United States Patent

[11] 3,575,676

[72] Inventors **Norman R. Beaudoin**
Bristol; Robert W.
Lauben, Farmington, Conn.

[21] Appl. No. **873,968**
[22] Filed **Nov. 4, 1969**
[45] Patented **Apr. 20, 1971**
[73] Assignee **General Electric Company**

[54] **HIGH-SPEED, HIGH-CURRENT SOLENOID**
12 Claims, 5 Drawing Figs.

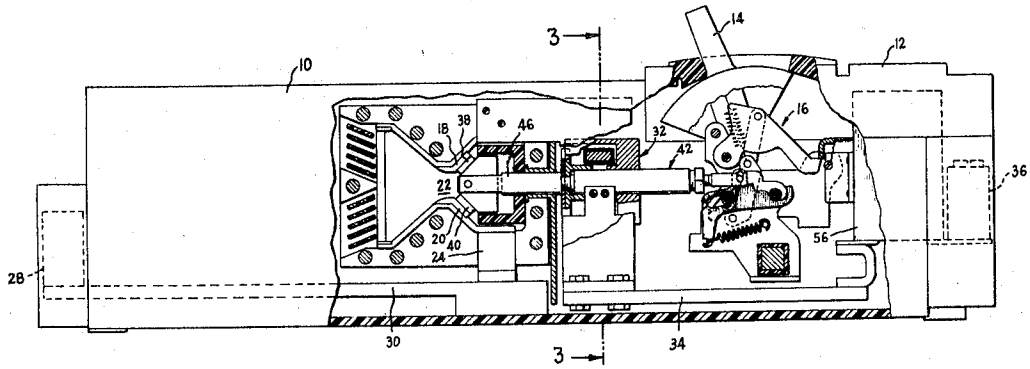
[52] **U.S. Cl.** **335/16,/**
[51] **Int. Cl.** **H01h 77/10**
[50] **Field of Search** ..... 335/16, 282, 299, 229, 224, 14, 17, 18, 21, 22, 24, 172, 174, 176, 195; 337/(Cursory); 219/235

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Primary Examiner—Harold Broome
Attorneys—Robert S. Smith, Robert T. Casey, D. M. Schiller, Frank L. Neuhauser, Oscar B. Waddell and Joseph B. Forman

ABSTRACT: A current-limiting circuit breaker incorporates an improved ultra high-speed solenoid operator for carrying continuous current loads substantially in excess of 100 amperes without exceeding 80° C. The solenoid operator is comprised of a generally C-shaped nonhelical winding of substantially one full turn having a cross-sectional area controlled to provide a minimum space factor and flux path, a magnetic cup-shaped stator including an efficient flux path return shell confining the winding and a generally cylindrical armature axially projecting into the winding and having a radial flange spaced from the shell by a small radial gap to reduce the length of the flux path through air while completing a flux path of minimum reluctance.



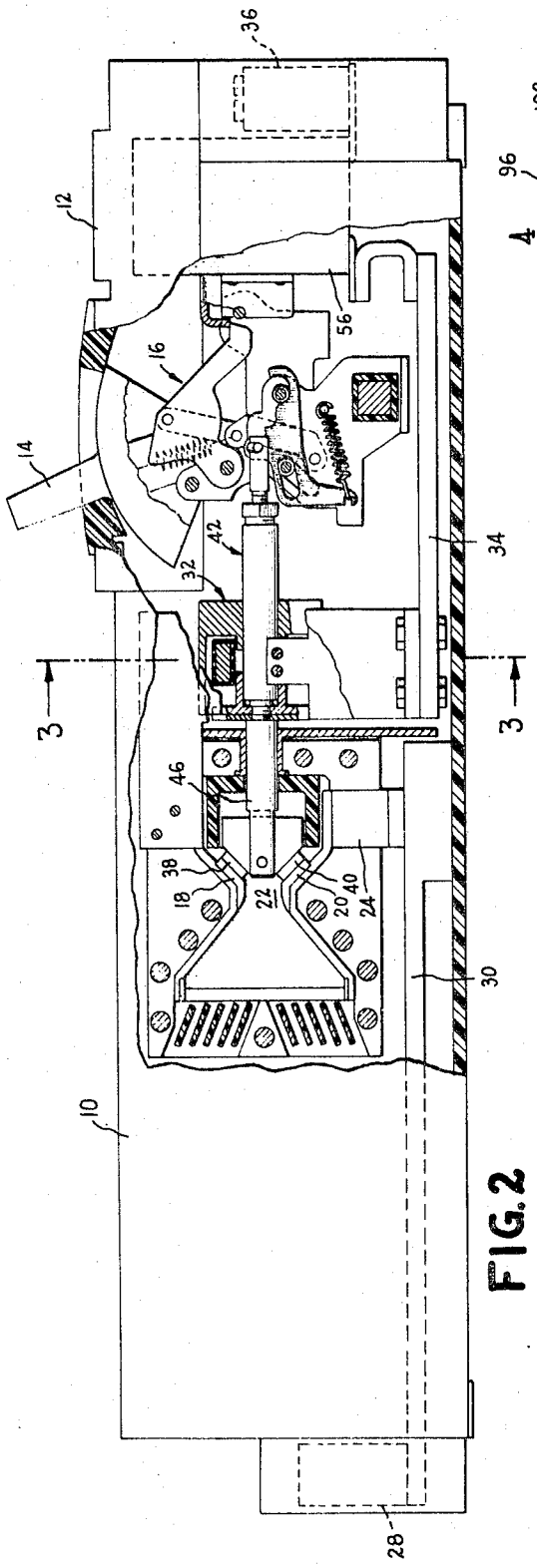


FIG. 2

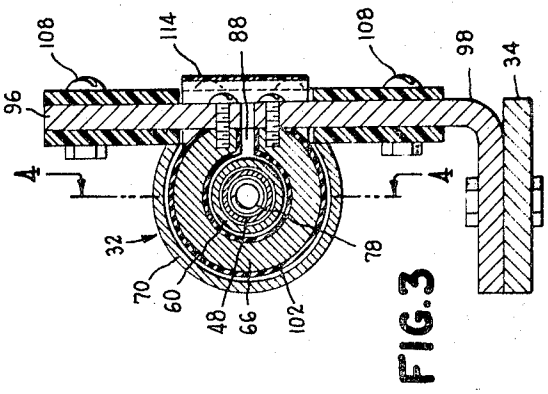


FIG. 3

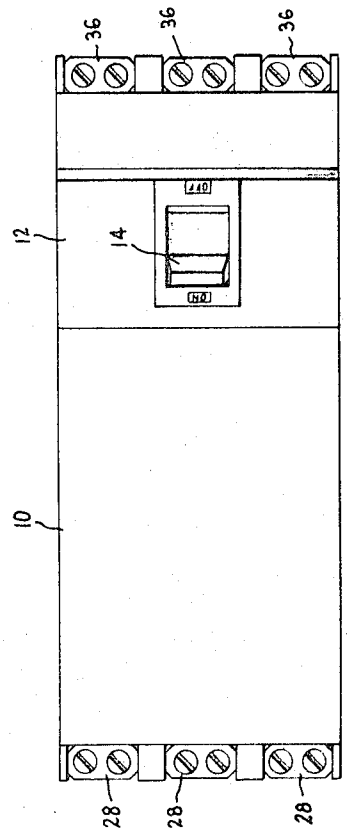


FIG. 1

INVENTORS
NORMAN R. BEAUDOIN
ROBERT W. LAUBEN
BY Robert W. Smith
ATTORNEY

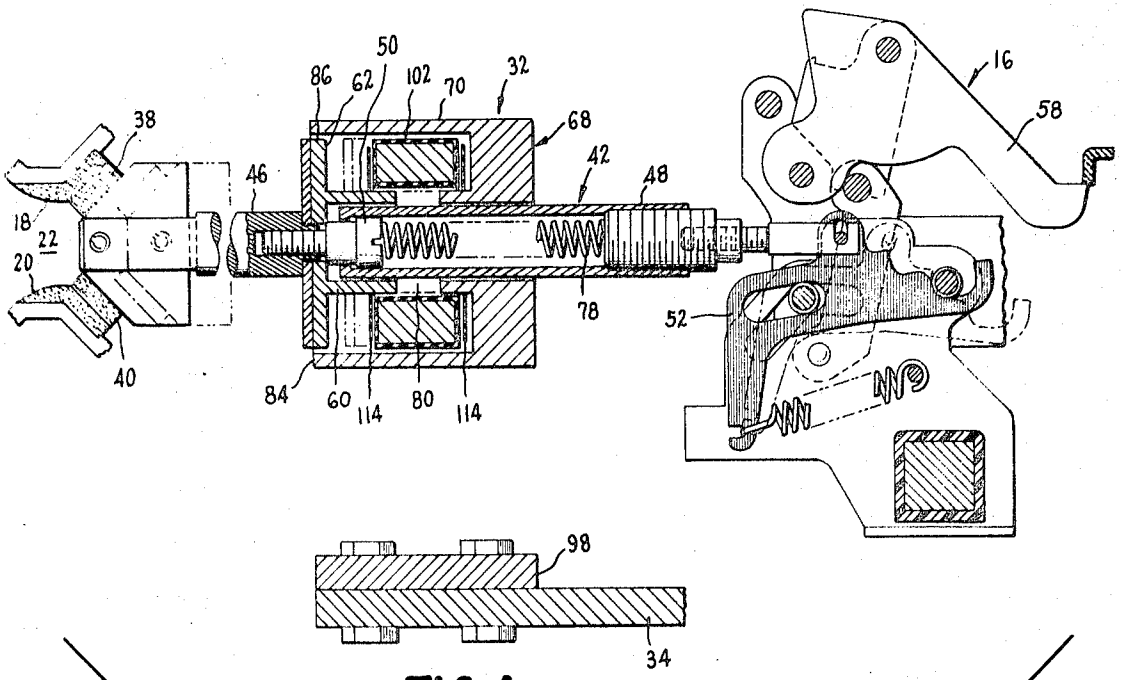


FIG. 4

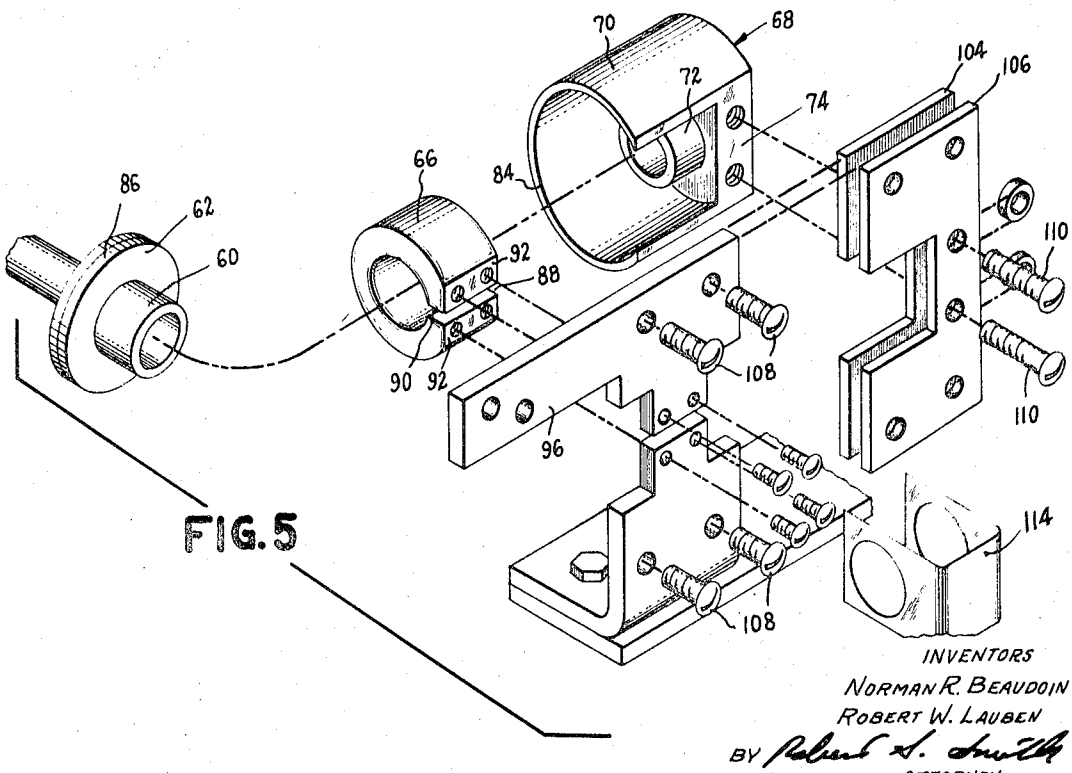


FIG. 5

INVENTORS
NORMAN R. BEAUDOIN
ROBERT W. LAUBEN
BY Robert L. Smith
ATTORNEY

HIGH-SPEED, HIGH-CURRENT SOLENOID

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates generally to circuit breakers and is particularly concerned with a new and improved current-limiting circuit breaker having a high-speed contact operator.

Recently a new type of electric circuit breaker has been developed which performs a current-limiting function as well as the functions of conventional prior art circuit breakers in acting as a switch and in automatically interrupting low level short circuit current overloads. These new current-limiting circuit breakers incorporate a high-speed contact-operating mechanism, such as a solenoid, to provide the desired current interruption in substantially less than one-half cycle of a 60 cycle per second time wave. Although conventional solenoid construction has provided effective and reliable operation at continuous current loads of about 100 amperes and less, it has been found that an increase in the current-carrying load capacity of the circuit breaker causes undesirably excessive heating, i.e., temperatures in excess of 80° C., and a substantial loss in efficiency.

Accordingly, it is an object of the present invention to provide a new and improved high capacity current-limiting circuit breaker capable of handling continuous current loads substantially in excess of 100 amperes without overheating and yet still provide current interruption at the ultra high speeds characteristic of current-limiting circuit breakers of lower current-carrying capacity for current levels substantially in excess of its rating.

Another object of the present invention is to provide a current-limiting circuit breaker of the type described having an inline high-speed contact operator designed for carrying continuous current loads of up to about 400 amperes without exceeding a temperature of 80° C. Included in the object is the provision for an operator having a minimum mean flux path providing a faster response time and a more efficient operation.

A further object of the present invention is to provide a circuit breaker of the type described capable of trip indicating at all short circuit levels and incorporating a new and improved solenoid operator having a stator construction capable of controlling the efficiency of the solenoid and hence the solenoid trip point at dI/dt's within a range up to 20,000 amperes per millisecond.

A still further object of the present invention is to provide a current-limiting circuit breaker of the type described incorporating a new and improved contact operator of the solenoid type having a substantially reduced flux path length through air coupled with an ultra high-speed response time and a greater efficiency of operation.

Still another object of the present invention is to provide a new and improved current-limiting circuit breaker of the type described incorporating the features set forth hereinbefore in a compact and economical unit exhibiting ease of assembly and durability of construction.

Other objects will be in part obvious and in part pointed out more in detail hereinafter.

These and related objects are accomplished in accordance with the present invention by providing a current-limiting circuit breaker with an ultra high-speed solenoid operator comprised of a generally C-shaped solenoid winding of less than one full turn and a minimum flux path, a stator including a flux path return shell and a generally cylindrical armature having a radial flange reducing the length of the flux path through air.

A better understanding of the objects, advantages, features, properties and relationships of the invention will be obtained from the following detailed description and accompanying drawings which set forth an illustrative embodiment and are indicative of the way in which the principle of the invention is employed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a top plan view of a three-pole circuit breaker incorporating the features of the present invention;

FIG. **2** is an enlarged elevational view, partially broken away and partially in section, illustrating the operating mechanism associated with one pole of the circuit breaker of FIG. **1**;

FIG. **3** is an enlarged sectional view of the high-speed solenoid operator taken along the line **3–3** of FIG. **2**;

FIG. **4** is a further enlarged side elevational view of the movable contact arm assembly of the circuit breaker of FIG. **2** including the contact operating mechanism associated therewith, the view being taken along the line **4–4** of FIG. **3** and showing the positioning of the assembly when the contacts are in both their closed and open circuit positions; and

FIG. **5** is an exploded perspective view of the high-speed solenoid operator shown in FIG. **3**.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to the drawings in greater detail wherein like referenced numerals indicate like parts throughout the several FIGS., a three-pole electric circuit breaker of the current-limiting type is shown in FIG. **1** as having a generally rectangular housing **10** including an insulating cover **12** through which extends a manually operated handle **14** movable between its ON, OFF and TRIP positions. The handle **14** is operatively connected to a conventional contact-operating mechanism, generally designated **16**, of the overcenter toggle linkage type for manually opening and closing all circuits controlled by the breaker.

A single contact operating mechanism **16** actuates all three of the breaker's three poles. The contact operating mechanism **16** is located on the center pole. Additionally, as is conventional, manual operation of the handle **14** will effect simultaneous opening and closing of all circuits controlled by the breaker while automatic opening of any one circuit will result in a corresponding open circuit condition throughout the entire circuit breaker.

As shown in FIG. **2**, each pole of the circuit breaker is provided with a pair of spaced stationary contacts **18**, **20** fixedly positioned within an arc-initiation chamber **22** of the current-limiting circuit breaker. The stationary contacts are mounted on a field strap assembly, partially shown at **24**, with stationary contact **18** being electrically connected to its line terminal **28** through a conductive line strap **30** while the other stationary contact **20** is electrically connected through a high-speed solenoid operator **32** mounted on trip unit strap **34** to a load terminal **36** at the opposite end of the housing. A pair of movable contacts **38**, **40** are secured to a movable contact arm assembly **42** passing through the solenoid operator **32**, the assembly **42** being adapted for linear movement toward and away from the stationary contacts. In this manner the movable contacts **38**, **40** are moved into and out of surface-abutting contact with stationary contacts **18** and **20**, respectively, causing the desired open and closed circuit conditions.

The embodiment of the movable contact arm assembly chosen for illustrative purposes is best shown in FIG. **4** as including an elongated contact rod **46** fixedly mounting the movable contacts **38**, **40** at one end thereof. The rod **46** is axially secured to a tubular operating shaft **48** by means of the axially extending connector **50** which provides a lost motion connection between the rod and the shaft. The tubular shaft **48** extends rearwardly from the contact rod **46** and passes axially through the high-speed solenoid operator **32** for linkage with the conventional overcenter mechanism **16**, the linkage being completed through a high-speed connecting plate **52** operatively associated with the overcenter mechanism **16**.

Thus, manual operation of the handle **14** between its ON and OFF positions causes linear movement of the movable

contact arm assembly **42** relative to the stationary contacts to effect the desired open and closed circuit conditions illustrated by full and phantom lines, respectively, in FIG. **4**. With the manual operating handle **14** in its ON position so that the full-line closed circuit condition exists, the occurrence of an excessive current load or low level short circuit current condition will cause activation of a trip unit **56** electrically connecting trip unit strap **34** and load terminal **36**. The trip unit **56** will effect release of the releasable lever **58** coupled to mechanism **16** resulting in a shift of its pivot point. This shift is sufficient to cause activation of the mechanism **16** together with retraction of the movable contact arm assembly **42** and opening of the circuit across the breaker. The handle **14** is also thereby moved to its TRIP position to visually indicate the tripped condition of the breaker.

As best shown in FIG. **4** the elongated contact rod **46** fixedly mounts a magnetic armature **60** of the solenoid operator **32** so that upon activation of the solenoid the armature will be attracted rearwardly causing movement of not only the armature but also the contact rod **46** and movable contacts **38**, **40** fixedly secured thereto. The solenoid armature **60** is a generally cylindrical tubular member telescopically received over the operating shaft **48** to facilitate the relative movement therebetween permitted by the lost motion connection, the connector **50** being fixedly secured to both the contact rod **46** and armature **60**. A thin, planar flange **62** integrally extends radially inwardly and outwardly of the cylindrical armature **60** from one end thereof at substantially a right angle thereto. The inwardly extending portion of the flange mounts the armature **60** on contact rod **46** for fixed retention thereon by the connector **50**. The outwardly projecting portion of the magnetic flange is disclike in configuration with a diameter approximately equal to the outside diameter of the winding **66**.

The stator **68** of the solenoid operator is a cup-shaped steel member having a generally arcuate tubular shell portion **70** and a smaller cylindrical pole piece **72** disposed within the shell and integrally connected thereto through a mounting base portion **74** of relatively greater thickness. The stationary pole piece **72** is substantially identical to the cylindrical armature **60** in configuration and diameter and is fixedly positioned in coaxial alignment with both the armature and the shell portion **70**. Thus, as best seen in FIGS. **3** and **4**, a cross-sectional view of the circuit breaker's high-speed solenoid operator **32** reveals a plurality of coaxially aligned concentric members from the central contact spring **78** mounted within the tubular operating shaft **48** to the arcuate outer shell **70** of the stator. Both the pole piece **72** and the armature **60** are positioned within the winding **66** of the solenoid operator and during normal closed circuit position are in spaced confronting relationship thereby defining a solenoid operating gap **80** which in the preferred embodiment has a length of about nine thirty-seconds inch. The outer shell **70** of the stator circumscribes the winding **66** and forms a substantial portion of the magnetic flux return path. Advantageously, the shell is of sufficient length so that its free end **84** is positioned in spaced juxtaposed relationship with the peripheral edge **86** of the disclike flange **62** when the armature is in its fully withdrawn or "on" position. In this manner there is provided a minimum air gap between the stator and the armature which the flux path must traverse thereby substantially improving the efficiency of the solenoid's operation. Additionally, the construction of the present invention reduces the solenoid trip point to a level which permits coordination with the conventional automatic trip mechanism of the breaker while at the same time permitting greater control over the trip point at *dI/dt*'s within a range up to about 20,000 amps/millisecond.

As mentioned hereinbefore, stationary contact **20** is fixedly and electrically connected to the load terminal **36** through the solenoid operator **32** and particularly through the nonhelical solenoid winding **66**. Thus, during normal operation current continuously flows through the winding which, in accordance with the present invention, readily handles continuous current flow of up to about 400 amperes without overheating, that is, without developing temperatures in excess of 80° C. As shown, the winding **66** is a solid conductive member of generally cylindrical configuration having only slightly less than one full turn. In the preferred embodiment it is an axially cored copper member having a smoothly arcuate interior surface interrupted only by a narrow slot **88** extending through the entire thickness of the member along its full length. The end surfaces **90** defining the slot **88** are in substantially parallel fully confronting relationship.

The outer surface of the solenoid winding **66** is arcuate except for a pair of flat terminal faces **92** adjacent the slot **88** and at right angles to surfaces **90**. The flat faces **92** provide large areas assuring good surface contact between the winding **66** and the current-carrying connecting plates **96**, **98** secured thereto.

The cylindrical solenoid **66** provides a winding of only slightly less than one full turn with an effective electrical path of about 0.9 turn and exhibits a generally rectangular cross-sectional configuration which in the embodiment illustrated possesses a length approximately equal to twice that of its thickness. It will be appreciated that the length of the solenoid also is advantageously about twice the length of and centrally located with respect to the solenoid gap **80** so that it not only provides the necessary working length but also exhibits a cross-sectional area which results in a minimum space factor and minimum flux path length for the required armature movement. As shown, the solenoid winding is covered by a thin coating of insulating plastic **102** such as nylon or epoxy which covers all exposed surfaces of the winding with the exception of the flat terminal faces **92** and thus is electrically insulated from the circumscribing stator shell **70** and pole piece **72** as well as armature **60** and flange **62**.

The entire solenoid operator **32** is supportably mounted on the trip unit strap **34** by means of the current-carrying connector plate **98**. As best shown in FIG. **5**, a pair of flat insulating strips **104**, **106** are threadably secured to opposite sides of plates **96**, **98** by the connectors **108** and in turn mount the cup-shaped stator **68** in assembled relationship with the winding **66** and armature **60**. The stator **68** is, of course, of segmented configuration to accommodate both the concentricity of the assembly **32** and its own mounting on strips **104**, **106** by the threaded connectors **110** extending through the strips for secure attachment to its mounting base portion **74**. As shown in FIG. **4**, the stator is mounted in such a way that the stationary pole piece **72** extends into the cored winding for a distance equal to approximately one-fourth of the solenoid's length. Additionally, a thin sheet **114** of insulating material is preferably mounted within the assembly so as to cover both ends of the solenoid winding **66** and further isolate them from both the stator and armature. The pole face areas of the armature and the stator advantageously are designed so that in conjunction with the configuration of the solenoid winding a one-half cycle trip point of about 8,000 A r.m.s. is provided. Additionally, as mentioned hereinbefore, the outwardly extending radial flange of the armature is in close spaced relationship to the shell of the stator so that the flux path through the shell and armature has a minimum length of travel through air.

In operation, a low level short circuit current condition will effect an open circuit condition through activation of the trip unit **56** and overcenter operating mechanism **16**. On the other hand, a high level short circuit current flow through the winding **66** will immediately create a magnetic field of sufficient strength to cause movement of armature **60** along a distance of ⅛ inch within about 2 milliseconds. Thus, the contacts are immediately fully opened, followed by trip indicating movement of handle **14**. As mentioned hereinbefore, this high efficiency, high-speed operation is associated with the minimum space factor, minimum flux path and low reluctance design of the solenoid operator of the present invention which substantially reduces the length of the

flux path in air. At the same time, the C-shaped, 0.9 turn winding is capable of continuous normal operation at current loads of up to 400 amperes without exceeding 80° C.

As will be apparent to persons skilled in the art, various modifications, adaptations, and variations of the foregoing specific disclosure can be made without departing from the teachings of the present invention.

What we claim is new and desire to secure by Letters Patent of the United States is:

We claim:

1. A current-limiting circuit breaker comprising:
   a. a pair of relatively movable contacts;
   b. a contact rod assembly operatively connected to the contacts for effecting movement thereof between open and closed circuit positions;
   c. a high-speed operator in driving engagement with the contact rod assembly for moving the contacts out of a closed circuit position in response to the occurrence of a predetermined high level current condition across the contacts;
   d. said high-speed operator comprising a generally C-shaped solenoid winding electrically connected to the contacts for continuously carrying currents well below said predetermined high level current condition without overheating;
   e. a generally cylindrical stator fixedly mounted in proximity to said winding and including a flux path return shell; and
   f. an armature operatively connected to the contact rod assembly for driving the contacts out of the closed circuit position in response to activation of the winding by said predetermined high level current condition, said armature including means cooperating with the stator for reducing the length of the flux path in air.

2. The circuit breaker of claim 1 wherein the C-shaped solenoid winding is a cored cylindrical conductor of nonhelical configuration forming an effective winding of substantially one full turn.

3. The circuit breaker of claim 2 wherein the conductor has a generally rectangular cross-sectional area configured to provide a minimum space factor and flux path length.

4. The circuit breaker of claim 2 wherein the conductor has a pair of fully confronting end surfaces defining a longitudinally extending turn-limiting slot.

5. The circuit breaker of claim 1 wherein the C-shaped conductor is a cored cylindrical member forming an effective winding of less than one full turn and having a generally rectangular cross-sectional configuration providing a minimum flux path, the conductor having a pair of planar terminal faces at each end of the winding facilitating continuous current flow through the winding with minimum heating.

6. The circuit breaker of claim 1 wherein the stator is a cup-shaped member positioned coaxially of the winding and having a tubular stationary pole member through which extends the contact rod assembly, the return shell coaxially confining the stationary pole member.

7. The circuit breaker of claim 1 wherein the stator is a generally tubular member positioned coaxially of the solenoid in underlying relationship therewith, the contact rod assembly extending through said tubular member for axial movement relative thereto, the return shell confining said tubular member and being integrally connected thereto at one end thereof, said armature being mounted for movement with said contacts coaxially of said tubular member.

8. The circuit breaker of claim 1 wherein the armature is a tubular member mounted with the contact rod assembly for telescopical movement into the winding.

9. The circuit breaker of claim 1 wherein the armature is a generally cylindrical member provided with a radially extending flange movable along the flux path return shell in close spaced relationship therewith during the magnetically responsive movement of the armature, said flange forming a portion of the flux path and effectively reducing the length of the flux path in air.

10. The circuit breaker of claim 1 wherein the stator includes a cylindrical stationary pole piece and the armature is a generally cylindrical member, said pole piece and said member being positioned within the winding in spaced coaxial confronting relationship.

11. The circuit breaker of claim 1 wherein the stator includes a cylindrical tubular member positioned coaxially within the winding and integrally connected to the flux path return shell, coaxially enclosing the stator and integrally connected thereto at one end thereof, the armature being a generally cylindrical member mounted in spaced confronting relationship to said tubular member for movement longitudinally of the shell, the armature including a radially extending flange in close spaced relationship with the shell forming a portion of the flux path and effectively reducing the length of the flux path in air.

12. The circuit breaker of claim 1 wherein the C-shaped winding is a cored cylindrical conductor of less than one full turn having a generally rectangular cross-sectional configuration providing a minimum flux path, the stator includes a tubular stationary pole piece positioned within the winding and a mounting base portion integrally connecting the pole piece to the flux path return shell, the armature is a generally cylindrical member fixedly mounted relative to at least one of the movable contacts in coaxial alignment with the pole piece, the armature including a radially extending flange in adjacent spaced relationship to the return shell for movement longitudinally thereof toward and away from the pole piece, said flange effectively reducing the flux path length in air.