United States Patent

[11] **3,590,188**

[72] Inventors **Russell E. Frink; William H. Fischer, both of Pittsburgh, Pa.**
[21] Appl. No. **576,740**
[22] Filed **Sept. 1, 1966**
[45] Patented **June 29, 1971**
[73] Assignee **Westinghouse Electric Corporation Pittsburgh, Pa.**

[54] **FLUID-BLAST CIRCUIT INTERRUPTER WITH PISTON ASSEMBLY AND ELECTROMAGNETIC DRIVING MEANS**
14 Claims, 38 Drawing Figs.

[52] U.S. Cl. **200/148,** 335/201
[51] Int. Cl. **H01h 33/90**
[50] Field of Search 200/148, 146, 50.15; 335/201, 18

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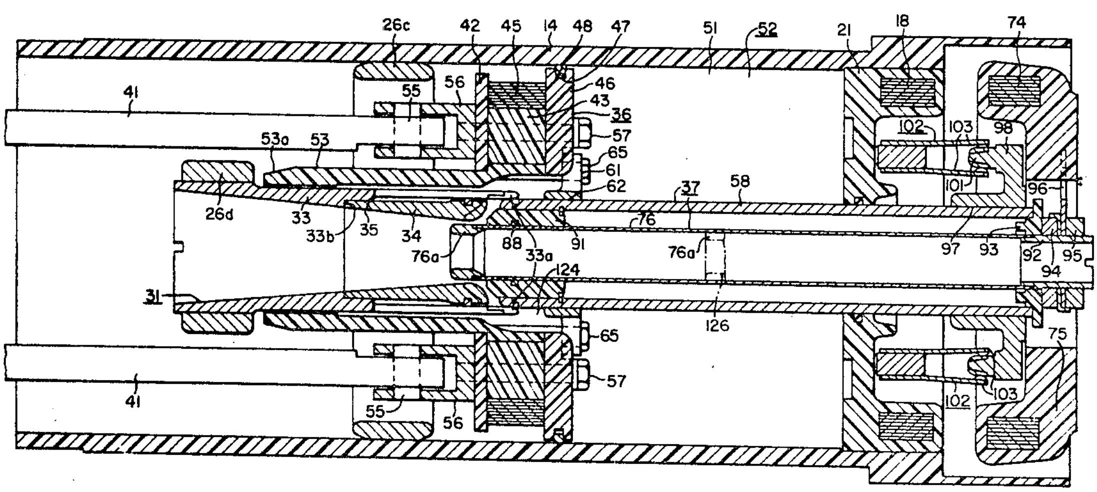
ABSTRACT: An improved piston-type fluid-blast circuit interrupter is provided having a stationary operating cylinder, within which reciprocates a movable piston assembly carrying the movable contact assembly of the interrupter. Electromagnet means including three accelerating coils, one movable with the piston assembly, another located in the closed end of the operating cylinder, and a third coil movable with a driver unit, are all connected in series during the opening operation of the interrupter. The driver unit is mechanically connected through the closed end of the operating cylinder with the movable piston assembly. The magnetic attraction between the piston coil and the coil at the closed end of the operating cylinder, and the magnetic repulsion forces between the coil at the closed end of the operating cylinder and the coil carried by the driver unit, all contribute to magnetically assisting the fluid-driving motion of the piston assembly and so effecting interruption.

The movable contact structure comprises a main movable contact and an inner movable arcing probe movable together and insulated from each other with the three accelerating coils connected between the main movable contact and the movable arcing probe in the closed position of the interrupter.



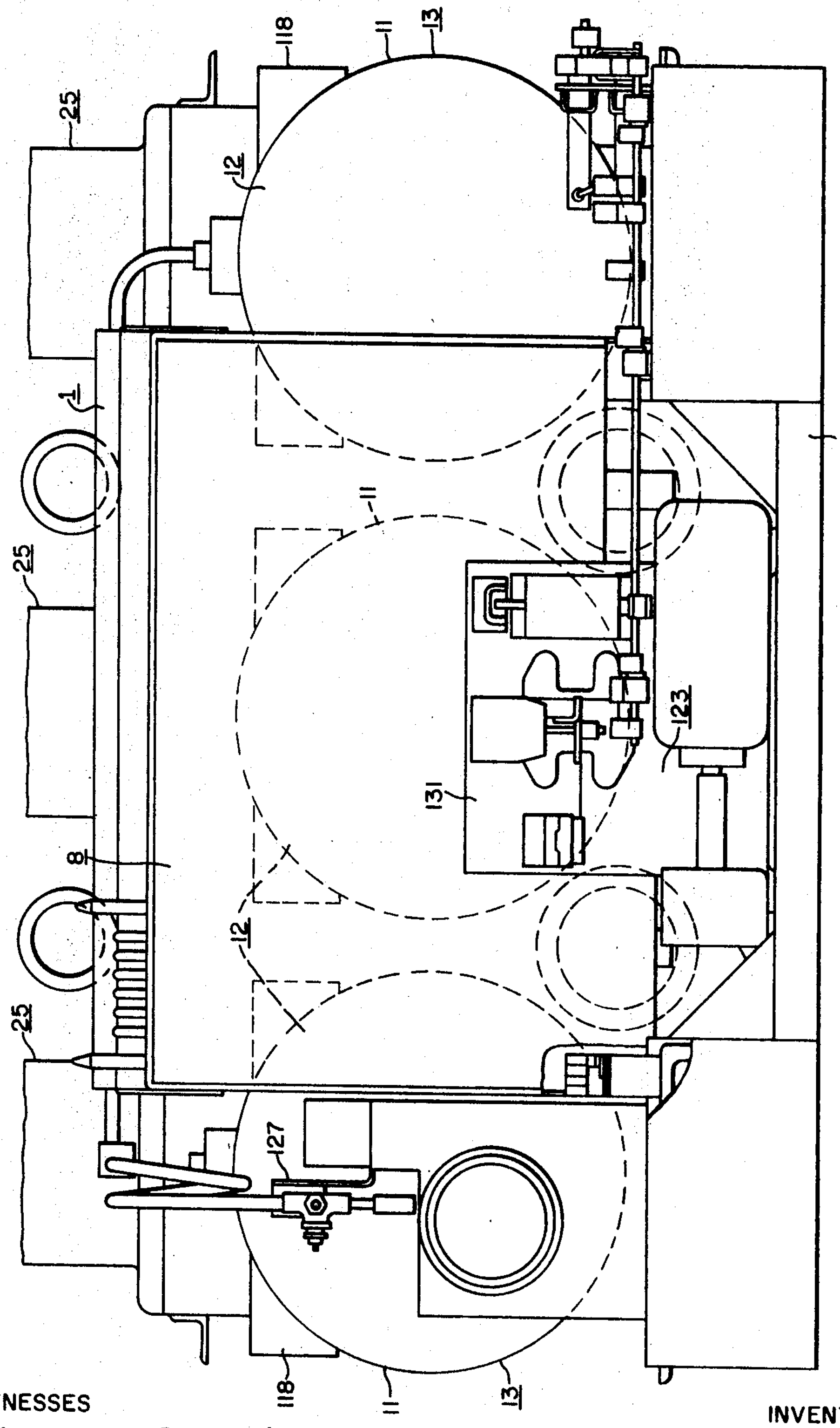


FIG.1.

WITNESSES

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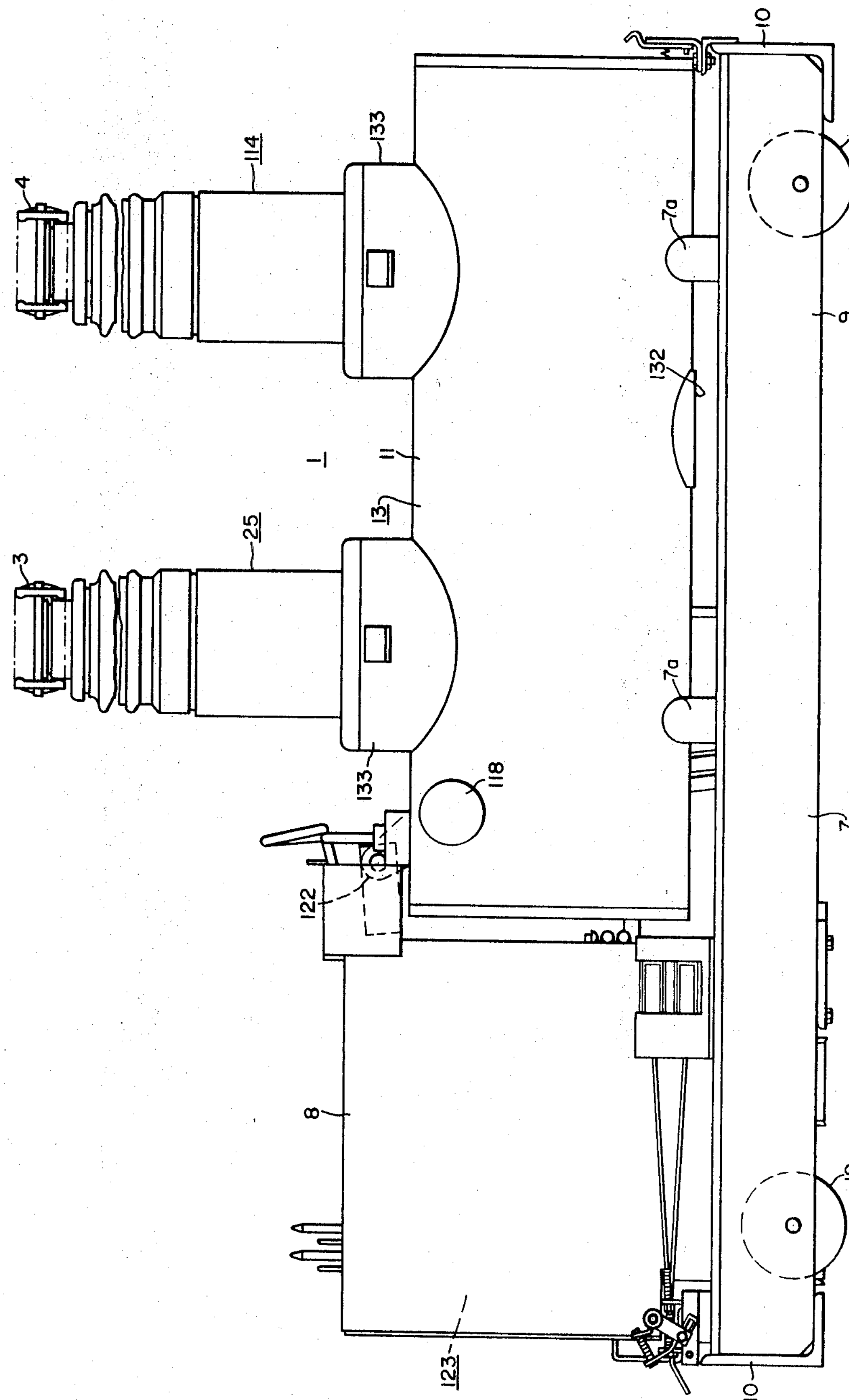

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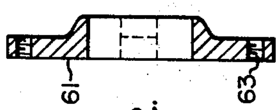

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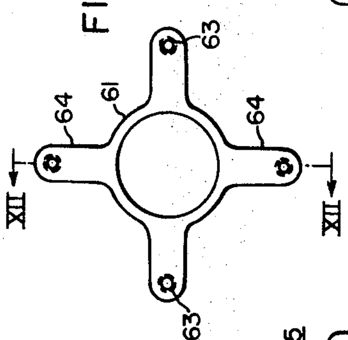

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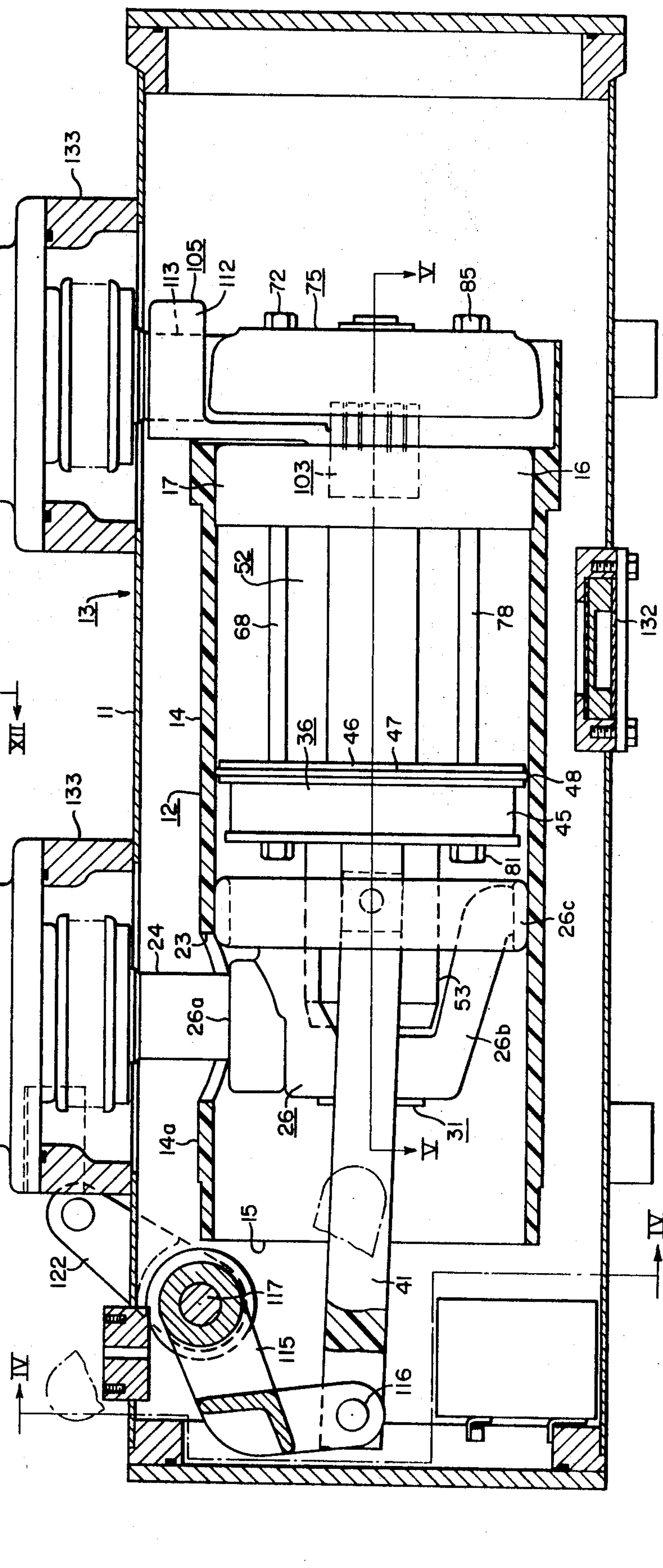

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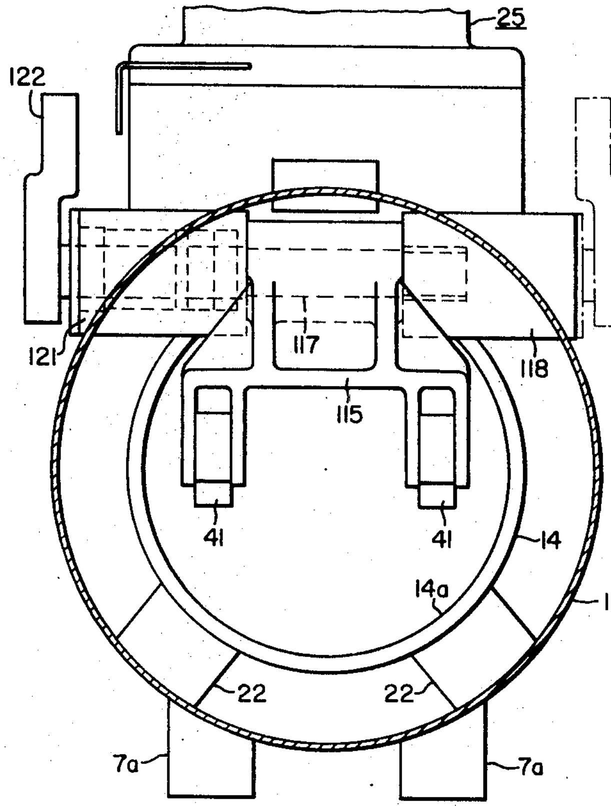

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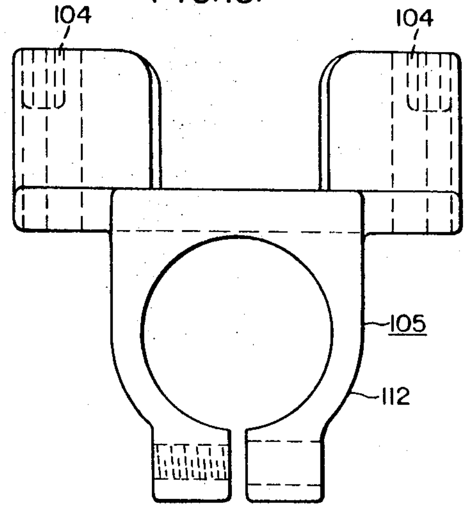

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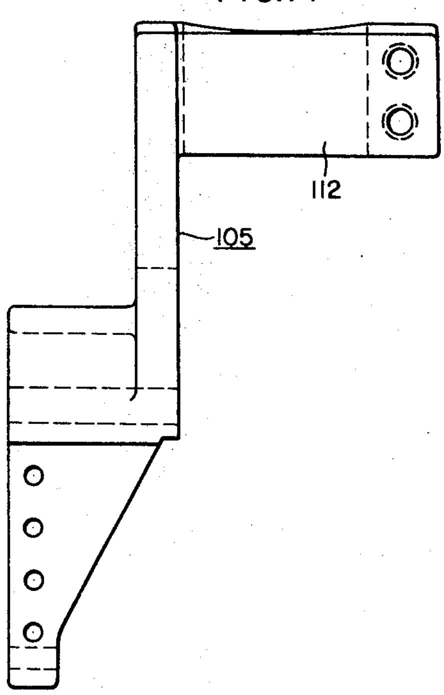

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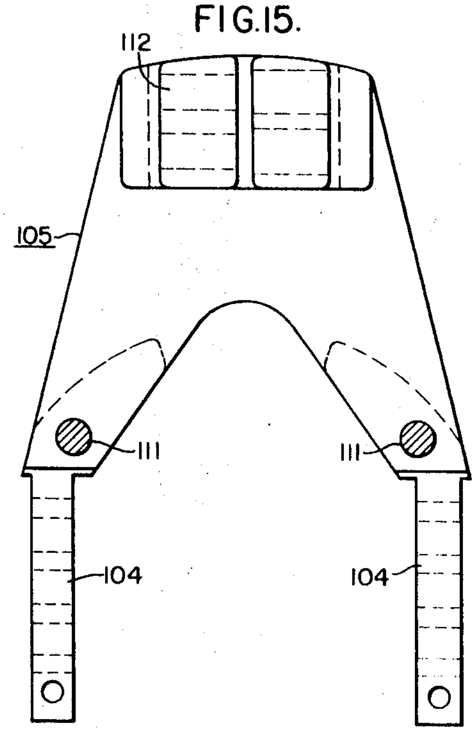

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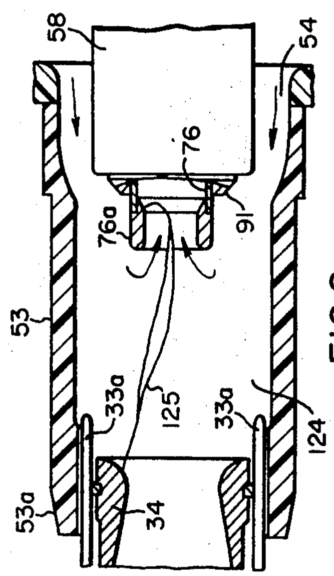

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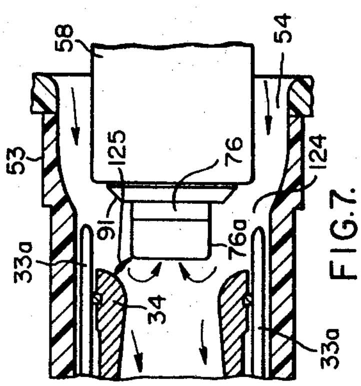

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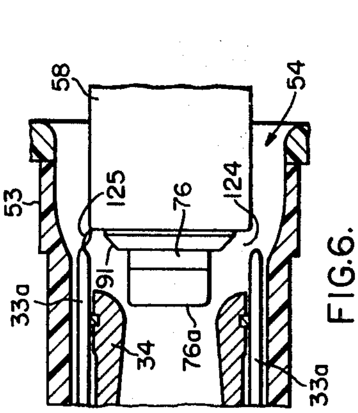

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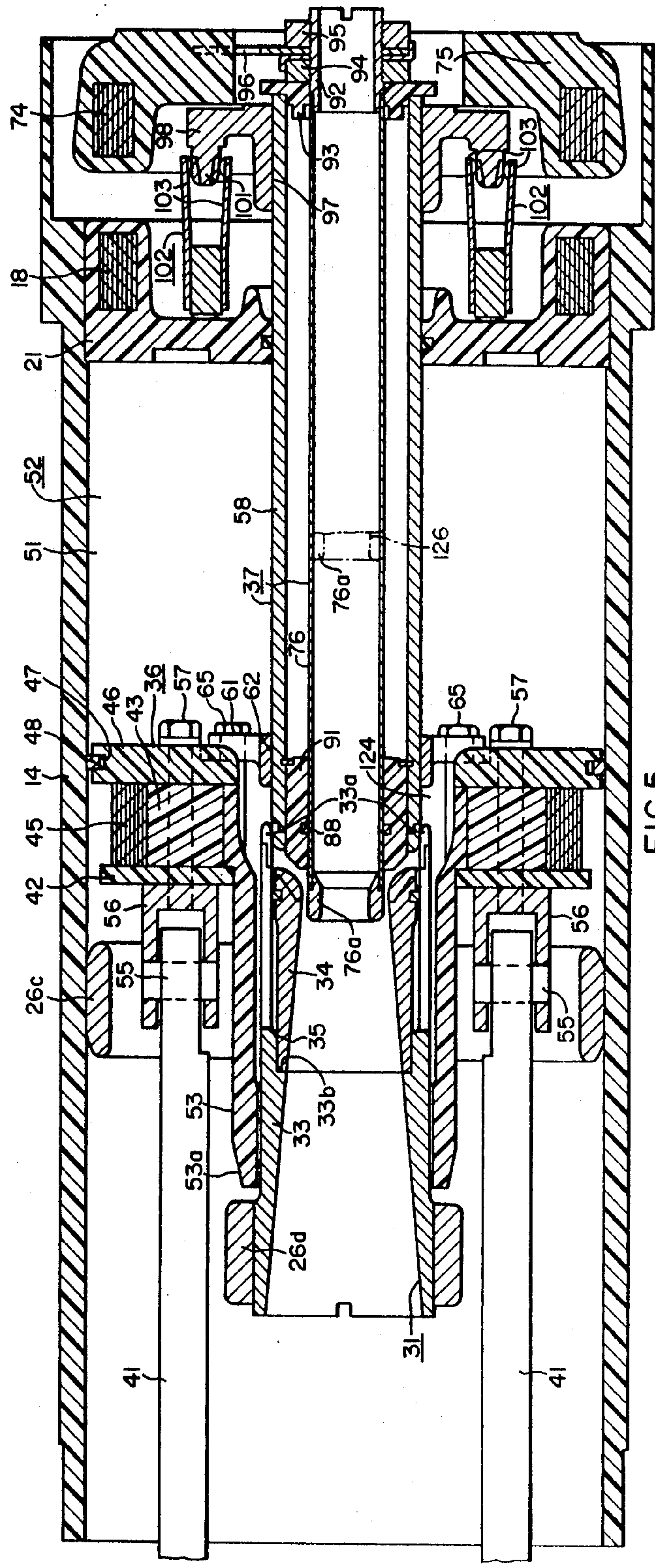

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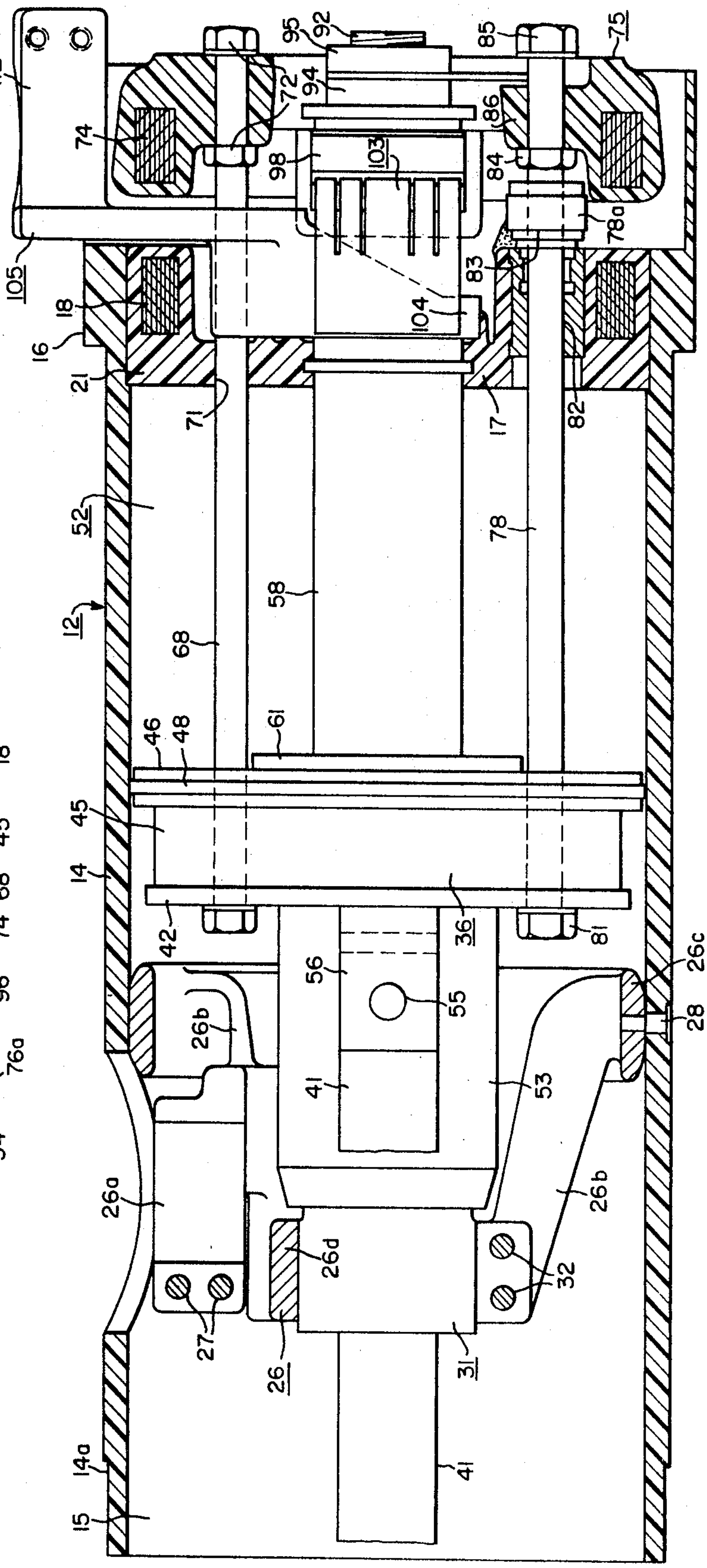

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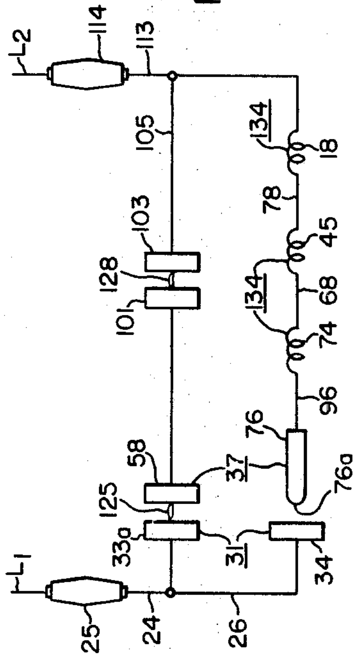

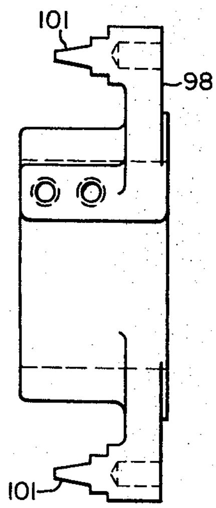

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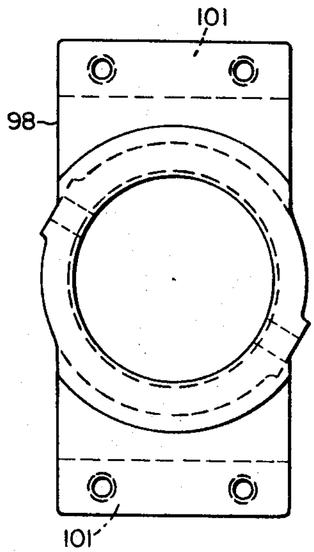

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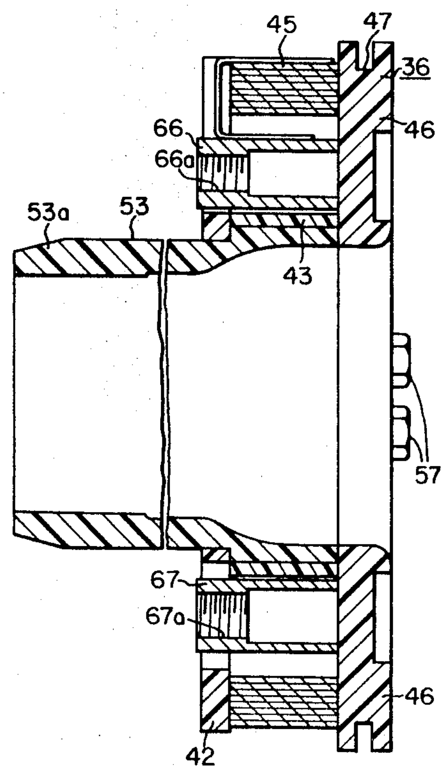

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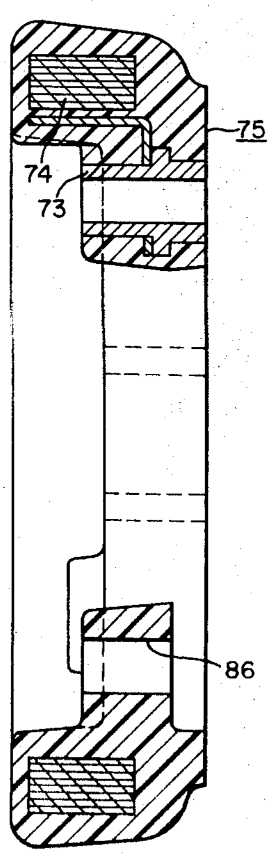

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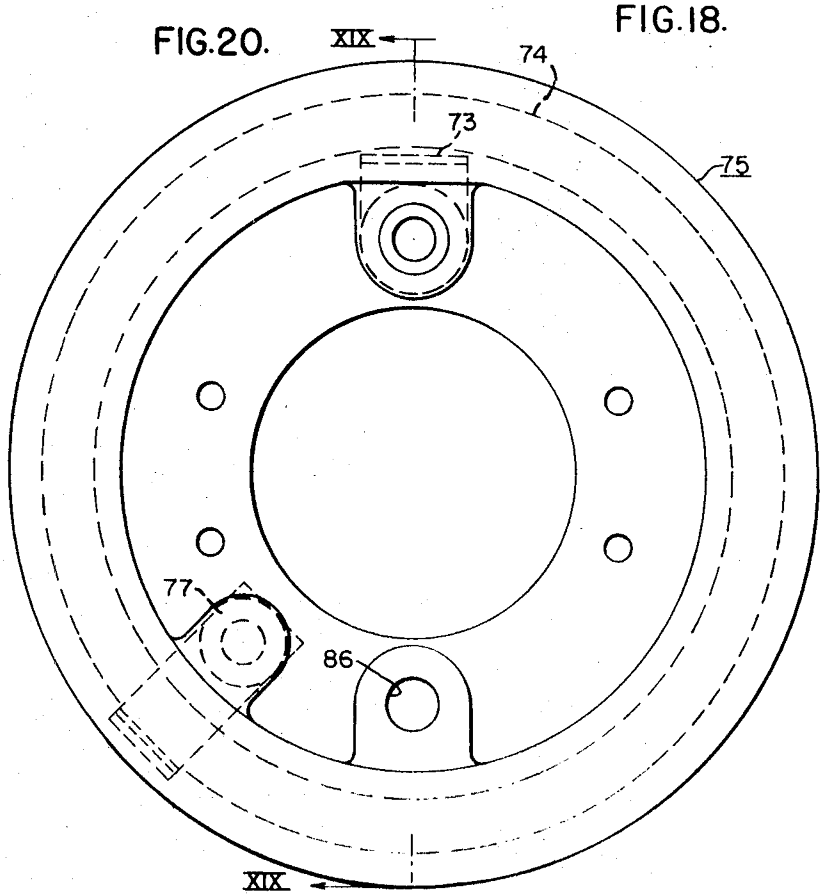

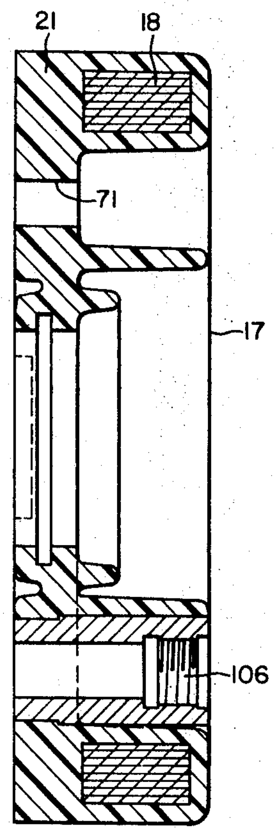

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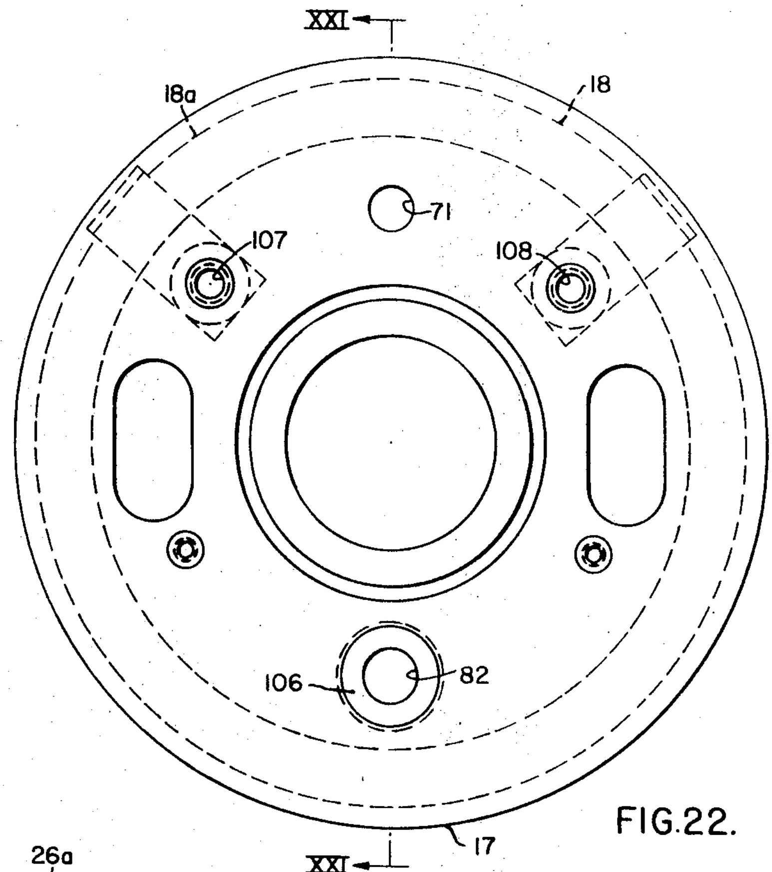

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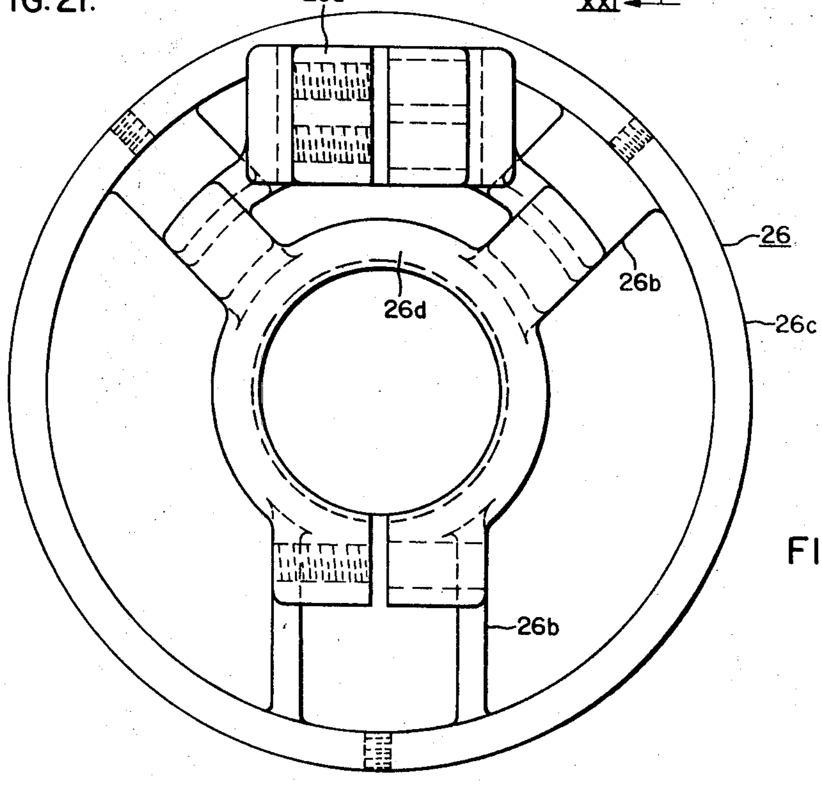

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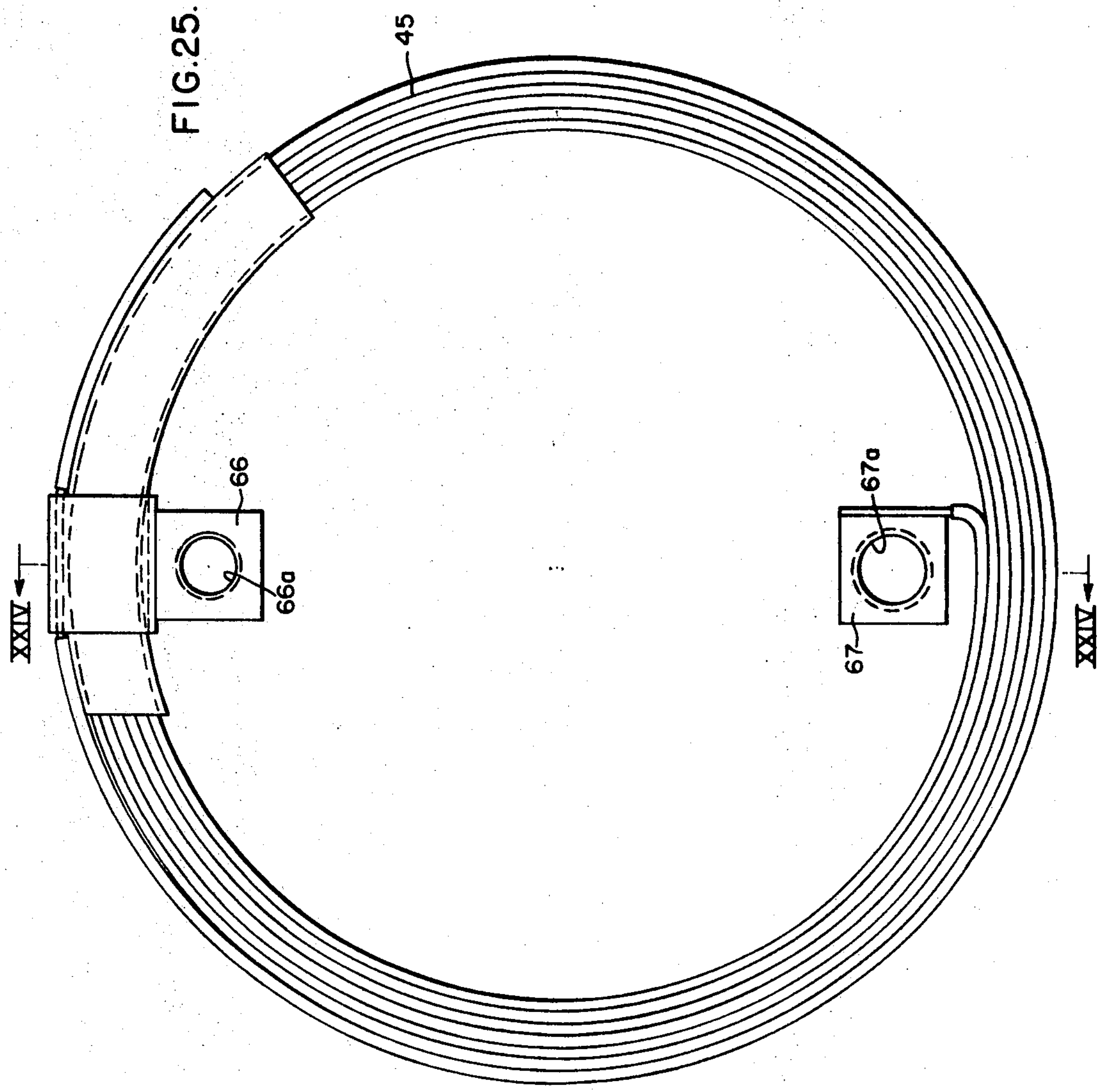

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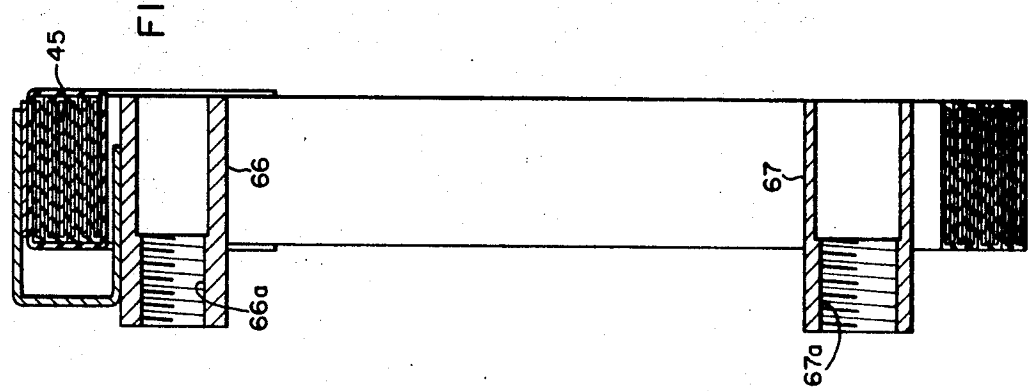

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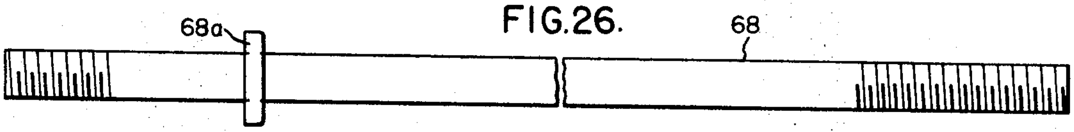

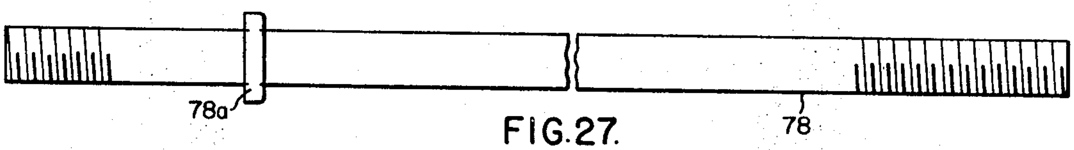

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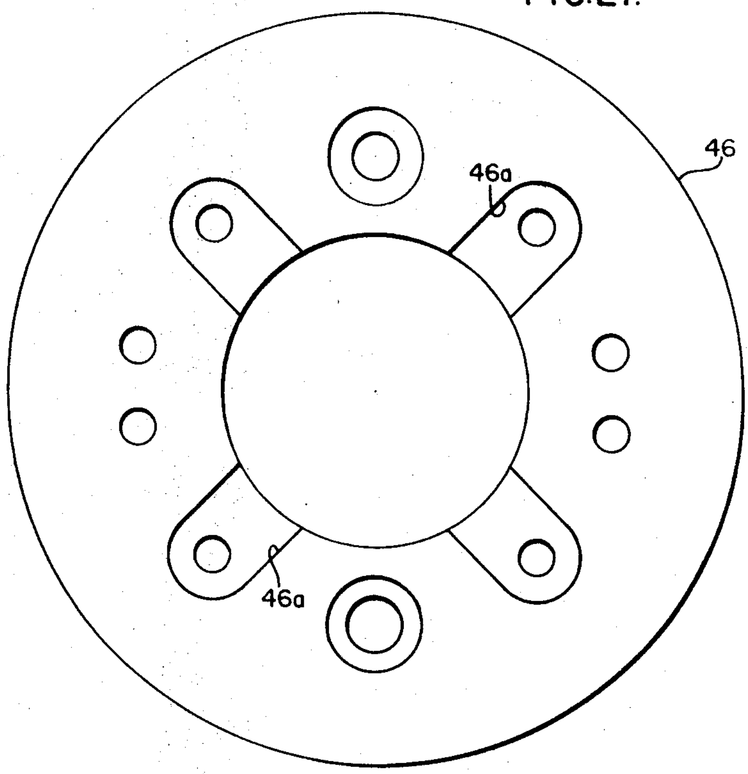

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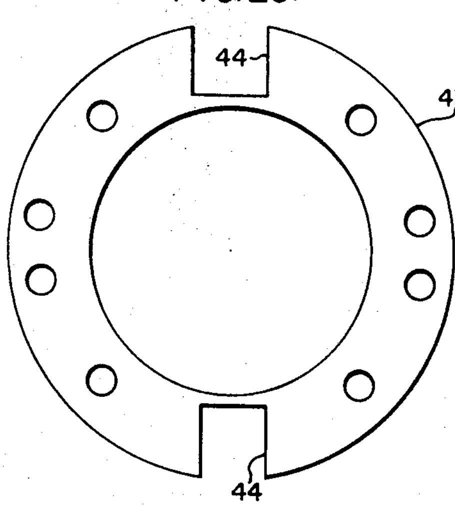

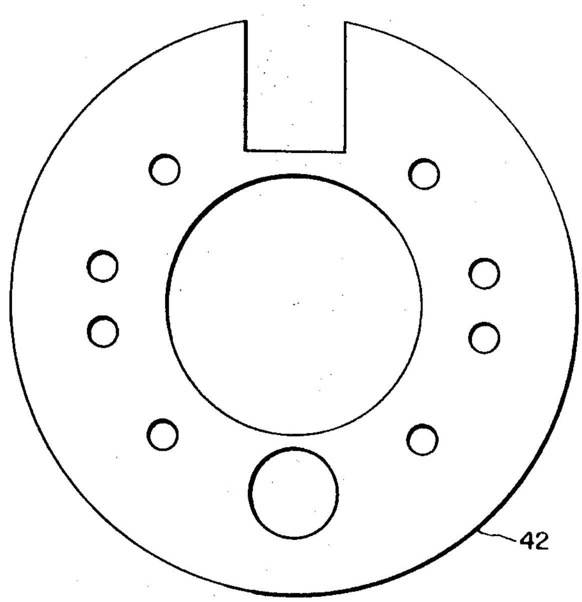

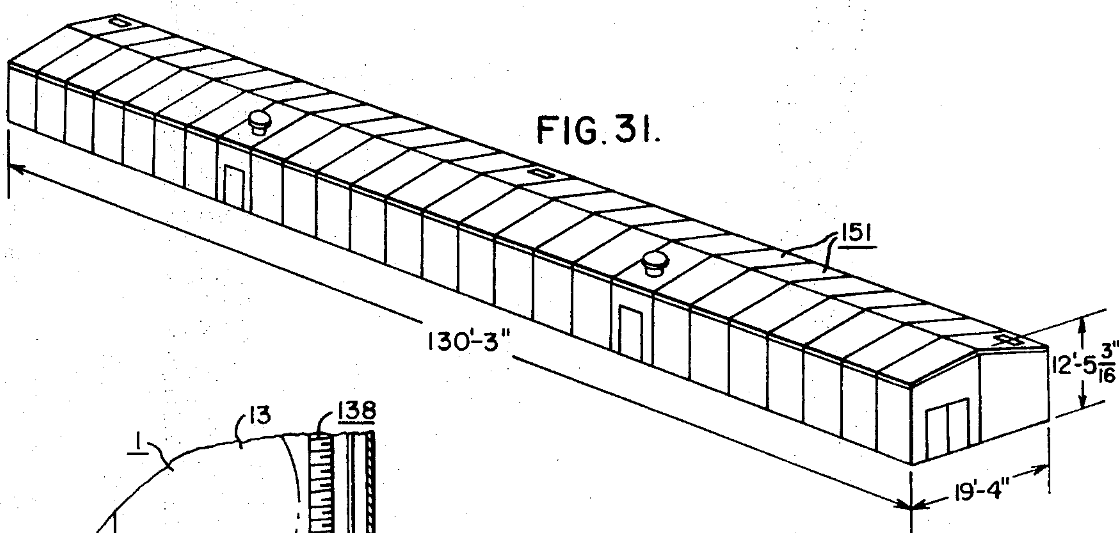

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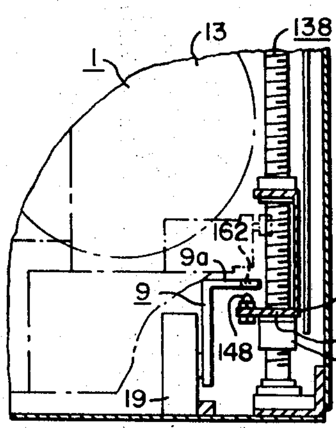

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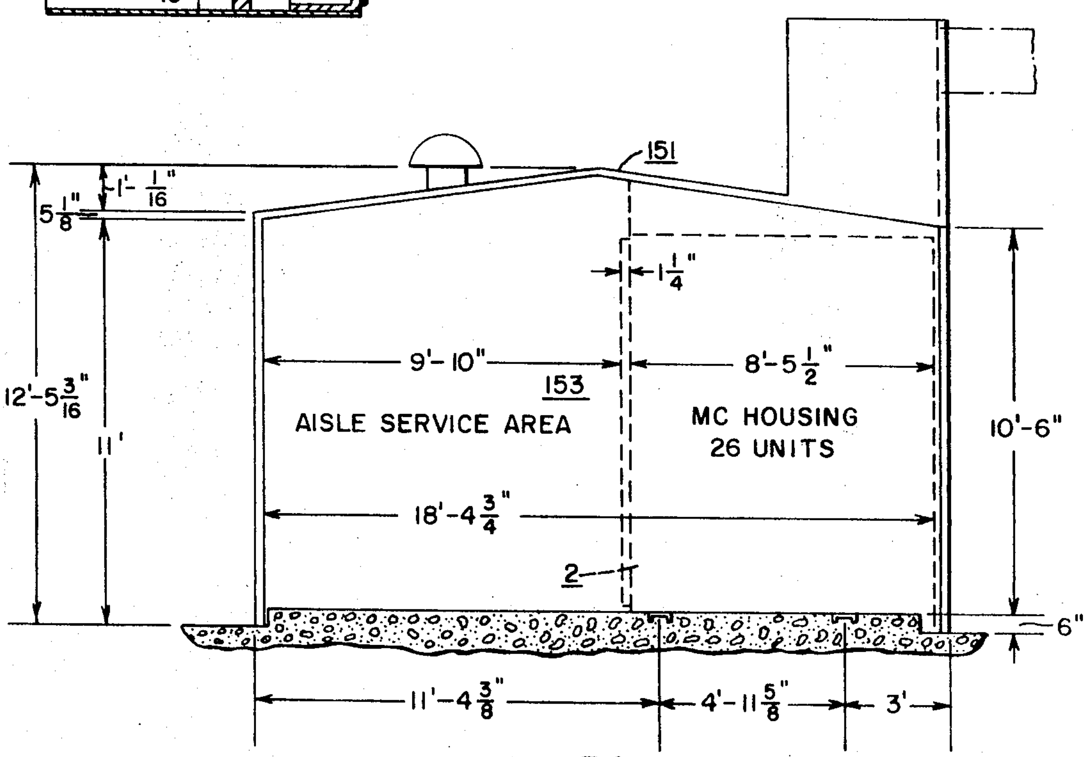

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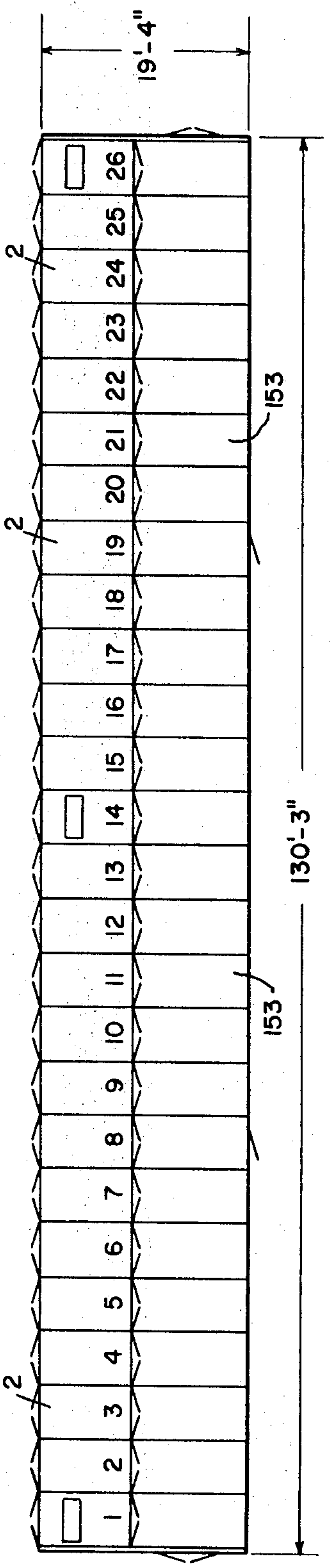
19'-4"
130'-3"
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FIG. 32

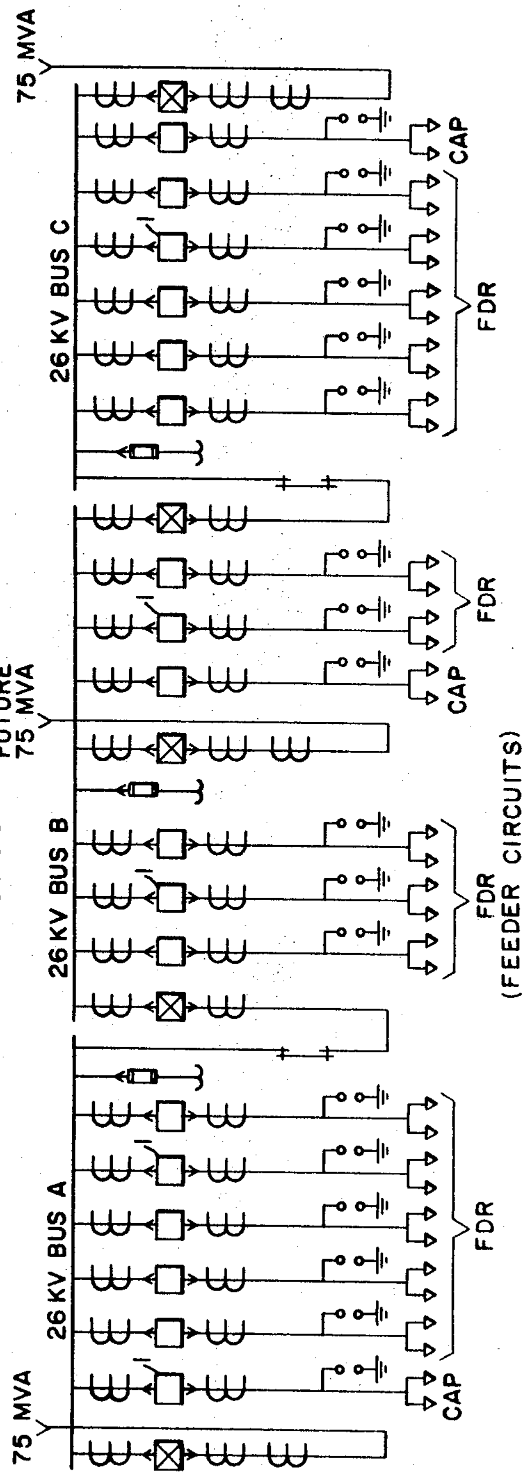
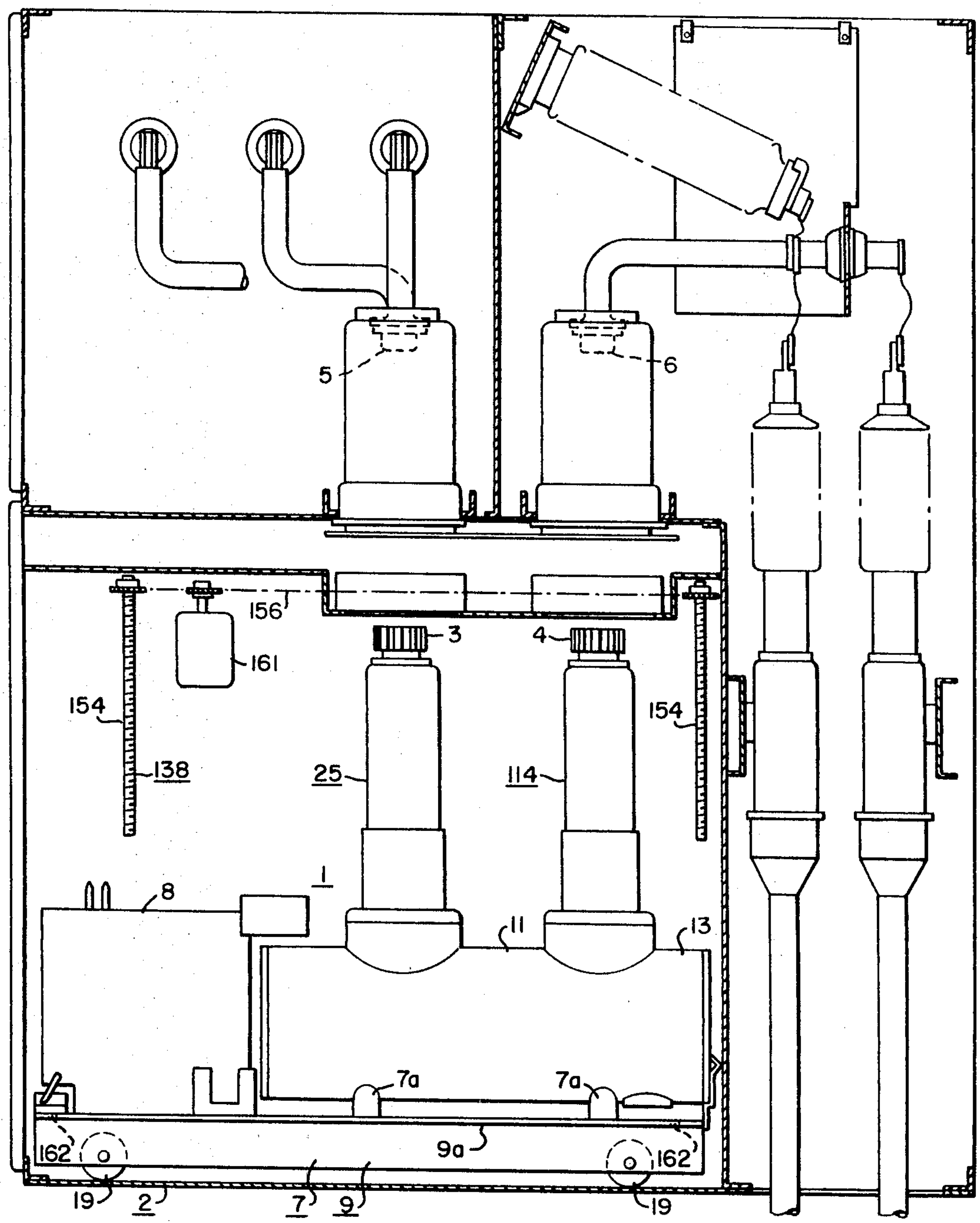

75 MVA
26 KV BUS C
CAP
FDR
FDR
CAP
FUTURE
75 MVA
26 KV BUS B
FDR
(FEEDER CIRCUITS)
26 KV BUS A
FDR
CAP
75 MVA

FIG. 33



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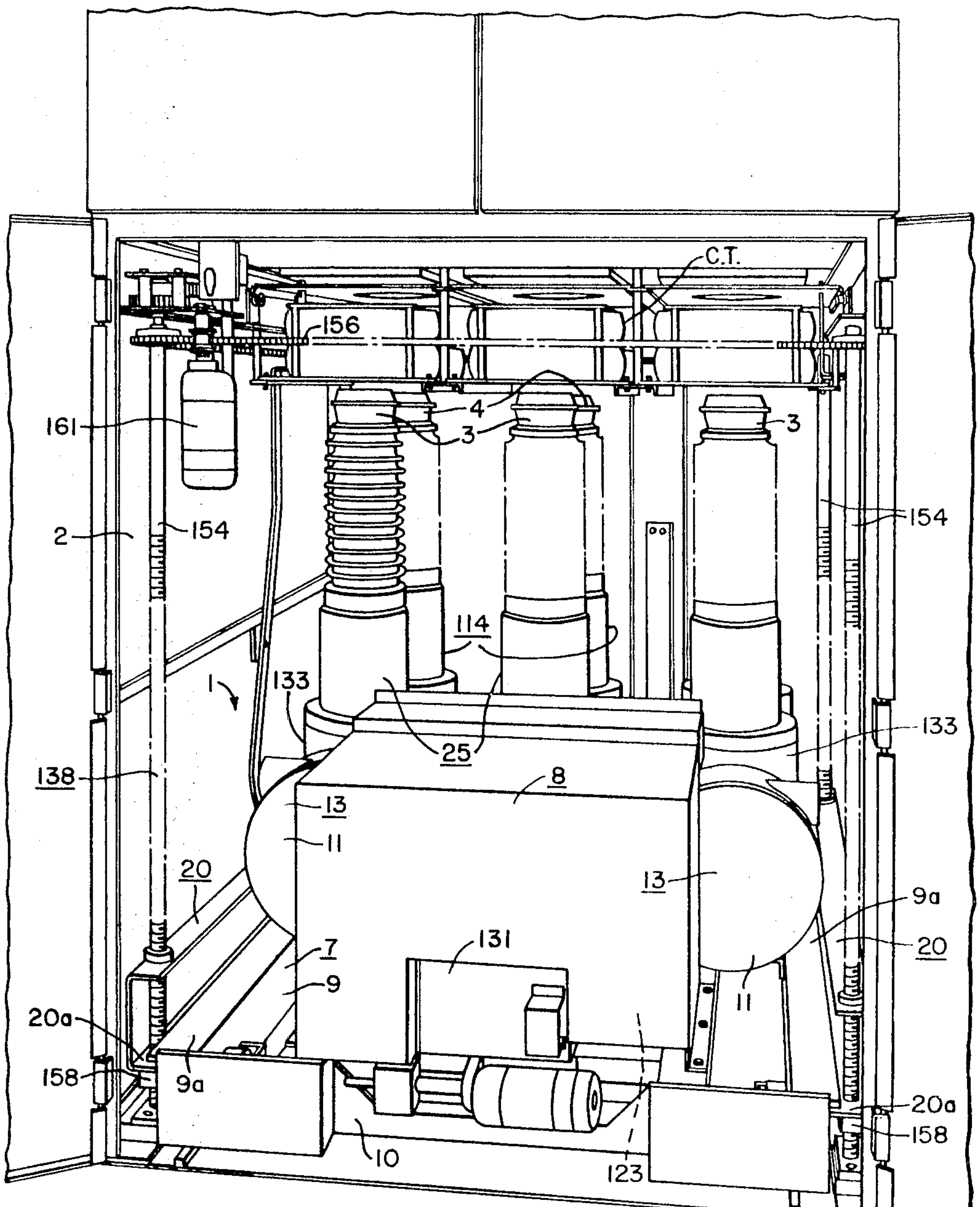
C.T.
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FIG. 37

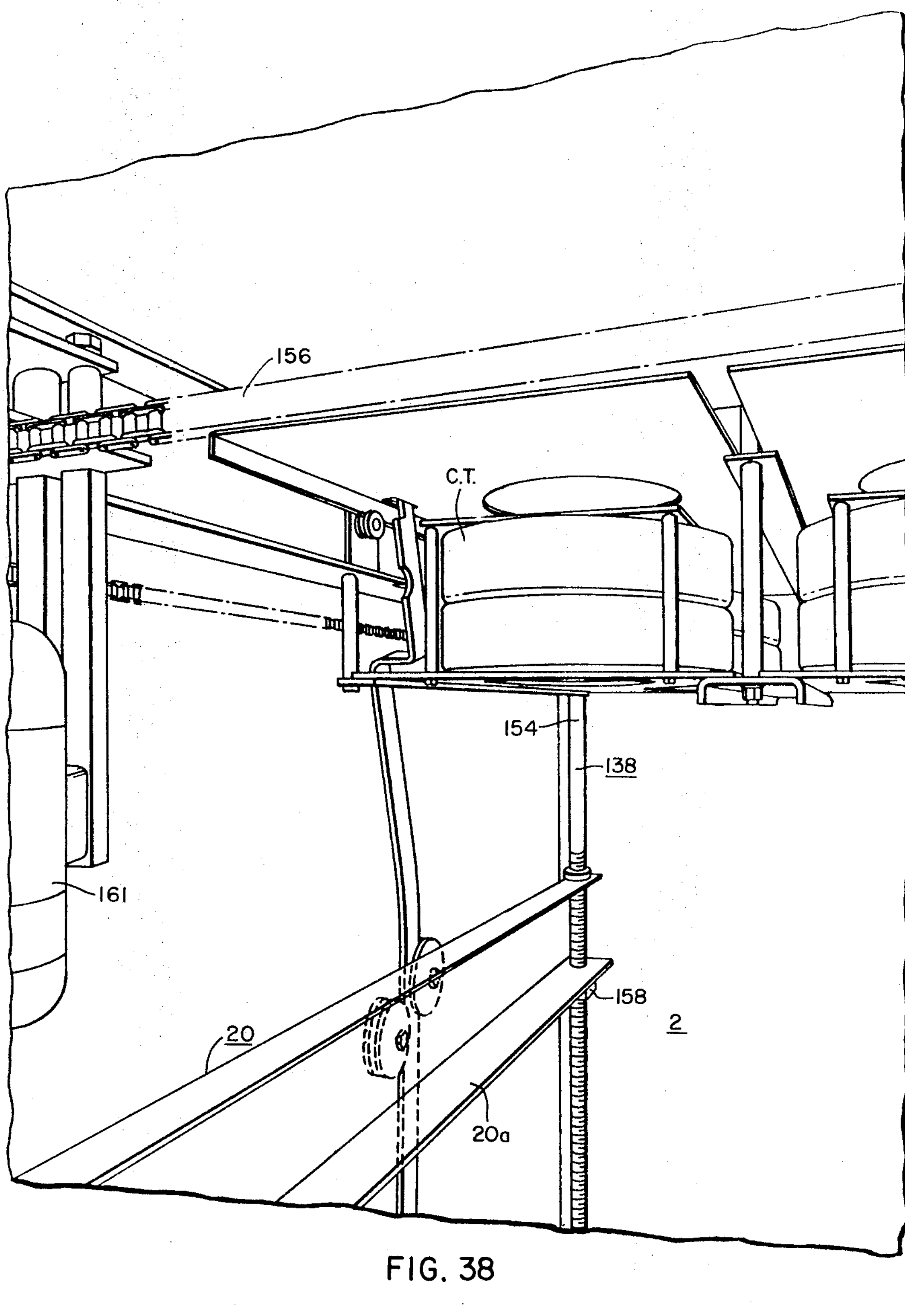

FIG. 38

FLUID-BLAST CIRCUIT INTERRUPTER WITH PISTON ASSEMBLY AND ELECTROMAGNETIC DRIVING MEANS

This invention relates generally to fluid-blast circuit interrupters, and, more particularly, to fluid-blast circuit interrupters of the type having a piston assembly associated therewith for generating fluid under pressure to be forced into the established arc to effect the extinction thereof.

As well known by those skilled in the art, the general trend in metal-clad switchgear over the past decade has been to higher voltages and to higher interrupting ratings. In 1955, approximately 80 percent of the production of a large electrical company was 5 kv. switchgear. In 1965, for example, the same manufacturer accounted for only 47 percent of his total switchgear production in 5 kv. units. In addition to this general trend to higher voltage switchgear, the trend has been to higher interrupting ratings for circuit breakers. Up until 1957, the highest interrupting rating available in metal-clad switchgear was 500 MVA. In that year, the first 750 MVA breakers were made available. In 1958, metal-clad switchgear with 1,000 MVA breakers were made available. Currently, in 1966, 34.5 kv. metal-clad switchgear with breakers having an interrupting capacity of 1,500 MVA are now for the first time available.

The first requirement for any line of switchgear is a reliable circuit breaker. Various types of interrupters have been proposed. However, to increase the voltage and interrupting ratings, it has been proposed to use puffer-type structures. Basically, the puffer concept is not new. It consists essentially of a pair of separable contacts, a piston and a cylinder all mounted in a reservoir containing a suitable arc-interrupting gas. The contacts and piston are mounted in such a way that as the contacts are parted, the piston moves to drive the gas in the cylinder through the arc to interrupt it. Such devices were investigated as long as 20 years ago using the then-available interrupting gases. A moderate degree of success was attained at that time. However, the devices were too inefficient to warrant further development.

The discovery of the ability of sulfur-hexafluoride (SF_6) gas to interrupt an arc gave the puffer interrupter a new boost, and the first commercial application of the puffer interrupter was a load-break disconnecting switch capable of switching load currents at voltages up through a 161 kv. on a single break.

Following this, a series of prototype puffer interrupters were built with the final one being capable of interrupting 50,000 amperes at 22 kv. across a single break. However, the back pressure in the operating cylinder created by the arc required a piston-driving force of 10,000 to 12,000 pounds for interruption of the highest currents. This would require too large a mechanism to make this a practical breaker. At this point in the development period, the discovery was to use a magnetic puffer. This would provide a good interrupter, and the power to operate it would not be too great. It was proposed to use the short circuit current to drive the piston. Experience with magnetic air circuit breakers has shown the tremendous force available from coils carrying fault current. It was proposed to shunt this current into coils and let them do the work of mechanically driving the piston.

A series of calculations was made to determine what force could be obtained from coils carrying high current. The calculations were based on a system of 3—10 inch diameter 10 turn coils arranged for attraction and repulsion over a 7 inch stroke. These calculations showed that a 21,000 ampere short circuit current through these coils would produce a force of 12,100 pounds at the beginning of the stroke. A 42,000 ampere short would produce a force of 48,000 pounds. The discovery was made that here was a means of obtaining the high force required to drive the piston for the circuit interrupter. Accordingly, a general object of the present invention is to provide an improved fluid-blast circuit interrupter having magnetic means serially connected into the electrical circuit, and taking advantage of the short circuit energy to improve the fluid-blast operation of the interrupter.

Another object of the present invention is to provide an improved fluid-blast type of circuit interrupter having improved piston-operated means associated therewith, and electromagnetic driving means to assist in the operation of said piston means.

Another object of the present invention is the provision of an improved fluid-blast circuit interrupter in which a plurality of accelerating coils are used to assist in the operation of the associated piston assembly to more rapidly generate fluid under pressure, which is subsequently ejected into the arcing region to rapidly effect the extinction thereof.

Another object of the present invention is the provision of an improved fluid-blast circuit interrupter having highly effective piston-moving means and fluid-directing means associated therewith.

Still a further object of the present invention is the provision of an improved fluid-blast circuit interrupter of compact size, and operating in a highly efficient manner to quickly generate the required amount of high-pressure fluid, such as gas, and to effectively direct the gas under high pressure toward the established arc to effect circuit interruption.

Still a further object of the present invention is the provision of an improved fluid-blast circuit interrupter having a stationary operating cylinder with a cylinder head closing one end thereof, in which a stationary accelerating coil is positioned, and providing a movable piston assembly carrying the movable contact structure in which a second accelerating coil, which is movable, is carried to assist in the opening and fluid-compressing stroke.

Still a further object of the present invention is the provision of an improved fluid-blast circuit interrupter having more efficient venting means associated with the contact structure to highly effectively direct the generated fluid blasts into the arcing region for most efficient arc extinction.

In U.S. Pat. application filed Sept. 1, 1966, Ser. No. 576,616 now U.S. Pat. No. 3,524,958, issued Aug. 18, 1970 to Russell E. Frink, and assigned to the assignee of the instant application, there is illustrated and described a novel fluid-blast circuit interrupter having piston means associated therewith, which is assisted by an electromagnetic driving means, which is inserted into the series electrical circuit during the opening operation. It is a further object of the present invention to improve the interrupting circuit interrupter of the aforesaid patent application rendering it of highly efficient operation and of compact dimensions.

In U.S. Pat. application filed Sept. 1, 1966, Ser. No. 576,739 now U.S. Pat. No. 3,524,959, issued Aug. 18, 1970 to Russell E. Frink, and assigned to the assignee of the instant application, there is illustrated and described a novel fluid-blast circuit interrupter incorporating piston means assisted by an electromagnetic driving structure including a pair of accelerating coils, and utilizing arcing-horn means to effect arc transfer, and consequent insertion of the two accelerating coils into the circuit during the opening operation. It is a further object of the present invention to improve upon the transfer-arcing means of the aforesaid patent application to provide an improved fluid-blast circuit interrupter of highly efficient operation and operable in a very short span of time, such, for example, as three cycles.

In U.S. Pat. application filed Sept. 1, 1966, Ser. No. 576,707, by William H. Fischer, and assigned to the assignee of the instant application, there is disclosed movable arcing-horn means for effectively inserting electromagnetic means, including a pair of accelerating coils, into the electrical circuit to augment the piston-driving effect of an associated fluid-moving means. It is still a further object of the present invention to improve upon the movable arcing-horn means of the aforesaid Fischer application to provide an improved circuit interrupter of compact and highly efficient construction.

In U.S. Pat. application filed Sept. 1, 1966, Ser. No. 576,583 by William H. Fischer, and assigned to the assignee of the instant application, there is described and claimed a novel fluid-blast circuit interrupter using novel venting-arcing horn arrangements for inserting the electromagnetic means serially into the circuit to assist the piston-driving effort of an associated fluid-moving means for rapid circuit interruption. It is still a further object of the present invention to improve upon the vented arcing-horn means of the aforesaid Fischer application to provide an improved and highly effective circuit interrupter suitable for widespread commercial application.

As well known by those skilled in the art, a fluid-blast circuit interrupter utilizing piston means for fluid-pressure generation, and a subsequent forcing of the fluid under pressure into the established arc, the mechanical effort required of the operating mechanism becomes more severe during the interruption of high-amperage fault currents. If the mechanical driving effort is provided exclusively by the piston-operating arrangement, to accommodate high-current fault interruption, an extremely powerful operating mechanism is required. In an effort to reduce the power requirements imposed upon the associated operating mechanism, it is desirable to provide some means utilizing the energy in the associated electrical circuit to assist the mechanical requirements of the moving piston means during fault-current interruption. By so doing, it results that the power requirements of the operating mechanism may be held to a minimum. In other words, for low, or load-current interruption, the power supplied by the associated operating mechanism may be sufficient in itself to provide the desired piston-driving effort suitable for high-pressure gas generation. On the other hand, during heavy fault-current interruption, a desirable "assist" is provided by the electromagnetic means, as set forth in the present invention, as described hereinafter.

As set forth in U.S. Pat. No. 3,524,958 if a pair of accelerating coils have the windings suitably arranged, there will be an attractive force set up between the two coils. On the other hand, the pair of coils may be so wound as to provide a repulsive force existing between the coils. It is a further object of the present invention to incorporate these attractive and repulsive magnetic forces to assist in the fluid-driving effort of a piston assembly operated in conjunction with a fluid-blast circuit interrupter.

For a particular commercial circuit-interrupting application, rating factors which are required are as follows:

Nominal 3 phase volt-amperes, MVA	1, 500
Rated maximum voltage, KV	38
Rated symmetrical short circuit current at maximum voltage, ka	23
Maximum symmetrical short circuit current, ka	38
Maximum asymmetry factor	1. 2
Rated Interrupting time, cycles	3
1 minute 60 cycle withstand insulation level, KV	80
Impulse withstand insulation level, KV	150
Rated continuous currents, amps	1, 200–3, 000

By incorporating the novel electromagnetic means with the particular positioning and arrangement of the associated elements, it has been possible to meet the stringent requirements, as set forth above.

In accordance with a preferred embodiment of the invention, there is provided a stationary operating cylinder within a surrounding metallic tank structure containing a suitable arc-extinguishing gas, such as sulfur-hexafluoride (SF_6) gas, at a pressure of say 75 p.s.i. One end of the aforesaid stationary operating cylinder is closed by a stationary piston head having a stationary accelerating coil encapsulated therein. Movable longitudinally within the stationary operating cylinder is a movable piston assembly carrying the movable contact structure, the latter comprising an outer main contact and an inner arcing contact insulated from the outer main contact. Associated with the movable piston assembly is a movable accelerating coil. The movable piston assembly is connected through the closed end of the operating cylinder with a movable driving assembly, the latter comprising a movable repulsion coil. A stationary contact assembly is situated adjacent the open end of the stationary operating cylinder. The arrangement is such that during the opening operation the main arc, established between the main contacts, is carried by the gas flow to impinge onto the movable arcing contact to thereby insert serially into the electrical circuit being interrupted the three accelerating coils. Thus, the initial mechanical movement of the movable piston assembly, as supplied by a conventional mechanism, is augmented and assisted by the electromagnetic driving means including a plurality of, such as three, accelerating coils inserted serially into the electrical circuit. This is particularly advantageous during heavy fault-current interruption.

Further objects and advantages will readily become apparent upon reading the following specification taken in conjunction with the drawings, in which:

FIG. 1 is an end elevational view of a three-phase truck-mounted removable circuit-interrupter unit, involving three individual pole-units;

FIG. 2 is a side elevational view of the truck-mounted removable three-phase circuit-interrupting unit illustrated in FIG. 1;

FIG. 3 is a vertical sectional view taken through one of the three pressure tank structures of FIGS. 1 and 2, illustrating the circuit-interrupting element mounted therein, the contact structure being illustrated in the closed-circuit position;

FIG. 4 is a vertical sectional view of the pressure tank taken along the line IV–IV of FIG. 3 looking in the direction of the arrows, the contact structure being illustrated in the closed-circuit position;

FIG. 5 is a considerably enlarged horizontal sectional view taken through the interrupting element of FIG. 3, substantially along the line V–V of FIG. 3, the contact structure being illustrated in the closed-circuit position;

FIG. 6 is a fragmentary view of a portion of the contact structure illustrating the establishment of the main-current arc during the initial portion of the circuit-opening operation;

FIG. 7 is a view similar to that of FIG. 6, but showing the main-current arc as having transferred to the movable arcing contact;

FIG. 8 is a fragmentary view, similar to that of FIGS. 6 and 7, but showing the contact structure in the position at which the transferred arc is about to be interrupted;

FIG. 9 illustrates a vertical sectional view taken through the improved interrupting element of the present invention, the contact structure being illustrated in the closed-circuit position;

FIG. 10 is a diagrammatic view illustrating the accelerating coils with their connections to the contact structure;

FIGS. 11 and 12 show, respectively, in plan, and in vertical section, the supporting spider member secured to the main movable contact tube;

FIGS. 13—15 illustrate views of the supporting rear casting clamp for the rear terminal stud;

FIGS. 16 and 17 illustrate, respectively, side and front views of the movable rear main contact, which is threaded to the rear end of the main movable contact tube;

FIG. 18 is a vertical sectional view taken through the movable piston assembly with the contact structure omitted, and illustrating the terminals for the movable accelerating piston coil and the insulating nozzle member;

FIGS. 19 and 20 illustrate, respectively, in vertical section, and in end elevational view, the end moving driving accelerating, or repulsion coil for the interrupting element;

FIGS. 21 and 22 illustrate, respectively, in vertical section, and in end elevation, the stationary accelerating cylinder-head coil, which is fixedly secured in the end of the operating cylinder to close the same at one end;

FIG. 23 is an end elevational view of the stationary conducting supporting casting, which is clamped to the terminal stud of the front terminal bushing;

FIGS. 24 and 25 are, respectively, vertical sectional views and end elevational views of the piston accelerating coil;

FIG. 26 is a side elevational view of the upper connecting rod for the movable piston assembly;

FIG. 27 is a side elevational view of the lower connecting rod for the movable piston assembly;

FIG. 28 is an end elevational view of the movable piston member;

FIG. 29 is an end elevational view of the insulating spacer element disposed interiorly of the movable piston accelerating coil;

FIG. 30 is an end elevational view of the front insulating clamping plate for the movable piston assembly;

FIG. 31 is a perspective view of a substation for housing, for example, 34.5 kv. outdoor metal-clad switchgear for controlling transformer and feeder circuits;

FIG. 32 is a diagrammatic plan view of the substation of FIG. 31 illustrating the multiplicity of metal-clad switchgear cells disposed in contiguous relationship, and fronting on an operating aisle;

FIG. 33 is a diagrammatic view of the transformer, bus, capacitor and feeder circuits to indicate the functioning of the cell units of FIG. 32;

FIG. 34 is an end elevational view of the metal-clad switchgear units of FIG. 32, indicating the aisle service area and the space occupied by the 26 cell units;

FIG. 35 is a sectional view taken through one of the cell units illustrating the elevating mechanism for providing vertical travel of the individual removable circuit-interrupting units, the figure showing the circuit-interrupting unit in the lowered disconnected position;

FIG. 36 is a fragmentary vertical sectional view illustrating the engaging portions of the frame of the removable circuit-interrupting unit and the lifting channel members vertically movable within the cell structure; and,

FIG. 37 is a perspective view looking into the interior of the breaker compartment of the cell structure with the circuit breaker in the lowered disconnected position; and,

FIG. 38 is a fragmentary perspective view of the cell structure.

Referring to the drawings, and more particularly to FIGS. 1 and 2 thereof, the reference numeral 1 indicates a three-phase truck-mounted fluid-blast circuit interrupter unit of the type which may be rolled into an associated cell structure 2 (FIG. 35). As well known by those skilled in the art, in metal-clad switchgear equipment it is customary to have cells or cubicles 2, as shown in FIG. 35, into which are rolled removable interrupting unit equipment 1.

In more detail, with reference to FIG. 2, a frame assembly 7 is provided to support the circuit breaker 1 on support bosses 7*a* welded to the underside of the tanks. The frame assembly 7 is welded up from structural steel sections 9, 10. Rollers 19 are provided to facilitate operative movement into and out of the cooperable cell structure 2.

In the movable switchgear interrupting equipment 1, set forth in FIGS. 1 and 2, after the equipment is rolled into the associated cubicle structure 2, suitable means are provided to effect a vertical upward movement of the entire equipment on vertically movable rails 20, (FIG. 37) as hereinafter discussed, so that the main movable disconnecting contacts 3, 4 may contactingly engage an associated pair of spaced stationary disconnecting contacts 5, 6 (FIG. 35), which are supported by the cubicle, or cell structure 2.

The present invention is particularly concerned with the interrupting structure of the equipment illustrated in FIGS. 1 and 2. It will be noted that, generally, there is provided an operating mechanism compartment, generally designated by the reference numeral 8, and three heavy metallic tanks 11, which enclose the respective interrupting elements 12 associated with each pole-unit 13. Disposed within each of the three-tank structures 11 is the interrupting assembly, generally designated by the reference numeral 12, and comprising a stationary insulating operating cylinder 14 having one end 15 thereof open, and having the other end 16 thereof closed by a base portion 17, the latter including a stationary accelerating coil 18 embedded in a suitable plastic 21, for example, epoxy resin, as shown in FIG. 21.

The front end 14*a* of the stationary operating cylinder 14 is supported, as by bolted connections, to four bosses 22, (FIG. 4) the latter being welded interiorly of the tank structure 11. Extending downwardly through an opening 23 provided adjacent the front end 14*a* of the stationary operating cylinder 14 is a line-terminal stud 24, which extends upwardly through the front terminal bushing 25 of each pole-unit 13. The terminal stud 24 is clamped to a stationary conducting supporting casting, generally designated by the reference numeral 26, and shown more clearly in FIGS. 3 and 23 of the drawings.

With reference to FIGS. 5 and 9 of the drawings, it will be noted that the stationary support casting 26 has a clamping portion 26*a* of bifurcated construction, which clamps by bolts 27 to the lower interior end of the terminal stud 24 extending through the front terminal bushing 25 of the device. In addition, the stationary casting 26 has a spider portion 26*b* with an integrally formed support ring 26*c*, which is bolted as at 28 (FIG. 9) to the stationary operating cylinder 14. Moreover, the stationary conducting casting 26 has a threaded supporting portion 26*d*, which adjustably threadedly secures a stationary contact assembly, generally designated by the reference numeral 31 (FIG. 5). With reference to FIG. 9, it will be observed that once the proper adjustment of the stationary contact structure 31 is obtained, clamping bolts 32 may be tightened, and the structure is then rigid.

As shown in more detail in FIGS. 5 and 9 of the drawings, the main stationary contact assembly 31 comprises a main stationary contact 33 of generally tubular configuration, and having a plurality of flexible main contact fingers 33*a* formed at the right-hand end thereof. Disposed interiorly of the tubular main contact structure 33 is a conducting metallic arcing nozzle member 34, which is fixedly secured, as by brazing at 35, to the interior of the outer main contact tube 33 up against a shoulder portion 33*b* (FIG. 5) thereof. Both the main flexible contact fingers 33*a* and the nozzle arcing member 34 have arc-resisting tip portions of a suitable arc-resistant metal, such as copper-tungsten or silver-tungsten alloys.

Movable lengthwise of the stationary operating cylinder 14 is a movable piston assembly 36 carrying a movable contact structure 37. As shown more clearly in FIGS. 3, 4 and 5 of the drawings, a pair of insulating operating links 41 cause the rightward opening movement of the movable piston assembly 36 carrying therewith the movable contact structure 37.

The movable piston assembly 36 (FIG. 5) includes an annular insulating clamping plate 42 (FIG. 30), an annular insulating spacing plate 43 having notches 44 provided therein, as shown in more detail in FIG. 29, to accommodate a moving first accelerating piston coil 45 shown in FIGS. 24 and 25. In addition, the moving piston assembly 36 includes an insulating annular piston plate 46 (FIG. 28) having an outer peripheral groove 47, in which a piston ring 48 is inserted to prevent the escape of compressed gas 51 out of the region 52 of the operating cylinder 14 and around the outer periphery of the piston assembly 36. As mentioned previously, the right-hand base end 16 of the operating cylinder 14 is closed by the annular head 17. As a result, gas within the region 52 is compressed, and is forced to flow in a leftward direction through a movable insulating nozzle member 53, which is clamped between the two insulating plates 42, 46 and interiorly of the insulating spacing member 43. See FIG. 5 in this connection.

The left-hand end 53*a* of the movable nozzle member 53 constantly slides upon the outer surface of the main tubular contact 33, and assists the guiding motion of the piston assembly 36, as well as providing the desired flow for the compressed gas past the separable contact structure 31, 37. FIGS. 6—8 generally show the flow path for the compressed fluid 51, as indicated by the arrows 54.

As shown in more detail in FIG. 5 of the drawings, the insulating links 41 have pivotal connections, by means of pivot pins 55, to bifurcated members 56, the latter being bolted by bolts 57 extending through the three insulating members 42, 43 and 46. In addition, with reference to FIGS. 11, 12 and 5, it will be noted that the main tubular movable contact 58 has a supporting spider 61 (FIGS. 11 and 12) fixedly secured thereto, as by brazing at 62, and the support spider 61 has holes 63 in the radially outwardly extending arms 64 thereof, through which extend supporting bolts 65, which additionally clamp the insulating plates 42, 43 and 46 together.

The movable first accelerating coil 45 has a configuration configuration more clearly shown in FIGS. 24 and 25, and has a pair of terminal lugs 66, 67 having threaded openings 66*a*, 67*a* therethrough. The first accelerating coil 45 is wound of heavy copper strap, for example, with the outer terminal lug 66 thereof electrically and mechanically connected to an upper conducting guide and piston rod 68 (FIG. 26), which extends through an aperture 71 (FIG. 21) in the cylinder head 17, and is electrically connected, by a bolted connection 72 (FIG. 9), to one terminal end 73 (FIG. 20) of a movable repulsion third coil 74 encapsulated in a driving unit 75 (FIG. 19) secured to the right-hand extremity of the movable contact structure 37, the latter comprising the outer tubular main contact tube 58 and an inner arcing tube 76 insulated therefrom, as shown in FIG. 5.

As will be more fully brought out hereinafter, the two first and second accelerating coils 18, 45 are so wound that they magnetically attract each other, whereas the second and third accelerating coils 18, 74 are so wound as to magnetically repel each other. The net result is a magnetically assisted opening fluid-driving motion of the piston assembly 36, as accelerated by the driving unit 75.

The other terminal 77 (FIG. 20) of the movable driving repulsion coil 74 is electrically connected to the inner arcing contact 76, which has a tubular configuration, as more clearly illustrated in FIG. 5.

With reference to FIG. 9 of the drawings, it will be noted that the terminal lug 67 connected to the inner strap of the movable accelerating coil 45 has a threaded connection 67*a* (FIGS. 18 and 24) to a relatively large conducting guide rod 78 (FIG. 27), which is bolted to the piston assembly 36 by a nut 81 (FIG. 9) so as to make metal-to-metal contact with terminal 67 of piston coil 45.

The right-hand end 78*a* of the relatively large conducting guide rod 78 extends through an opening 82 (FIG. 22) provided in the head 17 of the operating cylinder 14, and moves in sliding relationship with a tubular sliding contact 83 (FIG. 9). This sliding contact construction 83 shown more clearly in FIG. 9, is of ball construction, and is set forth in detail and claimed in U.S. Pat. application filed Oct. 13, 1965, Ser. No. 495,475, now U.S. Pat. No. 3,301,986, issued Jan. 31, 1967 to Russell E. Frink and assigned to the assignee of the instant application.

The right-hand end of the relatively large guide rod 78 is fixedly secured by bolts 84, 85 to an insulated portion 86 (FIGS. 9 and 20) of the moving driving unit 75. Reference may be had to the diagrammatic view of FIG. 10 for assistance in understanding the electrical connections to the three accelerating coils 18, 45 and 74.

The inner tubular arcing contact 76 has an arc-resisting tip portion 76*a*, which is fixedly secured to the left-hand extremity thereof, as by brazing. Additionally, the tubular arcing contact 76 has a support ring 88 brazed thereto, which serves to seat a split insulating spacing member 91, which serves to insulate the left-hand end of the inner tubular arcing contact 76 from the outer tubular main contact 58. Also the right-hand end of the inner movable tubular arcing contact 76 has a tubular threaded insert 92 fixedly secured thereto, as by brazing. An insulating washer 93, together with a pair of clamping nuts 94, 95, serves to support the electrical strap connection 96 to the moving driving coil 74 and also to fixedly and insulatingly support the inner arcing tube 76 from the outer main contact tube 58.

Threadedly secured to the right-hand end of the main contact tube 58, as at 97 is a rear secondary main contact structure, generally designated by the reference numeral 98. The rear secondary movable main contact structure 98 assumes the form of a casting, shown in FIGS. 16 and 17, and has a pair of movable secondary main contacting portions 101, of wedge configuration, which mate with two sets 102 (FIG. 5) of flexible main stationary secondary contact fingers 103, which are secured to downwardly extending arms 104 of a rear secondary contact support casting 105, shown in more detail in FIGS. 13—15 of the drawings.

The stationary second accelerating coil 18 has one terminal lug 106 (FIG. 21) thereof, as mentioned, making sliding electrical contact with the lower conducting guide rod 78, and has a pair of terminal lugs 107, 108 electrically connected to the outer strap 18*a* thereof making threaded supporting and electrical connection by a pair of bolts 111 (FIG. 15), which extend through the two mounting holes of the rear supporting casting 105 of the device.

The rear support casting 105 has a laterally extending bifurcated clamping portion 112 (FIG. 13), which embraces the rear terminal stud 113 extending upwardly through the rear terminal bushing 114 of the interrupting unit 1. As shown in FIG. 3, the rear support casting 105, by securement to the cylinder head 17, serves additionally for the entire support of the right-hand end of the operating cylinder 14, as viewed in FIG. 3.

With reference to FIGS. 3 and 4 of the drawings, it will be noted that a crankshaft 115 is pivotally connected, as by means of pivot pins 116, to each of the two insulating operating links 41. The crankshaft 115 is pinned so as to rotate with a drive shaft 117, one end of which is journaled in a bearing 118 (FIG. 4) provided internally of the tank structure 11. The other end of the drive shaft 117 extends through a seal 121 externally of the tank structure, and has welded thereto, at the outer extremity thereof, a crank arm 122, which is connected to the operating mechanism 123 disposed within the mechanism compartment 8. The operating mechanism 123 may be of any suitable type. Preferably, however, there is employed a spring-stored-energy operating mechanism of the type set forth in U.S. Pat. No. 3,183,332 issued May 11, 1965 to Russell E. Frink and Paul Olson and assigned to the assignee of the instant application.

With reference to FIGS. 3 and 4 of the drawings, it will be observed that counterclockwise rotative motion of the external crank arm 122 and drive shaft 117 will effect rightward opening fluid-driving motion of the piston assembly 36, as viewed in FIGS. 3 and 5. This mechanical movement, as brought about by the operating mechanism 123, causes a flow of compressed gas from the region 52 past the spider 61, and through the orifice opening 124 provided in the insulating nozzle member 53. This gas flow serves to transfer the main current arc 125, which is initially established between the separable main contacts 33*a*, 58 across the insulating spacer 91 to be successively carried to positions illustrated in FIGS. 7 and 8 of the drawings. Since the rightward opening movement of the piston assembly 36 also causes separation of the rear movable secondary main contacts 101 away from the rear stationary secondary main contacts 103, there occur two breaks in the electrical circuit, as illustrated in FIG. 10 of the drawings. Since the arc voltage at the two breaks builds up, and since the resistance through the parallel circuit, including the accelerating coils 18, 45 and 74, offers less impedance, the arc 125 transfers to the separable arcing contacts 34, 76, and thereby inserts the three accelerating coils serially into the electrical circuit. Fig. 8 illustrates the arc location at the time when the accelerating coils are in series circuit, and at a time when the gas flow is about to effect final arc extinction. Continued opening movement inserts an isolating gap into the circuit, as indicated by the dotted lines 126 in FIG. 5.

From the foregoing description, it will be observed that there is provided a first piston coil 45, a stationary second coil 18, and a moving repulsion third coil 74, all of which are inserted electrically into the circuit by an interrupting break and an auxiliary secondary break, with reference being had to FIG. **10** in this connection.

Certain broad features of the electromagnetic means which is used in the present invention are set forth and claimed in U.S. Pat. application, filed Sept. 1, 1966, Ser. No. 576,616, now U.S. Pat. No. 3,524,958 issued Aug. 18, 1970 to Russell E. Frink, and assigned to the assignee of the instant invention. Additionally, certain features of the contact and nozzle construction are set forth and claimed in U.S. Pat. application, filed Sept. 1, 1966 Ser. No. 576,711, now U.S. Pat. No. 3,529,108 issued Sept. 15, 1970 to Robert M. Roidt, and assigned to the same assignee. The concept of having opposite venting through both the stationary contact structure and the movable tubular arcing contact to maintain the arc terminals thereon is set forth and claimed in U.S. Pat. application filed Sept. 1, 1966 Ser. No. 576,583 by William H. Fischer, and assigned to the assignee of the instant application. The broad concept of using an arcing horn to insert the accelerating coils **18, 45** and **74** into the circuit is set forth and claimed in U.S. Pat. application filed Sept. 1, 1966 Ser. No. 576,739, now U.S. Pat. No. 3,524,959, issued Aug. 18, 1970 to Russell E. Frink, and assigned to the assignee of the instant application.

Although various suitable arc-extinguishing fluids may be used, it is preferred to use a highly efficient arc-extinguishing gas, such as sulfur-hexafluoride (SF) gas, at a pressure of say 75 p.s.i., for example. Suitable gas-pressure measuring equipment **127** (FIG. **1**) is provided within the mechanism compartment **8**, so that an alarm circuit may be actuated upon an unduly low-pressure decrease within the tanks. However, the circuit interrupter may lose down to 40 p.s.i. before difficulty is encountered.

OPENING OPERATION

When the circuit interrupter unit 1 is closed, the current path is from the front terminal bushing **25**, to the front support casting **26**, to the tubular stationary contact **33**, to the tubular moving contact **58**, to the movable T-shaped contact member **98**, to the rear stationary auxiliary contact fingers **103**, to the rear stationary terminal casting **105** (FIG. **15**), and to the rear terminal bushing **114** stud **113** of the rear terminal bushing.

When the circuit breaker is opened, the movable piston assembly **36** is moved to the right by the operating mechanism **123**, compressing the gas within the space **52** of the operating cylinder **14**, and drawing arcs **125, 128** (FIG. **10**) between the left-hand main contacts *33a*, **58** and between the contacts **101** of the movable T-shaped contact member **98** and the stationary contact fingers **103** on the right-hand end of the interrupting element **12**. These arcs are paralleled by the three accelerating coils **18, 45**, and **74**, and since the three accelerating coils form a lower impedance path, the current quickly transfers to the accelerating coils. The current path is now from the stationary arcing contact **34**, through the arc **125** to the moving tubular arcing contact **76**, through the strap connector **96** at the right to the "driver" or third coil, **74** to the upper guide rod **68**, to the first piston coil **45**, to the lower guide rod **78**, to the sliding ball contact **83**, to the second cylinder coil **18** and to the rear terminal casting **105**. The three accelerating coils are so wound so that the movable piston coil **45** is attracted by the stationary cylinder coil **18**, and the "driver" coil **74** is repelled by it. This magnetic attractive and repulsive action provides a powerful "assist" to the moving piston **36** in driving gas through the main arc **125** and accomplishing its interruption. Tests show that for a maximum fault level, approximately 10 percent of the driving energy is supplied by the operating mechanism **123**, and 90 percent by the three accelerating coils **18, 45** and **74**.

The following table indicates the remarkable interrupting performance of a three-phase model. Tests were made at 38 kv. and 22 kv., and with an ungrounded neutral, and at maximum settings.

With reference to FIGS. **1** and **2** of the drawings, it will be noted that there is provided a pressure-control panel assembly **131**. It consists of a pressure gauge, a filling valve, and a pressure switch. From this assembly there is a manifold connecting to the tanks **11** of the three interrupting pole-units **13**. The pressure switch is arranged to provide an alarm if the gas pressure leaks off, the alarm being provided before the lower limit for fault interruption is reached. At the lowest pressure limit, the switch will operate to trip the breaker and lock it out. The switch is temperature compensated.

Each pole-unit assembly **13** includes the grounded metallic tank **11** with a pressure-release rupture disc **132** (FIG. **3**) mounted in the bottom of the tank **11**. It is placed at the bottom of the tank **11** so that if it operates, the fragments will be directed toward the floor. As shown, the top of each tank **11** has two flanges **133** (FIG. **2**) to which the bushings **25, 114** are bolted.

In fluid-blast circuit interrupters of the piston-operated, or "puffer" type, the operating mechanism has, in the past, been required to supply the energy requirements to interrupt high currents. However, pressure in the cylinder from the back pressure of the arc made the mechanism power, required to drive the piston, so excessive as to make the designs uneconomical. The interrupting assembly of the present invention, which has been described above, uses coils of 6½ turns each, for example, creating approximately 90 percent of its driving energy by a magnetic interaction of the accelerating

	Test voltage, kv.	Internal currents-symmetrical			Internal currents-asummetrical			Internal time cycles
		$\phi1$	$\phi2$	$\phi3$	$\phi1$	$\phi2$	$\phi3$	
Test Number:								
2-50244AL	38	1,050	1,065	990	1,170	1,275	1,050	2.70
2-50244AM	38	1,050	1,080	975	1,050	1,200	1,200	2.20
2-50244AN	38	2,100	2,130	1,980	2,130	2,480	2,580	2.60
2-50244AO	38	4,300	4,300	4,050	4,300	5,150	5,150	2.55
2-50244AP	38	8,420	8,500	8,100	8,500	9,820	9,900	2.55
2-50244AQ	38	12,150	12,000	11,550	12,150	13,950	13,050	2.57
2-50244AR	38	(1)	(1)	(1)	(1)	(1)	(1)	(1)
2-50244AS	38	11,550	11,700	11,550	12,450	12,150	13,650	2.60
2-50244AT	38	13,500	19,000	12,250	14,000	19,350	13,750	2.65
2-50244AU	38	18,500	16,500	18,250	20,000	19,500	20,750	2.63
2-50244AV	38	22,350	21,500	21,500	25,000	22,000	25,000	2.62
2-50244AW	38	24,200	23,750	22,750	26,200	24,500	30,250	2.70
2-50244AX		(2)	(2)	(2)	(2)	(2)	(2)	(2)
2-50244AY	22	1,740	1,830	1,710	1,860	1,830	2,550	2.18
2-50244AZ	22	7,900	8,100	7,800	11,380	8,320	10,000	3.20
2-50244BA	22	1,710	1,860	1,710	2,700	1,890	2,400	2.15
2-50244BB	22	7,900	8,000	7,820	11,400	8,300	9,980	3.05
2-50244BC	22	15,800	16,550	15,800	23,150	17,200	19,300	2.55
2-50244BD	22	23,100	23,900	23,100	30,600	24,000	27,900	3.18
2-50244BE	22	25,900	26,700	25,900	30,900	27,000	30,000	2.95
2-50244BF	22	28,000	29,700	28,800	33,000	29,700	32,900	2.55
2-50244BG	22	32,100	32,400	32,400	29,200	32,800	35,600	2.50
2-50244BH	22	32,900	34,800	33,600	39,800	34,800	37,500	2.50
2-50244BI	22	34,400	35,600	34,800	44,000	35,600	42,000	2.55
2-50244BJ	22	37,300	37,800	37,400	50,400	37,800	49,300	2.68

[1] No test—breaker not tripped.
[2] No load timing test.

coils when interrupting currents of the order of 40,000 amperes. A three-phase model has, in fact, interrupted over 50,000 amperes, and this was not its limit.

In addition to the basic interrupting ability of the puffer-type circuit interrupter described above, there are several other advantages to this type of interrupter. First of all, since the interruption is in an atmosphere of SF_6 gas, there is complete freedom from fire hazard. Secondly, since the interruption takes place inside a sealed pressure vessel, there is virtually no interruption noise. As described above, the contacts for the breaker operate in a sealed chamber filled with sulfur-hexafluoride (SF_6) gas at 75 p.s.i. for example. A separate chamber is provided for each phase, and the piston, magnetically driven by the fault current in the circuit, forces the high-velocity stream of gas through the arc stream and extinguishes the arc **125** in 1½ cycles, or less. Experience has indicated little or no decrease in interrupting ability down to 30 p.s.i. gas pressure. At atmospheric pressure, the breaker will maintain its insulation value and will safely interrupt load currents at rated voltage. Sulfur-hexafluoride (SF_6) gas has proved to be remarkably inert, with excellent interrupting and insulating properties. Chemically, sulfur-hexafluoride (SF_6) gas is one of the most stable compounds, and, in the pure state, or under normal service conditions, is inert, nonflammable, nontoxic, and odorless.

As pointed out above, the interruption takes place in SF_6 gas, stored under pressure in a metal tank. Gas flow for interruption is provided by the magnetically assisted piston, and no separate tanks, external piping compressors, or blast valves are required. Also, with the SF_6 gas at a nominal pressure of 75 p.s.i. the gas does not liquify at the temperatures that will be experienced in operation, and there is no need for auxiliary heaters. Experience has shown that there is little deterioration of the gas with repeated interruptions, which eliminates the need for its reconditioning, as would be necessary with oil as the interrupting medium.

Internal insulation is furnished by the SF_6 gas, with sufficient striking distances to withstand operating voltage at atmospheric pressure. The gas also insulates the bushings.

As shown in FIGS. **35** and **37**, the circuit-breaker unit **1** may be lifted from the disconnect, or test position, to the connected position by a motor-operated four-screw elevating mechanism **138** mounted in the stationary cell structure **2**. Guide pins **148** (FIG. **36**) will ensure proper location of the breaker unit **1** upon the elevating mechanism **138**, and will ensure alignment of the primary and secondary contacts **3**, **5** and **4**, **6** (FIG. **35**). Each stationary section includes a control station, limit switches and line within electrical interlock to prevent operation of the raising and lowering mechanism when the control jumper is in place. In addition, each circuit-breaker unit **1** is equipped with a mechanical interlock, which prevents raising or lowering the breaker in the stationary structure **2** without tripping open the breaker. The circuit-breaker unit **1** cannot be closed when the circuit-breaker unit is at any point between the connected and the test positions.

As shown in FIGS. **36** and **37**, the removable circuit breaker unit **1** is raised to the engaged position by four jackscrews **154** in the corners of the cell **2**. These jackscrews **154** are coupled together by a roller chain **156** (FIG. **38**) around the top of the cell **2**. The lower ends of the jackscrews **154** engage nuts **158** (FIG. **37**), which lift the two channel-shaped members **20**, which, in turn, lift the breaker unit **1** to the engaged position. Both the up and down position of the removable circuit-breaker unit **1** are controlled by limit switches, which cut off the motor **161** (FIG. **37**) when the breaker is in the correct position.

The lifting frame assembly **138** comprises a pair of parallel-disposed lifting rails **20** of channel-shaped configuration which extend completely lengthwise of the breaker cell **2** as shown more clearly in FIG. **37**. The lower inwardly extending flange **20*a*** underlies the flange **9*a*** of the steel section **9**, as shown in FIG. **36**, with the spaced guide pins **148** on the rails **20** centering in holes **162** (FIG. **36**) disposed adjacent the ends of each steel angle section **9**.

In the perspective view of FIG. **31**, illustrating a multiplicity of such units, the circuit-breaker units and the housing cell structures **151** are so designed and constructed that the 3,000 ampere removable circuit-breaker unit may be placed in any 1,200 ampere housing, but mechanical interference prevents placing a 1,200 ampere breaker in the operating position of a 3,000 ampere housing.

A sheltered operating aisle **153** (FIG. **34**), of ample width for handling the removable circuit-breaker units, extends the length of th e metal-clad switchgear equipment **151**. The enclosures are weatherproof with sloping roof sections for all areas. Heating is provided in the operating area.

From the foregoing description it will be apparent that there has been illustrated and described a novel fluid-blast circuit interrupter utilizing electromagnetic means, including a plurality of accelerating coils, to speed up the piston motion on heavy or fault-current interruption. By so doing, the energy requirements of the operating mechanism **123** (FIG. **2**) may be minimized. In addition, the use of such electromagnetic accelerating coil means **134** (FIG. **10**) has enabled the compression of the required gas flow to be obtained in a minimum of time. Finally, the several elements of the interrupting assembly **12** have been so positioned and interrelated in a compact and closely spaced arrangement, so that all three pole-units **13** may be operated from the same operating mechanism **123**.

Details of the lifting mechanism are set forth and claimed in U.S. Pat. application filed Sept. 19, 1966 Ser. No. 580,426 by John M. Kozlovic now U.S. Pat. No. 3,435,162, issued Mar. 25, 1969 and assigned to the assignee of the instant invention.

Although there has been illustrated and described a specific structure, it is to be clearly understood that the same was merely for the purpose of illustration, and that changes and modifications may readily be made therein by those skilled in the art, without departing from the spirit and scope of the invention.

We claim as our invention:

1. In combination, a pressurized metallic tank having a pair of spaced terminal bushings extending therein, said pressurized metallic tank having an arc-extinguishing gas disposed therein at least at atmospheric pressure, a circuit-interrupting element supported within said tank and comprising separable stationary and movable contact structures, said stationary contact structure being hollow so as to provide an exhausting flow of gas therethrough during interruption, a movable piston assembly carrying the movable contact structure and reciprocally operable within a stationary operating cylinder having a closed end portion, said movable contact structure including concentrically arranged conducting tubes, one an outer main movable contact and the inner one an arcing probe contact both movable together and both insulated from each other, electromagnetic piston-assisting means including a first accelerating coil carried by said movable piston assembly and a second stationary accelerating coil supported at the closed end portion of the operating cylinder, said electromagnetic means also including a third movable accelerating coil carried by a movable driver-unit disposed externally of the operating cylinder and mechanically connected through the closed end of the operating cylinder with the movable piston assembly so as to move therewith, said electromagnetic piston-assisting means being electrically connected between said concentrically arranged conducting tubes, and inserted electrically into the series electrical circuit during the opening operation to magnetically assist the movement of said piston assembly during fault-current interruption.

2. The combination according to claim **1**, wherein the pressurized gas is sulfur-hexafluoride (SF_6) gas.

3. The combination according to claim **1**, wherein the stationary contact structure comprises a hollow outer tubular main contact having outer contact fingers and an inner nozzle-conducting member spaced from the surrounding fingers.

4. The combination of claim **1**, wherein the movable piston assembly carries an insulating nozzle member which slides over the stationary tubular main contact to direct the gas flow through the stationary inner conducting nozzle member.

5. The combination according to claim 3, wherein the movable piston assembly carries an insulating nozzle member which slides over the stationary tubular main contact to direct the gas flow through the stationary inner conducting nozzle member.

6. The combination of claim 1, wherein the mechanical means interconnecting the driver unit and the movable piston assembly comprises a spaced pair of conducting connecting rods which serve additionally as coil-connecting means.

7. The combination of claim 1, wherein the mechanical means interconnecting the driver unit and the movable piston assembly comprises at least one piston rod which serves additionally as a coil-connecting function.

8. A fluid-blast piston-type circuit interrupter including a first relatively stationary main contact structure, a cooperable movable main contact structure cooperable therewith to carry the line current in the closed-circuit position of the circuit interrupter, said movable main contact structure establishing arcing and including a main movable first contact portion and a movable first arcing probe contact portion movable together with the first arcing probe portion insulated from the main movable first contact portion, a second separable series pair of cooperable contacts one stationary and the other movable and separable in response to separation of the first contacts, piston means including a piston operable within an operating cylinder for forcing fluid under pressure toward said arcing to effect the extinction thereof, electromagnetic means for assisting in the fluid-driving motion of said piston means including first, second and third accelerating coils, said three accelerating coils being electrically connected in series between said movable first arcing probe contact portion and said stationary contact of the second separable series pair of cooperable contacts, said first accelerating coil being supported by the movable piston, said second accelerating coil being supported by the closed end of the operating cylinder for magnetic attraction, means defining a driver unit mechanically connected to the movable piston and extending externally of the closed end portion of the operating cylinder and carrying said third accelerating coil, whereby the repulsive magnetic forces between the third accelerating coil and the second accelerating coil further assist piston-driving motion, and the separation of the first and second series-related contact structures will thereby electrically insert said three accelerating coils into the circuit to utilize attractive and repulsive magnetic forces to augment the driving motion of the piston means.

9. The fluid blast piston type circuit interrupter of claim 8, wherein the first relatively stationary main contact structure is hollow so as to permit an exhausting flow of fluid therethrough during the interruption process.

10. The fluid blast piston-type circuit interrupter of claim 9, wherein an insulating nozzle member is carried by the movable piston assembly and slides over the hollow stationary first main contact structure.

11. The fluid blast piston-type circuit interrupter of claim 8, wherein the fluid comprises sulfur-hexafluoride (SF_6) gas.

12. The fluid blast piston-type circuit interrupter of claim 8, wherein the mechanical means for connecting the driver unit mechanically to the movable piston comprises at least one piston rod which serves additionally as a coil connecting function.

13. The combination according to claim 8, wherein the first relatively stationary contact structure comprises a hollow outer tubular main contact having outer contact fingers and an inner nozzle conducting member spaced from the surrounding fingers.

14. The fluid blast piston-type circuit interrupter of claim 8, wherein an operating mechanism is provided to give an initial motion to the movable piston to thereby facilitate the transfer of the main current arc to the first arcing probe portion and thereby insert the three accelerating coils serially into the circuit.