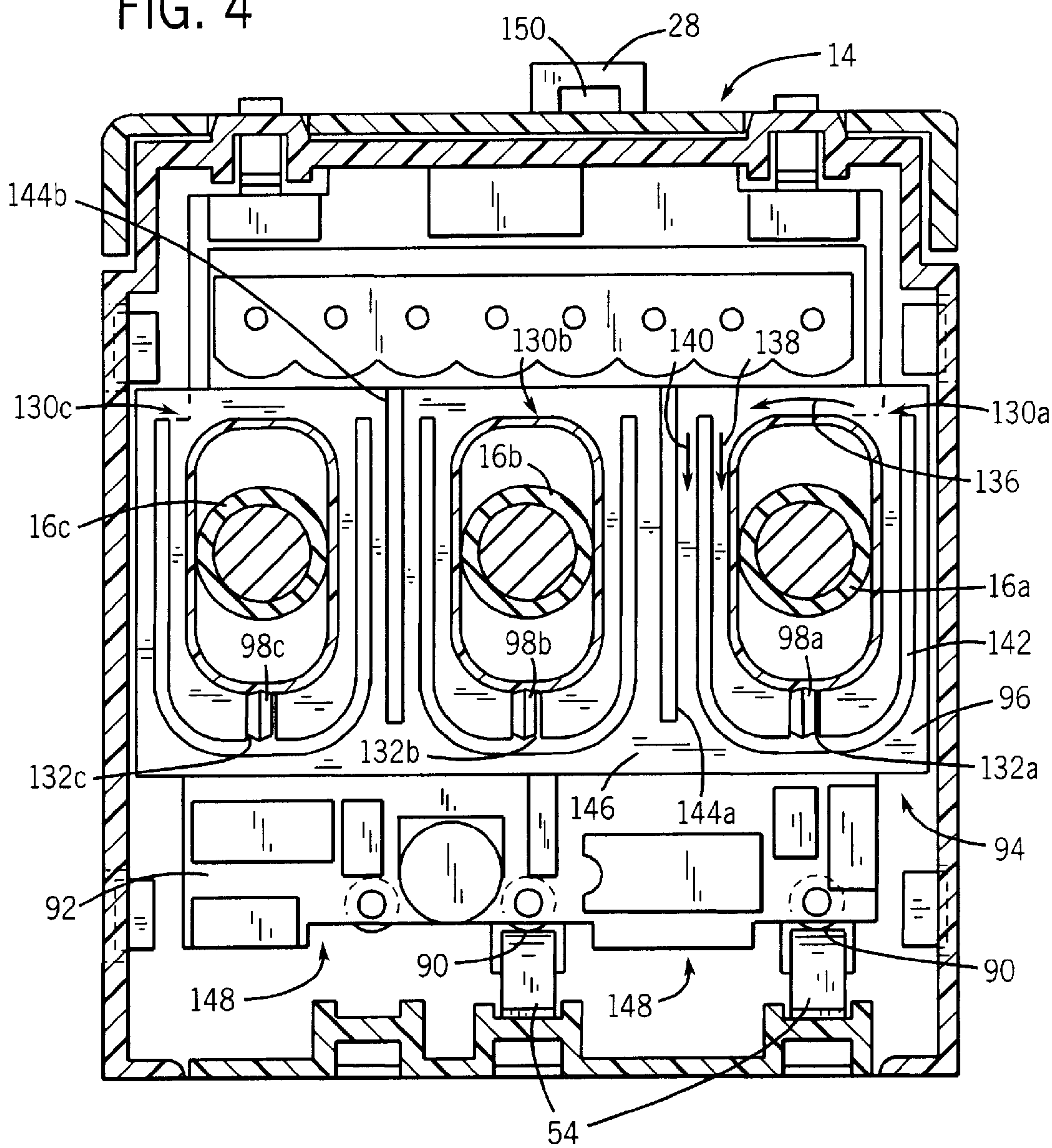
12
22a
56
20

FIG. 3

FIG. 4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28
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144b
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90
90
148
148
54

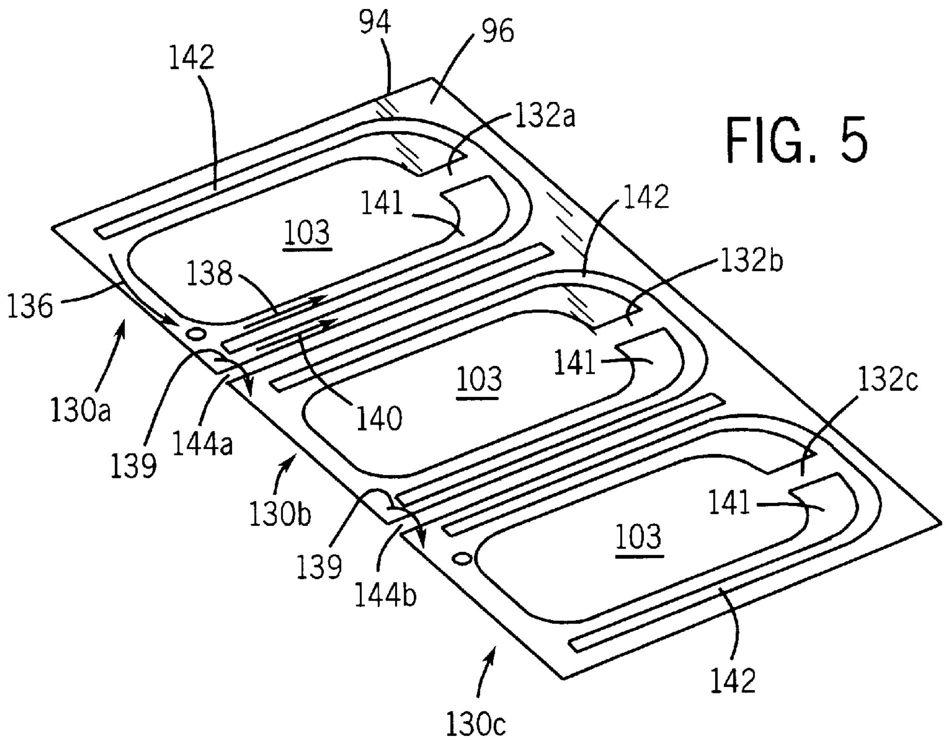
94
96
142
132a
141
103
142
138
132b
136
141
103
140
130a
132c
139
144a
141
103
130b
139
144b
142
130c

FIG. 5

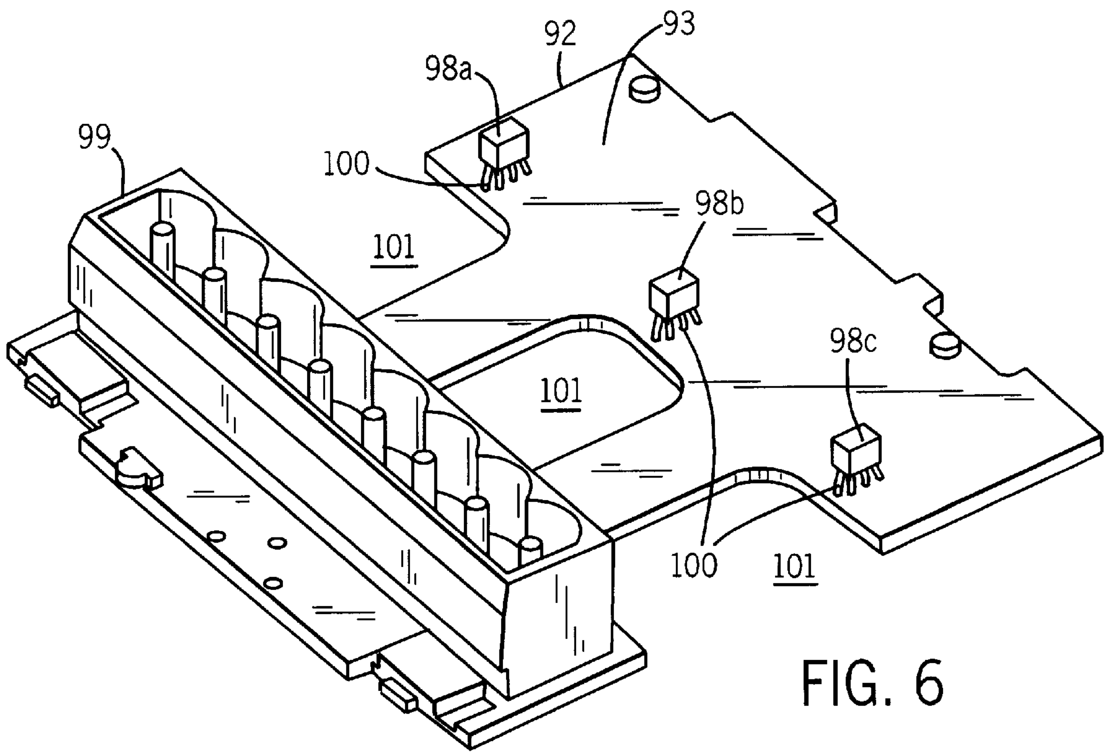
92
93
98a
99
100
98b
101
101
98c
100
101

FIG. 6

MAGNETIC FLUX CONCENTRATOR SHIELD FOR USE IN OVERLOAD RELAY

BACKGROUND OF THE INVENTION

The present invention relates generally to overload relays for electromagnetic contactors, and more particularly to a magnetic flux concentrator shield for use in an overload relay that minimizes cross pole magnetic flux interference in multiple pole contactor applications.

It is often times desirable in industrial applications to reduce the size of electrical devices, such as motor starters, while maintaining the rated electrical capacity. It is known to use Hall effect sensors for measuring current in a conductor when available space is critical. Multiple phase starters utilize a separate pole for each phase. Reducing the size of the contactor and overload relay of the starter reduces spacing between each pole. When sensitive devices such as Hall effect sensors are used, cross-pole magnetic flux contamination presents a problem. Magnetic flux generated by current flowing through a conductor in one pole may stray to an adjacent pole and be sensed by the Hall effect sensor in the adjacent pole, thereby affecting the accuracy and control function of the sensors and associated electronics. Therefore, it would be beneficial to have a magnetic flux shield in the overload relay that concentrates the magnetic flux generated by current through a conductor the flux straying into cent pole.

SUMMARY OF THE INVENTION

The present invention provides a magnetic flux concentrating shield that concentrates magnetic flux within a particular pole section while minimizing cross pole magnetic flux interference.

In accordance with one aspect of the invention, a magnetic flux concentrating shield comprises a slotted layer having a plurality of poles and a plurality of conductor apertures each capable of receiving a conductor therethrough. The shield includes a series of pole shielding slots which are at least partially located between the conductor apertures. Each pole has an inner magnetic flux path section on the layer surrounding each conductor aperture. Magnetic flux generated by each conductor is concentrated within each pole and stray magnetic flux generated by each conductor is substantially shielded from the inner magnetic flux path section of an adjacent pole by the pole shielding slots.

In accordance with another aspect of the invention, the magnetic flux concentrating shield comprises a plurality of slotted layers. Each slotted layer has a first, second and third conductor apertures. The magnetic flux concentrating shield includes a pair of substantially linear pole shielding slots, with each pole shielding slot at least partially located between the conductor apertures, and a contoured pole shielding slot surrounding each inner magnetic flux path section. The substantially linear pole shielding slots and the contoured pole shielding slots shield magnetic flux generated by the conductor of one of the poles from the inner magnetic flux path section of another of the poles.

In accordance with another aspect of the invention, the magnetic flux concentrating shield comprises a plurality of laminated members. The magnetic flux concentrating shield includes a plurality of pole sections, each having an aperture to receive a conductor transversely therethrough. Each pole section includes an inner magnetic flux path section having an air gap. A magnetic flux sensor is disposed within the air gap of the inner magnetic flux path section. The magnetic flux concentrating shield further includes a plurality of pole shielding slots so that when electrical current flows through the conductor of each pole section, a resultant magnetic flux is substantially prevented by the pole shielding slots from straying to the magnetic flux sensor of another pole section. In this manner, cross-pole magnetic flux sensor interference is minimized.

Various other features, objects and advantages of the present invention will be made apparent from the following detailed description and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a perspective view of a contactor with an overload relay connected thereto to form a motor starter in accordance with one aspect of the present invention.

FIG. **2** is a perspective view of the starter of FIG. **1** with the contactor and the overload relay separated.

FIG. **3** is a cross-sectional view taken along line **3**—**3** of FIG. **1** with the contactor and the overload relay connected.

FIG. **4** is a lateral cross-sectional view of the overload relay taken along line **4**—**4** of FIG. **3**.

FIG. **5** is prospective view showing a single layer of the magnetic flux concentrating shield in accordance with the present invention.

FIG. **6** is a perspective view of a simplified printed circuit board from the overload relay showing the magnetic flux sensors that are positioned within the magnetic flux concentrating shield of FIG. **5**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, a starter **10** is shown in perspective view. Starter **10** is a multi-phase starter as is used in industrial control applications, such as motor control, and includes contactor **12** and overload relay **14**. Contactor **12** is an electromagnetic contactor for switching supply current to a motor (not shown), while the overload relay **14** senses and measures the current to the motor, and shuts off or de-energizes the contactor **12** if too much current (overload) is flowing to the motor, thus protecting the motor. Overload relay **14** is shown connected with the contactor **12**. Overload relay **14** accepts a series of conductors **16***a*, **16***b* and **16***c* (shown partially in phantom) through overload relay housing **18**, to contactor housing **20** to be secured by lugs **22**. Overload relay **14** includes a pivotable cover **24** shown in a cover closed position. Overload relay cover **24** further includes an aperture (**26** of FIG. **2**) such that when cover **24** is in the cover closed position, a locking hasp **28** extends through cover **24** via aperture **26**. Other items such as switches **30** and LED indicator **32** may also show through or extend through cover **24** in a similar manner.

Referring to FIG. **2**, the cover **24** of the overload relay **14** is shown in a cover open position. The cover **24** in the cover open position permits visualization of conductors **16***a*, **16***b* and **16***c* (of FIG. **1**) as inserted through openings **17** in the overload relay **14** and into the contactor **12** during installation. Overload relay housing **18** includes a circular opening through which the rotary knob of a potentiometer **27** connected to a printed circuit board is disposed. Potentiometer **27** includes a screwdriver type slot **29** for adjustment of the full load amperage of the particular motor with which the starter **10** is to be used. Potentiometer **27** is covered when cover **24** is in the cover closed position, and a seal inserted through locking hasp **28** prevents unknown later adjustment of potentiometer **27**.

Contactor **12** is shown separated from overload relay **14** in FIG. **2** to better show the connection therebetween. In order to make the connection, the overload relay **14** includes flexing lock tabs **34**, which are each connected to a retaining projection **36**. Preferably, retaining projection **36** is T shaped as will be described in further detail with respect to FIG. 6A–6C. Retainer projections **36** are insertable into connecting slots **38** within housing wall **40** of contactor **12**. Each connecting slot **38** preferably has a general T shape with a receiving channel **42** for initially receiving the head **44** of retaining projection **36**. Receiving channel **42** terminates at one end in a retaining channel **46** which is narrower than the receiving channel **42**. During connection, the retaining projection **36** enters the receiving channel **42** and proceeds downwardly through the retaining channel **46**. Preferably, the head **44** of retaining projection **36** is wider then the retaining channel **46**, thereby preventing removal of retaining projection **36** through retaining channel **46**. The retaining projection **36** proceeds downwardly through retaining channel **46** until flexing lock tabs **34** snap under lip **48** of contactor housing wall **40**. One of ordinary skill will recognize that a different number of retaining projections **36** and connecting slots **38** may be utilized to accomplish a similar connection.

The contactor **12** includes a platform **50** which is integral with and extends substantially transversely to the plane of contactor wall **40**. Platform **50** includes supports **52** for supporting contoured coil terminals **54** which extend outwardly from within the contactor **12**. Although two contoured coil terminals are shown, it is contemplated that other numbers and arrangements of contoured coil terminals may be utilized. When coupled, the overload relay **14** is placed over the platform **50** to make an electrical connection with contoured coil terminals **54**.

Referring to FIG. **3**, the starter **10** is shown with contactor **12** connected to the overload relay **14**. The overload relay **14** has a simplified connection to the contactor **12** that includes a snap fit physical connection and an abutting electrical connection, which occur at substantially the same time.

Contactor **12** includes stationary contacts **56** mounted to the contactor housing **20**. A moveable contact **58** is mounted to a moveable contact carrier **60**. The moveable contact **58** is biased toward the stationary contacts **56** by a moveable contact biasing mechanism **62** which is located between the upper enclosure **64** of the moveable contact carrier **60** and the moveable contact **58**.

A magnetic core **66** surrounded by electromagnetic coil **68** in a conventional manner is located on a base portion **70** of contactor housing **20**. The magnetic core **66** is preferably a solid iron member. Electromagnetic coil **68** preferably runs on direct current, and as a result, magnetic core **66** need not be as large as other alternating current electromagnet counterparts having similar power capabilities. The overall size of contactor **12** is therefore reduced. When energized, magnetic core **66** attracts armature **72** which is connected to moveable contact carrier **60**. Moveable contact carrier **60** along with armature **72** are guided towards the magnetic core **66** with guide pin **74**.

Guide pin **74** is press fit or molded securely into moveable contact carrier **60** at one end in an inner surface **76**. Guide pin **74** is slidable along guide surface **78** within magnetic core **66**. The single guide pin **74** is centrally disposed and is utilized in providing a smooth and even path for the armature **72** and moveable contactor **60** as it travels to and from the magnetic core **66**, preventing the side to side motion during movement caused by uneven movement and partial locking of the moveable contact carrier **60**. Moveable contact carrier **60** is guided at its upper end **77** by surfaces on the contactor housing **20**. Guide pin **74** is partially enclosed by a resilient armature return spring **80**, which is compressed as the moveable contact carrier **60** moves toward the magnetic core **66**. Armature return spring **80** biases the moveable contact carrier **60** and armature **72** away from magnetic core **66**. The combination of the guide pin **74** and the armature return spring **80** helps to provide even downward motion of the moveable contact carrier **60** and helps prevent tilting or locking that may occur during contact closure. The moveable contact carrier **60** is guided along guide surface **78** to help provide a more level path to the magnetic core **66**. Additionally, lower end **82** of guide pin **74** may be used to cushion or dampen the downward movement at the end of its downward movement, such as in a dash-pot capacity, to help reduce bounce and cushion the closure of the armature **72** with magnetic core **66**. Appropriate tolerancing of the guide pin **74** surfaces **78** and housing **20** promotes its use in this capacity.

Turning now to the electrical connection between the contactor **12** and the overload relay **14**, a coil extension **84** extends from electromagnetic coil **68**. Coil extension **84** is connected to a contoured coil terminal **54**. The contoured coil terminal **54** extends outwardly from wall **40** of contactor **12**. Contoured coil terminal **54** extends onto and rests upon platform **50** so as to position itself to abuttingly engage an electrical conductor or rivet **90** which is part of printed circuit board **92** of the overload relay **14**. In operation, power is supplied to the printed circuit board **92** through a connector **99**, which is sized to receive, for example, a JP1 eight pin connector that plugs into the opening **101** of the overload relay **14**. Electrical power is directed through the printed circuit board **92** so as to be available through rivet **90** to establish an electrical connection to the coil **68** when the contoured coil terminal **54** contacts rivet **90**, as occurs when the overload relay **14** is snap fit onto contactor **12**.

Conductor **16***a*, as is the case with conductors **16***b* and **16***c*, extends through the overload relay **14** into contactor **12** and secured by lugs **22**. It is understood that similar connections are made on the opposite side of contactor **12** such that other conductors may be inserted therein and secured by lug **22***a* to complete a current path to contactor **12**.

As will be discussed in greater detail in the discussion of FIG. **5**, overload relay **14** includes a magnetic flux concentrating shield **94**. Because of the desirability of manufacturing the magnetic flux concentrating shield **94** by a stamping process, it is preferably made up of thin layers of laminated members **96** secured together. A magnetic flux sensor, such as a Hall sensor **98**, is inserted in the air gaps within each pole of the shield. The Hall sensor **98** is connected to printed circuit board **92** by leads **100** and is soldered to the printed circuit board **92**, such that it stands off from the printed circuit board **92**. The magnetic flux concentrating shield **94** is precisely positioned in the overload relay housing **20** about wall **95** so as to preserve the alignment of Hall sensor **98**. Hall sensor **98** and magnetic flux concentrating shield **94**, in combination with printed circuit board **92**, provide the necessary current measuring circuitry such that the contactor **12** is protected from and can be disabled during overload currents.

FIG. **4** is a cross-sectional view of the overload relay **14**, and as previously described, includes a magnetic flux concentrating shield **94**, which is preferably made up of layers of laminated members **96**. Locking hasp **28** is shown extending from overload relay **14**. The locking hasp includes a securing hole **150**, in which a tamper resistant seal, such as a wire or lead seal, to prevent unauthorized opening of the cover **24**.

Referring now to FIG. **5**, a single layer **96** of the shield **94** is shown. The shield **94** is preferably constructed of a ferrous material, such as steel, that has a lower magnetic reluctance than air and that is receptive to magnetic flux. It is understood that multiple layers **96** are used to achieve the desired magnetic field strength, but a single layer having a greater thickness may also be suitably employed. Each layer **96** of shield **94** includes a pole section **130***a*, **130***b* and **130***c* for the reception of conductors **16***a*, **16***b* and **16***c* (of FIG. **4**) therethrough respectively. Each pole section will receive generated magnetic flux proportionately to the magnitude and phase of the current passing through that pole section. Each pole section **130***a*, **130***b* and **130***c* includes an air gap **132***a*, **132***b*, and **132***c* into which resides a magnetic flux sensor, such as Hall sensors **98***a*, **98***b* and **98***c*. Hall sensors are utilized because they are small and fit easily within the space available in the overload relay. Because of the reduced available area, the spacing between individual poles can cause the Hall sensor in one pole to sense (additional) stray flux from an adjacent pole. During operation, current flows through conductor **16***a* in a direction passing transversely through member **96**. Such a current creates a magnetic flux path in a counter clockwise direction as indicated by arrow **136**. Flux path **136**, for example, is divided between inner flux path **138** on inner flux path section **141**, and outer flux path **140** which are divided by U shaped channels **142**. Outer flux path **140**, which provides an avenue for stray magnetic flux, is substantially prevented by pole shielding slot **144***a* from traveling directly to pole section **130***b*, but some stray flux does travel via gaps **139**. The magnetic flux to be measured is concentrated into primary flux path **138**, where it must jump through the air gap **132***a*, and ultimately through Hall sensor **98***a*. The elongated path created by pole shielding slots **144***a* and similarly **144***b* not only concentrates the magnetic flux to be measured for a particular pole into the Hall sensor for that pole, but also minimizes any stray magnetic flux from taking the elongated path or via gaps **139**, thereby shielding the Hall sensors of the adjacent poles from the effects of cross pole magnetic flux interference. U-shaped channels **142**, it will be recognized, also prevent magnetic flux from influencing Hall sensors **98***a*, **98***b* and **98***c* of adjacent poles, and therefore are considered pole shielding slots as well. Any configuration and placement of the pole shielding slots and U-shaped channels that minimizes magnetic flux transfer between pole sections is contemplated by the present invention. Additionally, although two pole shielding slots **144***a* and **144***b* and three U-shaped channels such as **142** are shown, it will be recognized that more pole shielding slots such as **144***a* and **144***b*, and additional channels **142**, in various configurations and shapes, may also be utilized to minimize cross-pole magnetic flux interference.

The amount of magnetic flux lines going across airgaps **132***a*–**132***c* is determined by both the length and width of the airgaps. The particular shielding and flux concentrating characteristics of the magnetic flux concentrating shield **94** are determined by the placement, configuration and widths of the linear pole shielding slots **144***a*–**144***b* and U-shaped channels, or contoured pole shielding slots **142**.

Referring now to FIGS. **5**–**6**, the printed circuit board **92** is shown without its associated electrical components except for Hall sensors **98***a*, **98***b*, and **98***c* and JP1 connector **99**. Hall sensors **98***a*–**98***c* are lifted off from the surface **93** of print circuit board **92** by leads **100**. The Hall sensors **98***a*–**98***c* stand off from the surface of the printed circuit board **92** so as to be self aligning within the air gaps **132***a*–**132***c*. The printed circuit board **92** and the magnetic flux concentrating shield **94** are both secured within the overload relay housing **20**, FIG. **3** and **4**, so as not to disturb the precise placement and orientation of the Hall sensors, which must be positioned with their sensitive faces perpendicular to the direction of magnetic flux. Printed circuit board **92** also includes openings **101** to receive conductors therethrough. In operation, multiple layers of magnetic flux concentrating shield **94** are placed such that Hall sensors **98***a*–**98***c* are positioned within airgaps **132***a*–**132***c* of the magnetic flux concentrating shield **94**. Conductor apertures **103** correspond with the openings **101** to allow conductors through the printed circuit board **92** and the magnetic flux concentrating shield **94**. The net effect is that the current conducted through each of the conductors **16***a*–**16***c* produces a magnetic flux through the shield **94** into Hall sensors **98***a*–*c* to obtain the current measurement for that conductor.

The present invention has been described in terms of the preferred embodiment, and it is recognized that equivalents, alternatives, and modifications, aside from those expressly stated, are possible and within the scope of the appending claims.

For example, the magnetic flux concentrating shield **94** may have many combinations and sizes of pole shielding slots and channels to effectively prevent cross-pole magnetic flux sensor corruption.

What is claimed is:

1. A magnetic flux concentrating shield comprising:

a slotted layer having a plurality of poles and having a plurality of conductor apertures, each conductor aperture capable of receiving a current carrying conductor therethrough, and including a series of pole shielding slots which are at least partially located between the conductor apertures, each pole having an inner magnetic flux path section on the layer surrounding each conductor aperture;

wherein when magnetic flux is generated by a current carrying conductor in a conductor aperture, the magnetic flux is concentrated within each respective pole and stray magnetic flux is substantially shielded from the inner magnetic flux path section of an adjacent pole by the pole shielding slots wherein the slotted layer is connected to and resides in an overload relay.

2. The magnetic flux concentrating shield of claim **1** wherein the slotted layer includes an air gap within each pole capable of receiving a magnetic flux sensor, the airgap located along the inner magnetic flux path and integral with the conductor aperture;

and wherein the pole shielding slots minimize the stray magnetic flux of one pole from entering the inner magnetic flux path section of an adjacent pole to prevent the stray magnetic flux from being sensed by the magnetic flux sensor of the adjacent pole.

3. The magnetic flux concentrating shield of claim **2** further comprising a magnetic flux sensor locatable in the air gap of the slotted layer.

4. The magnetic flux concentrating shield of claim **3** wherein the magnetic flux sensor is connected to and operatively associated with a printed circuit for providing power to a contactor.

5. The magnetic flux concentrating shield of claim **1** wherein the slotted layer is constructed of a material having a lower magnetic reluctance than air.

6. The magnetic flux concentrating shield of claim **1** wherein the slotted layer is constructed of a ferrous material.

7. The magnetic flux concentrating shield of claim **6** wherein the ferrous material is steel.

8. The magnetic flux concentrating shield of claim **1** wherein the slotted layer is stamp manufactured.

9. The magnetic flux concentrating shield of claim **1** wherein the slotted layer is a single laminate capable of being stacked to create a magnetic flux concentrating shield comprised of a plurality of single laminates.

10. A magnetic flux concentrating shield comprising a plurality of slotted layers, each slotted layer having (A) a first, second, and third conductor aperture corresponding to a first, second, and third pole, each conductor aperture capable of receiving a current carrying conductor therethrough, and having (B) pair of substantially linear pole shielding slots, each linear pole shielding slot at least partially located between the conductor apertures, each pole having an inner magnetic flux path section surrounding each conductor aperture and having a contoured pole shielding slot surrounding each inner magnetic flux path section; and

wherein when magnetic flux is generated by a current carrying conductor in each of the poles, the magnetic flux is concentrated within each respective pole and stray magnetic flux is substantially shielded from the inner magnetic flux path section of another of the poles by the substantially linear pole shielding slots and the contoured pole shielding slots.

11. The magnetic flux concentrating shield of claim **10** wherein each slotted layer includes an air gap within each pole capable of receiving a magnetic flux sensor, the airgap located along the inner magnetic flux path section and integral with the conductor aperture;

and wherein the pole shielding slots minimize stray magnetic flux of one pole from entering the inner magnetic flux path section of an adjacent pole to prevent the stray magnetic flux from being sensed by the magnetic flux sensor of the adjacent pole.

12. The magnetic flux concentrating shield of claim **11** further comprising a magnetic flux sensor located in the air gap of the slotted layer.

13. The magnetic flux concentrating shield of claim **12** wherein the magnetic field sensor is connected to and operatively associated with a printed circuit board for providing power to a contactor.

14. The magnetic flux concentrating shield of claim **10** wherein each slotted layer is constructed of a material having a lower magnetic reluctance than air.

15. The magnetic flux concentrating shield of claim **10** wherein each slotted layer is constructed of a ferrous material.

16. The magnetic flux concentrating shield of claim **15** wherein the ferrous material is steel.

17. The magnetic flux concentrating shield of claim **10** wherein each slotted layer is stamp manufactured.

18. The magnetic flux concentrating shield of claim **10** wherein **4** each slotted layer is a single laminate capable of being stacked to create a magnetic flux concentrating shield comprised of a plurality of single laminates.

19. The magnetic flux concentrating shield of claim **10** wherein the plurality of slotted layers are connected to and resides in an overload relay.

20. A magnetic flux concentrating shield comprising:

a plurality of pole sections, each pole section having an aperture to receive a conductor transversely therethrough and comprising:

an inner magnetic flux path section having an air gap;

a magnetic flux sensor disposed within the air gap of the inner magnetic flux path section; and

a plurality of pole shielding slots, such that when electrical current flows through the conductor of each pole section, magnetic flux flowing in each pole section is substantially prevented by the pole shielding slots from reaching the magnetic flux sensor in the inner magnetic flux path section of another of the plurality of pole sections, thereby minimizing cross-pole magnetic flux sensor interference.

21. The magnetic flux concentrating shield of claim **20** wherein the magnetic flux concentrating shield comprises a plurality of laminated layers.

22. The magnetic flux concentrating shield of claim **21** wherein each laminated layer is stamp manufactured.

23. The magnetic flux concentrating shield of claim **21** wherein the plurality of laminated layers are connected to and reside in an overload relay.

24. The magnetic flux concentrating shield of claim **20** wherein the magnetic flux sensor is a Hall sensor.

25. The magnetic flux concentrating shield of claim **20** wherein there are three pole sections.

26. The magnetic flux concentrating shield of claim **20** wherein each pole shielding slot is located between the inner magnetic flux path section of one pole section and the inner magnetic flux path section of another pole section.

* * * * *