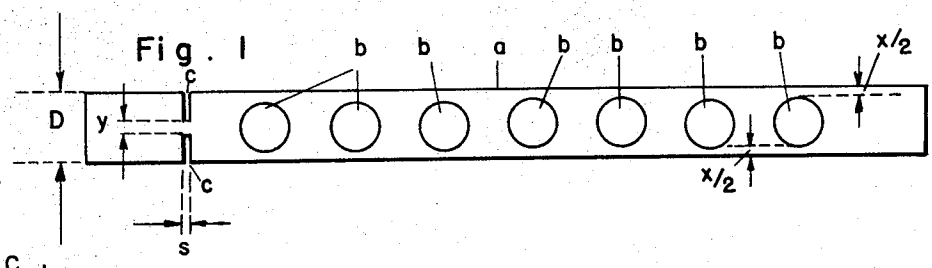
Dec. 29, 1959 F. J. KOZACKA 2,919,328

INTEGRATED MOLDED CASE CIRCUIT BREAKER CURRENT-LIMITING FUSE UNITS

Filed Aug. 13, 1956 4 Sheets-Sheet 1

Fig. 1



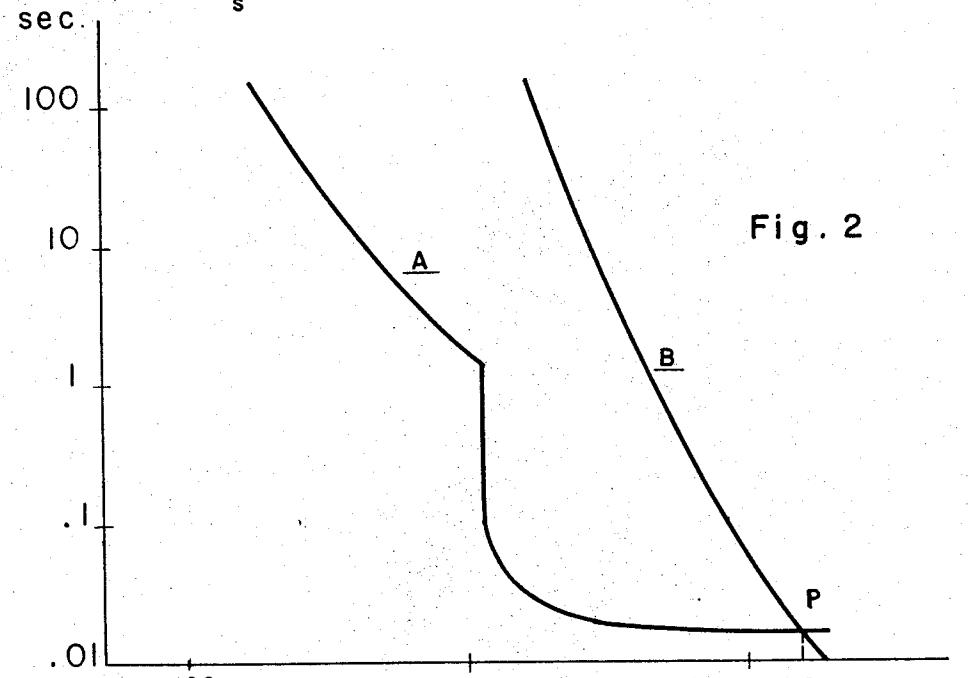


Fig. 2

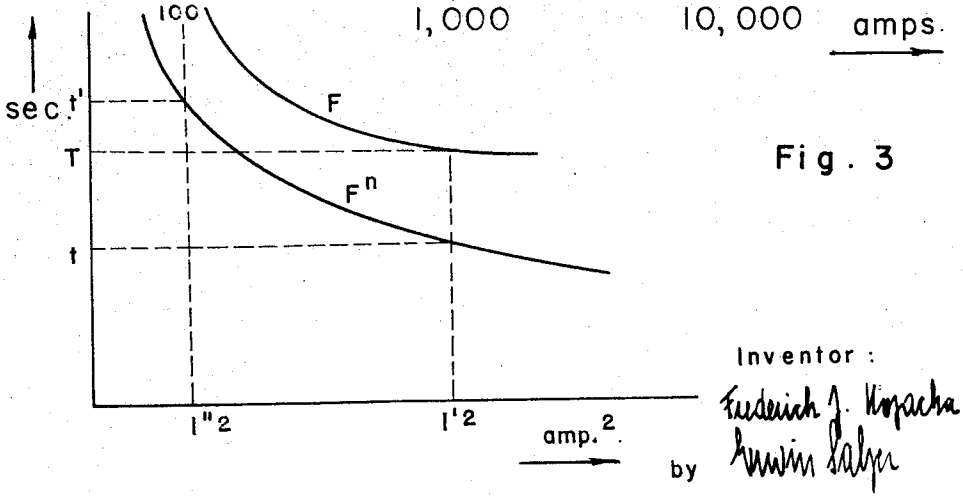


Fig. 3

Inventor:
Frederick J. Kozacka
by Irwin Salzer
Attorney

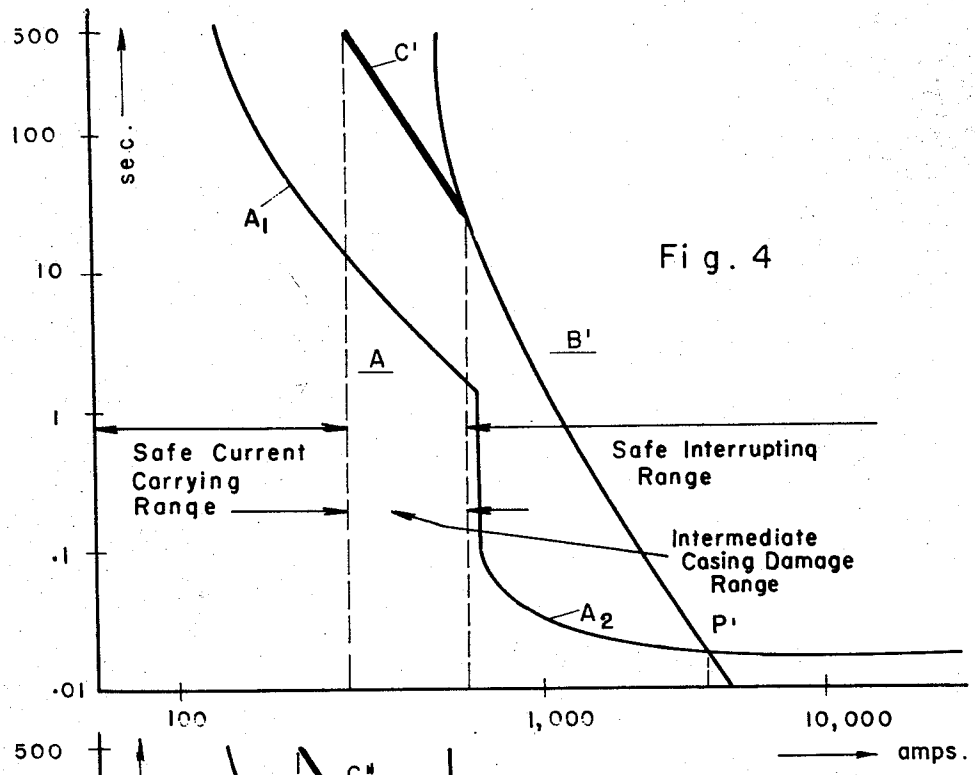


Fig. 4

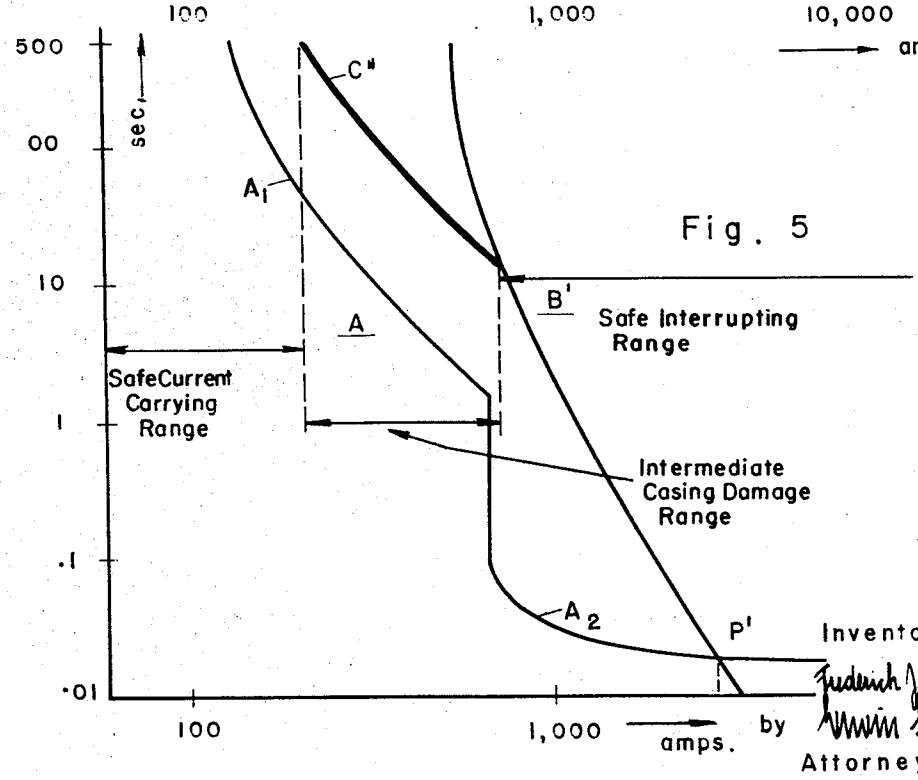


Fig. 5

Inventor:
Frederick J. Kozacka
by Irwin Salpeter
Attorney

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INTEGRATED MOLDED CASE CIRCUIT BREAKER
CURRENT-LIMITING FUSE UNITS

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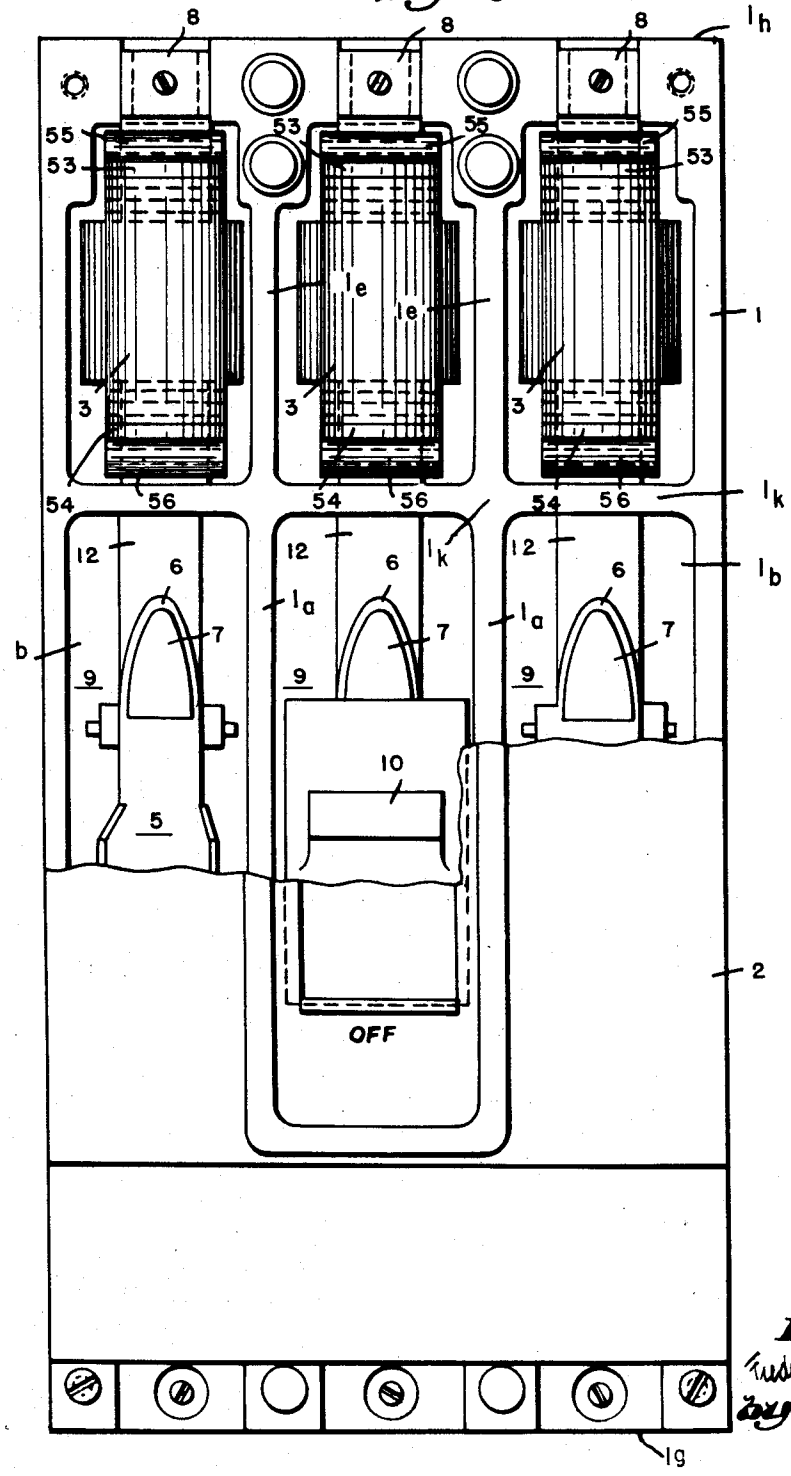
Fig. 6



Inventor:
Frederick J. Kozacka
by Irwin Salpa
Attorney

Dec. 29, 1959 F. J. KOZACKA 2,919,328

INTEGRATED MOLDED CASE CIRCUIT BREAKER
CURRENT-LIMITING FUSE UNITS

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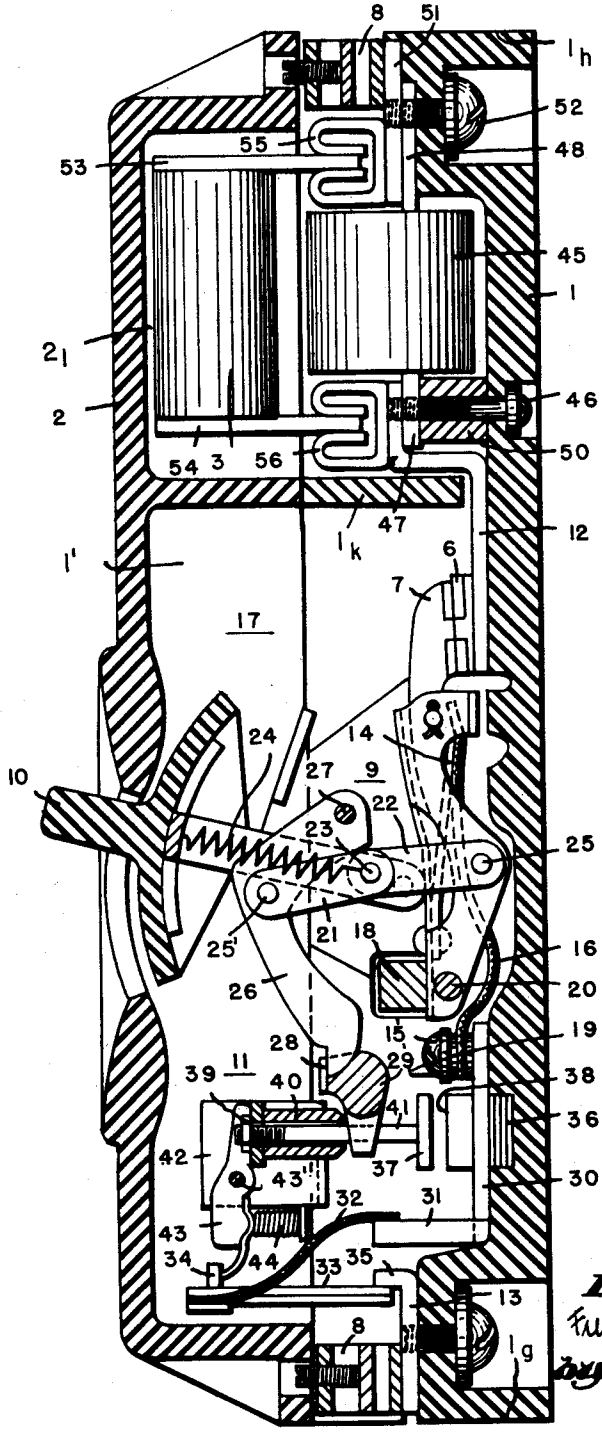
Fig. 7



Inventor:
Frederick J. Kozacka
by Irwin Lahyn
Attorney

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2,919,328

INTEGRATED MOLDED CASE CIRCUIT BREAKER CURRENT-LIMITING FUSE UNITS

Frederick J. Kozacka, South Hampton, N.H.

Application August 13, 1956, Serial No. 603,734

14 Claims. (Cl. 200—114)

This invention refers to excess current protective devices, and more particularly to combinations of molded case circuit breakers and current-limiting fuses.

Molded case circuit breakers have relatively limited interrupting capacities and it is, therefore, desirable to provide molded case circuit breakers with current-limiting back-up fuses. Current-limiting back-up fuses limit fault currents passing through the circuit breaker both as to peak and as to duration. The peaks of the let-through currents are substantially less than the peaks of the available fault currents, and the duration of the let-through currents are substantially less than one cycle of the current wave of the faulted circuit.

Great progress has been made in recent years in regard to size reduction of current-limiting fuses; yet the most compactly designed and constructed current-limiting fuses known heretofore are still much too bulky to be integrated into, i.e. built into, molded case circuit breakers of standard sizes.

It is, therefore, one object of this invention to provide molded case circuit breakers of standard sizes which are integrated with miniature current-limiting power back-up fuses therefor to jointly form a compact, self-sustained structural unit.

Another object of the invention is to provide integrated units comprising molded case circuit breakers substantially of standard sizes and miniaturized current-limiting power back-up fuses therefor wherein the fuses protect the circuit breaker against the dangerous effects of short-circuit currents, and short-circuit-current-like fault currents, and wherein the circuit breaker protects the fuses and more particularly the casings thereof against the dangerous effects of relatively small protracted overload currents.

Other objects and advantages of the invention will become apparent as this specification proceeds, and the features of novelty which characterize the invention will be pointed out with particularity in the appended claims forming part of this specification.

All parameters having a bearing upon the size of low voltage current-limiting fuses have been explored in the past. On the basis of published prior art data it appears to be impossible to design and construct sufficiently compact current-limiting fuses to achieve the objects of this invention. This invention is, therefore, predicated upon a reassessment of the possibilities of size reduction, or miniaturization, of low voltage current-limiting power fuses.

One of the variables having significant effects upon size is the material of which the casings of current-limiting fuses is made. Commonly used materials are vulcanized fiber, glass, various ceramic materials, paper, synthetic-resin-glass-cloth laminates, etc.

Progressive decrease of the size of the casing of a current-limiting fuse of given design is conducive to some kind of failure as the casing size is being progressively decreased. As casing size decreases, the operating temperatures of the casing tend to increase, and this may

cause damage to the casing. Ceramic materials lend themselves particularly well to size reduction inasmuch as they are generally capable of withstanding continuously the relatively high operating temperatures which result from size reduction. Synthetic-resin-glass-cloth laminates have generally smaller heat resisting properties than ceramics, but tend to have considerably higher bursting strength. There are many commercial current-limiting or so-called silver sand fuses wherein very little pressure is normally generated on blowing. With progressive size reduction the pressure build-up inside of the casing of a current-limiting fuse interrupting a major fault current becomes an important consideration. A starting point for a re-assessment of the possibilities of drastic size reduction or miniaturization is the question as to whether the heat resistant properties of ceramic materials, or the bursting strength of synthetic-resin-glass-cloth laminates, is more conductive to size reduction, i.e. has higher potentialities in regard to size reduction. Tests tend to indicate that there is no direct answer to this issue. Ceramic casings of current-limiting power fuses, when miniaturized beyond a certain point, tend to crack when the fuses blow on major fault currents. Synthetic-resin-glass-cloth laminate casings of power fuses, when miniaturized beyond a certain point, tend to suffer permanent thermal damage in the low overcurrent range of the fuses.

These negative test results indicate that it might perhaps be possible to achieve a drastic size reduction of current-limiting power fuses if the bursting strength of synthetic-resin-glass-cloth laminates could be utilized to contain the high pressures incident to blowing of miniaturized power fuses on major fault currents, and if some means could be devised to protect casings of synthetic-resin-glass-cloth laminates of miniaturized power fuses from being damaged by the excessive heat generation incident to relatively small protracted overloads.

For a better understanding of how acceptable structures, i.e. functionally satisfactory ultra-compact current-limiting fuses were evolved as outgrowth of the aforementioned tests, reference may be had to the accompanying drawings wherein:

Fig. 1 shows a known fuse link used to evolve a structure embodying the invention;

Fig. 2 is a diagram illustrating prior art current-limiting fuse and circuit breaker coordination;

Fig. 3 is a family of insulation damage characteristics;

Fig. 4 shows characteristics referring to a molded case circuit breaker with built-in miniature current-limiting power fuses, namely the tripping characteristic of the circuit breaker, the fusing characteristic or time-current characteristic of the current-limiting fuses, and the danger-temperature time versus current characteristic of the casing of the latter;

Fig. 5 are characteristics similar to those shown in Fig. 4;

Fig. 6 is a top-plan view of a molded case circuit breaker current-limiting fuse unit embodying this invention; and

Fig. 7 is a longitudinal section of the structure shown in Fig. 6.

Basically, any current-limiting fuse having a casing of a suitable synthetic-resin-glass-cloth laminate lends itself to size reduction along the following lines. Particularly good results can be achieved with fuse structures disclosed and claimed in the copending patent application of Frederick J. Kozacka, filed May 21, 1956, Ser. No. 586,047 for Current-Limiting Fuses With Fuse Links Arranged in Radial Planes now U.S. patent 2,826,660 issued March 11, 1958. Whatever the details of fuse structure to be miniaturized may be, it is generally desirable that the fuse links be made up of fusible elements of the gen-

eral character shown in Fig. 1. The fusible element shown in Fig. 1 consists of a ribbon or strip *a* of silver having a plurality of substantially equidistant circular perforations *b* of equal size, i.e. equal diameter. Each perforation *b* forms a point of reduced cross-sectional area the width of which is

$$2\frac{x}{2}=x$$

The fusible element *a* is further provided with an additional point of reduced cross-sectional area formed by a pair of very short lateral incisions *c*. The width *y* of the point of reduced cross-sectional area formed by incisions *c* is considerably less than the width *x* of the points of reduced cross-sectional area formed by perforations *b*, or

$$y \ll x \qquad (1)$$

As a result, on occurrence of major fault currents fusion occurs earlier at the point between incisions *c* than at any other point of ribbon *a*. The arc voltage generated at the point between incisions *c* is not sufficiently high to cause interruption of the circuit or to preclude the current from continuing to rise, but it is sufficiently high to reduce the rate of rise of the current while the link is in the process of fusing at points adjacent perforations *b*. The additional breaks formed at these points rapidly add their very considerable arc voltage to that generated between incisions *c*. Incisions *c* do not substantially reduce the current-carrying capacity of the link as long as the ratio of the width D of the link to the lengths *s* of the neck formed between incisions *c* is relatively large. The narrowness of this neck limits effectively the let-through energy

$$E=\int_{t=0}^{t=t_1} de \cdot di \cdot dt \qquad (2)$$

and consequently also the pressure rise inside the casing of the fuse during blowing thereof on major fault currents. Combining pressure-rise-limiting fusible elements of the type shown in Fig. 1 with miniaturized pressure resistant casings, i.e. miniaturized casings having a high bursting strength made of a suitable synthetic-resin-glass-cloth laminate, is of considerable importance in regard to achieving such drastic size reduction as required for integration of current-limiting fuses and of molded case circuit breakers of standard sizes to form compact self-contained structural units.

It will be understood that limiting the let-through energy at major fault currents is an important prerequisite of miniaturization since the casing of a miniaturized fuse may be subjected to an excessive thermal duty or excessive pressure over its entire current carrying and interrupting range including that of short-circuit currents. To protect the casing of a current-limiting fuse in the various current ranges involves different problems since casing failure is due to different causes in the various current ranges. When the problem of limiting the let-through energy to such an extent that the casing can withstand the thermal duty and the pressure incident to interruption of short-circuit currents is solved, then there remains the more difficult problem of precluding thermal damage to the casing in the range of relatively small overcurrents. It is with the latter problem that the invention is particularly concerned.

Referring now to Fig. 2, character A has been applied to generally indicate the tripping characteristic of a molded case circuit breaker plotted in conventional logarithmic scales. The frame size and the current rating of the circuit breaker are 100 amps. Reference character B has been applied to indicate the characteristic of a current-limiting back-up fuse for the circuit breaker. The current-limiting fuse comprises a sufficient number of ribbon type fuse links, preferably fuse links of the type shown in Fig. 1, to enable the fuse to carry currents of 100 amps. continuously without excessive heating. Both

characteristics A and B intersect at the cross-over point P. The current corresponding to cross-over point P is 15,000 amps. which is the interrupting capacity of the molded case circuit breaker. On the occurrence of the current $I=15{,}000$ amps. the circuit may be interrupted either by opening of the circuit breaker, or by blowing of any of the current-limiting back-up fuses of it. Any excess current smaller than I will be interrupted by parting of the contacts of the circuit breaker. Any excess current larger than I will be interrupted by the action of one or more of the current-limiting back-up fuses of the circuit breaker.

Whenever the size of the casing of a current-limiting power fuse of a given type and current carrying capacity is progressively decreased, the fuse tends to run at progressively higher temperatures. The initial reduction in size may result in but a small increase in the temperature of the casing, which may have no immediately perceptible effect, though it may more or less shorten the life of the organic insulating material of which the casing is made. A careful investigation of size reduction revealed that size reduction is conducive to critical current bands as pointed out below. A current-limiting fuse having a casing of reduced size made of a synthetic-resin-glass-cloth laminate will be able to carry currents up to a first critical value without damage to the organic insulating material of which the laminate is made. If the current is increased beyond a second critical value the fuse will blow before any thermal damage to the insulating casing thereof can occur. If the fuse is caused to carry currents in the range between said first critical value and said second critical value, the casing of the fuse is caused to suffer more or less severe thermal damage depending upon the extent to which size reduction has been carried into effect.

It is common practice to define various criteria for maximum temperature at which plastic insulating materials may be applied without damage. These criteria depend not only upon the nature of the plastic but also on what may be considered damage to, or deterioration of, a plastic insulating material. Where a relatively long life is expected, the criteria must necessarily be different from those obtaining where the life of insulation is expected to be but relatively short. The life of insulation does not depend so much on maximum temperatures as upon the times during which given temperatures are being maintained. An insulation damage curve shows the times required to cause a predetermined and well defined damage to an insulation test sample plotted against the temperature which must be maintained to bring about said damage. The definition of damage may be in terms of weight loss, or in terms of loss of flexural strength, etc. Fig. 3 shows particular insulation damage curves. In Fig. 3 the times necessary to cause a specified damage have been plotted against the squares of the heating current which, in turn, are substantially proportional to the heat generated. As a general rule, current-limiting fuses are designed in such a way that their casings are never subjected to excessive temperatures resulting in insulation damage, irrespective of the current within their rating which the fuses are caused to carry. Where the size of the casing of a properly designed fuse is being progressively decreased, an insulation damage curve of the type generally indicated at F in Fig. 3 may be plotted for a given reduced casing size. Further progressive reduction of the size of the casing may ultimately result in an insulation damage curve as indicated at F^n in Fig. 3. Generally speaking, progressive reduction of casing size (without reduction of current-carrying capacity) results in a family of insulation damage curves. The individual members of this family referring to relatively small casing sizes are situated below the members of this family referring to relatively large casing sizes. Thus curve F^n referring to a fuse having a casing of very small size is situated below curve F referring to a fuse having a casing of relatively large size. The current I' causes insulation damage to the relatively large casing if allowed

to flow during a period T, but damages the relatively small casing within the period *t*, where

$$t \ll T$$

The current I'' can be carried continuously by the fuse having the relatively large casing without damage to the casing, but the very same current will cause damage to the relatively small casing if allowed to flow during a period *t'*.

A current-limiting fuse having a casing of, or including, organic insulation, in order to be able to be integrated into a molded case circuit breaker of standard size, must be built so compactly as to be subject to insulation damage or, in other words, the casing of such a fuse will be thermally damaged if and when the fuse is caused to carry currents inside of the aforementioned band of relatively small currents. Such a miniaturized fuse, not capable of being applied alone, can be safely applied in combination with a molded case circuit breaker as back-up fuse therefor, provided that the overload tripping characteristic of the circuit breaker is adapted to cause interruption of the circuit before thermal damage can be done to the casing of the fuse. Assuming that the size of a given current-limiting fuse is being progressively reduced, resulting in a family of fuses of reduced size each having the current-carrying capacity required for a molded case circuit breaker of a predetermined frame size. The fuse whose casing has a diameter substantially equal to the width of a pole unit of the molded case circuit breaker may have an insulation damage characteristic situated relatively close to, yet still above, the overload tripping characteristic of the circuit breaker, i.e. the tripping characteristic of its overload tripping means. In other words, under such particular circumstances no change of the overload tripping characteristic of the molded case circuit breaker is required in order to apply the latter as a thermal protector for the casing of the miniaturized current-limiting fuse. Should a change of the overload tripping characteristic of the molded case circuit breaker be necessary, or desirable, in order to thermally protect the organic casing of the current-limiting fuse, the required adjustment of the tripping means to change the tripping characteristic should be such as not to unduly increase the tripping frequency of the circuit breaker, i.e. as to result in too many interruptions of the circuit.

As will be more apparent from the following, the inverse time-current characteristics of overload tripping devices of molded case circuit breakers matching the thermal characteristics of cables, motors, etc. are fairly compatible with the requirements for thermal protection of casings of synthetic-resin-glass-cloth laminates of current-limiting fuses miniaturized for integration with the frame structure of a molded case circuit breaker of standard frame size.

The table below indicates the approximate width available in molded case circuit breaker of various standard frame sizes for accommodating current-limiting fuses therein.

Frame Size (Amps.)	Approximate Width Available (Inches)
100	1.500
225	2.250
400	2.250
600	2.250

The above figures include the space needed for providing interphase barriers between fuses associated with different poles of a multipolar molded case circuit breaker.

Various considerations indicate that the desirable length of the current-limiting back-up fuses for the 100 ampere frame size 100 ampere current rating molded case circuit breaker should that be in the order of, and preferably less than, 2.5 inches, and the length of the current-limiting

fuses for the 225, 400 and 600 ampere frame size molded case circuit breakers rated respectively at 225, 400 and 600 amperes should be in the order of, and preferably less than, 3.00 inches. A reduction of more or less conventional current-limiting fuses with synthetic-resin-glass-cloth laminate casings to such small sizes can actually be achieved, provided that the danger temperature characteristic of their casing, or casing material damage time versus current characteristic, and the tripping characteristic of the molded case circuit breaker in combination with which they are applied are properly coordinated, as explained above.

Figs. 4 and 5 refer to a molded case circuit breaker having a 100 amp. frame size and a current rating of 100 amps., and to current-limiting miniaturized power fuses whose size has been reduced consistent with the requirements that have been set forth above.

In Fig. 4 the same circuit breaker tripping characteristic has been illustrated as in Fig. 2 and generally indicated by reference character A. Reference character A_1 has been applied to indicate that portion of the tripping characteristic which is attributable to the action of thermal overload tripping means, such as load-current-heated bimetal strips, and reference character A_2 has been applied to indicate that portion of the tripping characteristic which is attributable to the action of instantaneous electromagnetic tripping means. Fig. 4 shows further the blowing characteristic of a miniaturized current-limiting power fuse having a casing of melamin-glass-cloth laminate whose outer diameter is about 1.250 inches and whose length is about 2.500 inches forming an integral part of the molded case circuit breaker structure. This characteristic has been generally indicated by reference character B'. The cross-over point P' of A and B' is slightly below 8000 amps. The shift of the cross-over point from Fig. 2 to Fig. 4 is due to a reduction of the point of minimum cross-sectional area of the fuse links. This reduction is conducive to a reduction of the let-through energy, and to ready absorption of the latter by the miniaturized current-limiting fuse sructure. The normal size fuses to which Fig. 2 refers comprise fuse links whose length is 2 inches. The miniaturized fuses to which Fig. 4 refers comprise fuse links whose length is 1¼ inches. Due to the shorter length, each link, or fusible element, can carry a higher current. This enables a reduction of the number of fusible link elements, and of the volume of link metal needed to achieve the required current-carrying ability of 100 R.M.S. amps. The reduction of the volume of link metal makes it easier to effect circuit interruption in a limited space, and with a limited amount of pulverulent arc quenching filler, such as quartz sand. All this shows that there are factors tending to facilitate the interruption of major fault currents as casing size is decreased to the point of enabling integration of the fuse with a molded case circuit breaker substantially of standard size.

In Fig. 4 reference character C' has been applied to indicate a characteristic obtained by plotting the times required to heat the outer surface of the casing to 120 deg. C. against the currents which the fuse must carry during such times. 120 deg. C. is deemed the critical danger temperature for the particular material of which the casing of the fuse is made. Hence characteristic C' may be considered to be the danger characteristic of the casing of the fuse, or the equivalent thereof. If the fuse were used without the molded case circuit breaker in series with it, the casing of the fuse would be heated in a wide current range upward of 400 amps. above the permissible temperature limit without blowing; yet if integrated into the molded case circuit breaker and serially connected with it into an electric circuit, the casing of the fuse will never be subjected to a dengerous temperature because in the critical range upward from 400 amps. the molded case circuit breaker trips before

the danger temperature of the casing, i.e. 120 deg. C., can be reached. This is evidenced by the fact that characteristic A is situated below characteristic C'. The space between A and C' is so large as to suggest that in the particular case thermal protection of the casing of the current-limiting fuse by the overload or thermal tripping means of the circuit breaker would even enable a further size reduction of the fuse. The smaller the size of the casing, the hotter the fuse runs when carrying load currents, and the closer the thermal danger current range to the safe load current range. These are undesirable aspects of size reduction beyond the requirements imposed by the size of the associated automatic switching device or circuit breaker.

While the above considerations in regard to size reduction apply to any kind of current-limiting power fuses with casings of synthetic-resin-glass-cloth laminates, the degree to which size reduction can be achieved in any particular instance is not a matter unaffected by the specific design in hand. Size reduction is facilitated if the distance between the inner surface of the casing and the fuse links is relatively large, since this tends to protect the casing against excessive heat. Among various arrangements of fuse links inside casings of synthetic-resin-glass-cloth laminates that disclosed in the aforementioned copending patent application Ser. No. 586,047 lends itself particularly well to reduction to a diameter consistent with the width of a pole unit of a molded case circuit breaker of standard size.

The table below enables a comparison of the bulk of current-limiting fuses of standard size and miniaturized current-limiting fuses designed to be integrated into molded case circuit breakers of standard size.

In order to achieve the desired cross-over point of their respective characteristics, it is common practice to back up circuit breakers by current-limiting fuses whose current rating is much higher than the current rating of the protected circuit breaker. The table below has been prepared on the basis of conventional choices of ratings of current-limiting back-up fuses for circuit breakers. In this table L signifies length, D diameter, and V volume in inches and cubic inches, respectively.

Circuit Breaker Frame Size, amps.	Current Rating of Circuit Breaker, amps.	Current Rating of Normal Size Current-Limiting Back-Up Fuse	Normal Size Current-Limiting Back-Up Fuse			Miniaturized Current-Limiting Back-Up Fuse		
			L	D	V	L	D	V
100 (F)	100	600	3.31	2.5	14.88	2.18	1.218	2.52
225 (K)	225	1,600	3.81	3.0	26.90	2.84	2	8.92
400 (KL)	400	1,600	3.81	3.0	26.90	2.84	2	8.92
600 (L)	600	2,000	3.81	3.5	30.6	2.84	2	8.92

It will be noted from the above table that no current-rating has been assigned to the miniaturized current-limiting power fuses. This is not necessary. These fuses are constructed to have at least the same current-carrying capacity as each of the pole units of the automatic switching device or circuit breaker with which the fuses are associated and to cross the tripping characteristic of the automatic switching device or circuit breaker at a point below the interrupting capacity of the latter. The portion of time-current curve B' of the fuses which is situated above the tripping characteristic A of the circuit breaker is entirely irrelevant.

Fig. 5 is identical with Fig. 4, except for the fact that in the first-mentioned figure the casing material damage time versus characteristic C'' has been substituted for the danger temperature characteristic C'. The tests required for determining the danger temperature characteristic C' or the insulation damage characteristic C'' ought to be made with the fuses in their normal enclosure inside the automatic switch or circuit breaker or inside an equivalent enclosure simulating the conditions prevailing inside the automatic switch or circuit breaker. If characteristics C' and C'' were determined with the fuses outside an appropriate enclosure, the characteristics so obtained would not reflect actual conditions. As stated above, the casing material damage time versus characteristic is determined by taking account of the temperatures of a given insulating material as well as of the time during which the respective temperatures prevail.

The portion of the time-current curve or blowing characteristic B' situated above the danger temperature characteristic C' and above the casing material damage time versus characteristic C'', respectively, has been obtained by causing miniaturized current-limiting power fuses to carry predetermned currents irrespective of the resulting damage to their insulating casings. Some of the fuses used in making the tests resulting in the left upper end of characteristic B' were so seriously damaged as to constitute an operational hazard.

It will be understood that the danger temperature characteristic and the casing material damage time versus current characteristic of any given current-limiting fuse depends upon the nature of the synthetic resin used to manufacture the glass-cloth laminate. Silicone resins lend themselves to the design of compact current-limiting fuses on account of their ability to withstand elevated temperatures during long periods of time. Melamine resins lend themselves to the design of compact current-limiting fuses on account of the great bursting strength of their glass-cloth laminate. As a result of comparative tests conducted with casings of silicone-resin-glass-cloth laminates and melamine-resin-glass-cloth laminates it was found that preference ought to be given to the latter over the former. One of the reasons for reaching this conclusion is the important part played in size reduction by the favorable mechanical properties of melamine-glass-cloth-laminates. Another reason in favor of melamine-glass-cloth-laminates is the fact that the operating temperature of current-limiting fuses arranged in a common compact enclosure with a circuit breaker structure ought to be considerably less than the permissible maximum operating temperatures of silicone-glass-cloth-laminates. Hence it is not possible to fully utilize the heat resistant properties of silicone resins.

Figs. 6 and 7 refer to a structure more fully disclosed in the copending patent application of William S. Edsall Ser. No. 544,271, filed Nov. 1, 1955 for Protective Systems Including Circuit Interrupters and Current-Limiting Fuses and illustrate how current-limiting fuses and a molded case circuit breaker can be integrated to form a self-contained structural unit. In that particular embodiment each current-limiting fuse is shunted by a resistor. On blowing of any of the current-limiting fuses forming an integral part of the molded case circuit breaker all the poles of the circuit breaker are tripped simultaneously by the let-through current flowing through the fuse in the process of blowing and/or by the portion of the fault current flowing through the shunt resistor during blowing of the fuse and thereafter. As an alternative, each current-limiting fuse could be provided with a so-called striker pin adapted to operate a linkage adapted to unlatch the operating mechanism of the molded case circuit breaker.

As far as the present invention is concerned, it does not matter in which mode the molded case circuit breaker is being tripped incident to blowing of any of the current-limiting fuses associated with it.

In Figs. 6 and 7 reference numeral 1 has been applied to indicate the base and reference numeral 2 has been applied to indicate the cover or hood of a molded case circuit breaker. Base 1 has a plurality of parallel partitions 1_a molded integral therewith, dividing base 1 into a plurality of separate parallel channels 1_b. Base 1 forms three such channels 1_b and supports a circuit breaker structure 17 comprising three pole structures or pole units each accommodated in one of the three channels 1_b. Circuit breaker structure 17 is arranged in a space situated between two opposite parallel sides 1_g and 1_h of base 1. Three terminals 8 are arranged along each side 1_g, 1_h of base 1. Terminals 8 arranged at the side 1_g are intended to be connected to the load, and terminals 8 arranged at the side 1_h are intended to be connected to the power supply. The circuit breaker structure 17 comprises three fixed or stationary contacts 6 and three movable contacts 7 adapted to cooperate with the stationary contacts 6. Each of the three movable contacts 7 is mounted upon one of three movable switch arms 5 and forms an integral part thereof. Operating mechanism 9 includes the handle 10 and enables to move contacts 7 into engagement with, and out of engagement from, fixed contacts 6. An electroresponsive trip device generally indicated by reference numeral 11 is adapted to cause operating mechanism 9 to automatically separate contacts 7 from contacts 6 upon occurrence of relatively small overloads of inadmissible duration as well as upon occurrence of relatively large fault currents. Trip device 11 is arranged in a space situated between side 1_g of base 1, and one side of circuit breaker structure 17, i.e. the lower side thereof assuming base 1 to be mounted on a vertical wall. Each fixed contact 6 is supported by a metal strip 12 secured to base 1 and projecting through an aperture in a partition 1_k extending at right angles to partitions 1_a. Each movable contact 7 is provided with a braided shunt 16 conductively connecting the respective movable contact 7 to one of the terminals 15 of trip device 11. The opposite terminals of trip device 11 are formed by metal strips 13 upon which terminals 8 are mounted. Each pole of the circuit breaker includes a leaf spring 14 biasing one of the movable contacts 7 toward its cooperating fixed contact 6.

Cross tie 18 of insulating material joins the three switch arms 5 so that they form a unitary structure causing simultaneous movement of all contacts 7 to the closed positions and to the open positions thereof. The unitary structure formed by the three switch arms 5 and the cross-tie 18 is pivotally mounted on a frame structure 19 supporting all the parts of the operating mechanism 9 of the circuit breaker and forming an integral part thereof. Reference numeral 20 has been applied to indicate the pins securing the above referred to structural unit 5, 5, 5, 18 to frame structure 19. The operating mechanism 9 comprises also a toggle which is made up of the two toggle links 21, 22. The center pin 23 of toggle 21, 22 is operatively connected to handle 10 by means of the helical overcenter spring 24. Pivot 25 of toggle 21, 22 situated immediately adjacent to base 1 connects one end of toggle 21, 22 pivotally to the central switch arm 5. The opposite end of toggle 21, 22 is pivoted at 25' to cradle member 26. Pin 27 supports cradle or latch member 26 on frame 19. Normally cradle or latch member 26 is restrained in the position shown by a cooperating latch 28 on a trip bar 29 which extends transversely across, and is pivotally mounted on, base 1. Trip bar 29 which is preferably made of insulating material is, in turn, controlled by the trip device 11. Occurrence of an overload current of excessive duration, or of a short circuit current, causes operation of trip device 11, as a result of which trip bar 29 is rocked in counter-clockwise direction, as seen in Fig. 7. Hence latch 28 releases the lower end of cradle member 26, and the latter is moved under the action of overcenter spring 24 in clockwise direction about pivot pin 27. This movement of cradle or latch member 26 causes pin 23 to move across the center line of spring 24 which, in turn, causes toggle 21, 22 to collapse under the action of spring 24. During the collapse of toggle 21, 22 pin 25 thereof is moved from right to left, as seen in Fig. 7, and consequently the center switch arm 5 is pulled by spring 24 from the closed position to the open position thereof. Since all three switch arms 5 are tied together by cross-tie 18, the outer switch arms 5 and their contacts follow the opening movement of center switch arm 5. Upon tripping of the circuit breaker the operating mechanism thereof may be reset by moving handle 10 in closing direction which causes re-engagement of cradle or latch member 26 and latch 28.

The trip device 11 comprises electromagnetic tripping means for instantaneous operation adapted to trip at the occurrence of relatively large fault currents and thermal tripping means adapted to trip at the occurrence of relatively small overloads of excessive duration. Each channel 1_b of base 1 accommodates an electromagnetic and a thermal or overload tripping means. The current path through one pole of tripping device 11 comprises a conductor 30 fixedly secured to base 1 supporting on the upper end thereof the aforementioned terminal 15, to which braided conductor 16 is attached. The lower end of conductor 30 is provided with a projection or upright 31, to which braided conductor 32 is attached. Conductor 32 establishes a current path between bimetal strip 33 and conductor 30, or upright 31, respectively. The end of bimetal strip 33 remote from base 1 is provided with a steel pin 34 intended to serve as a latch element, whereas the end of bimetal strip 33 adjacent to base 1 is supported by conductor 13 fixedly secured to base 1. The upper portion of conductor 30 is arranged inside of a plurality of U-shaped steel laminations 36 which are magnetized upon flow of a large fault current through conductor 30. Movable armature 37 is biased by suitable spring means (not shown) away from base 1 and away from the pole surface 38 of magnetized steel laminations 36. Armature 37 is provided with a stem 41 arranged inside of a sleeve member 40 and supporting a screw nut 39 at the end thereof opposite from armature 37. If attracted toward pole surfaces 38, armature 37 moves nut 39 and sleeve 40 from left to right—as seen in Fig. 7—which results in a counter-clockwise rocking motion of trip-bar 29. Consequently latch 28 forming an integral part of trip bar 29 is moved out of engagement with cradle or latch member 26. Hence toggle 22, 23 is caused to collapse under the action of spring 24, and contacts 7 are caused to part from contacts 6.

Trip device 11 further comprises in each pole thereof a frame 42 fixedly mounted on base 1 and supporting a latch member 43 pivotally mounted at 43'. Latch member 43 is biased by a helical spring 44, and normally engages steel pin 34 on bimetal strip 33. The latter is heated by $i^2 \cdot r$ losses occurring therein. Overloads of excessive duration cause downward bending of bimetal strip 33, resulting in disengagement of steel pin 34 from latch member 43. Consequently latch member 43 is free to rotate under the action of helical spring 43 about in clockwise direction pin 43'—as seen in Fig. 7—causing a movement of sleeve 40 from left to right. This causes trip bar 29 to be rocked counter-clockwise, resulting in disengagement of latch 28 from cradle or latch member 26, and parting of contacts 7 from contacts 6.

The aforementioned transverse partition 1_k forms an integral part of base 1 and separates current-limiting fuses 3 and shunt resistor 45 from the circuit breaker structure 17. Conductors 12 extend across or through

partitions 1_k and are fixedly secured to base 1 by means of screws 46. Resistor 45 is substantially in the shape of a cylinder and comprises two blade contacts 47 and 48 for its insertion into the circuit of the circuit breaker. Blade contact 47 is arranged between an insulating spacer 59 and the upper end of conductor 12. Parts 1, 59, 47 and 12 are held together by screw 46. Blade contact 48 is jointly held in position with conductor 51 by a screw 52. The conductors 51 of each phase support the aforementioned terminals 8 situated at the side 1_h of base 1. Each current-limiting fuse 3 is provided with blade contacts 53, 54 arranged at right angles with respect to the general plane of base 1, each engaging one of a pair of fuse holders 55 and 56. Fuse holder 55 is supported by conductor 51 and fuse holder 56 is supported by conductor 12.

The size of current-limiting fuses 3 is relatively small. This is due to the fact that fuses 3 are considerably undersized, compared to the size normally required for back-up protection of a molded case circuit breaker of equal rating. The shunt resistors 45 reduce the current flow through, and the recovery voltage across, the circuit breaker upon blowing of fuses 3.

If the number of fuses blown is less than three, say but one, this still results in opening of all poles of the circuit breaker since blowing of any fuse 3 causes energization of the electro-magnetic tripping means 36, 37 associated with that particular phase, and consequently unlatching of latch 28.

It will be noted from Fig. 6 that insulating barriers 1*a* have extensions in the form of barriers 1_e of which each separates pairs of associated fuses 3 and shunt resistors 45. Resistors 45 are arranged at a lower level than fuses 3, each substantially in registry with one of the three fuses 3 inside one of the channels formed by barrier extensions 1_e. Fuses 3 are arranged in the space defined by partitions 1_k, 1_e, above base 1, and are separated from each other by extensions 2_i of partitions 1' provided in cover 2.

On occurrence of small overloads bending of bimetal strips 33 causes rocking of trip bar 29 and separation of all contacts 6, 7. In case of relatively small fault currents still well within the interrupting capacity rating of the circuit breaker, armature 37 is attracted by pole faces 38 and causes rocking of trip bar 29 and separation of all contacts 6, 7. Fuses 3 do not blow unless a large fault current occurs. The let-through current through any of the fuses 3 is sufficiently high and of sufficient duration to energize the magnet system 30, 36, 41 to cause rocking of trip bar 29 and separation of all contacts 6, 7. The fuses 3, if blown, ought to be replaced before any attempt is made to reclose the circuit breaker.

If desired, an interlock may be provided to preclude reclosing of the circuit breaker prior to renewal of blown fuses. However, as a general rule, such an interlock is not needed and, therefore, has not been shown.

While, in accordance with the patent statutes, I have disclosed the specific details of one embodiment of the invention, it is to be understood that these details are merely illustrative and that many variations thereof may be made without departing from the spirit and the scope of the invention. It is my desire, therefore, that the language of the accompanying claims shall be interpreted as broadly as possible, and that it be limited only as required by the prior state of the art.

I claim as my invention:

1. In combination a base of molded insulating material defining an elongated channel having a predetermined width; a circuit breaker pole unit having a predetermined current-carrying capacity accommodated in said channel; a current-limiting fuse having at least said current-carrying capacity adapted to be connected in series with said pole unit in an electric circuit for protection of said pole unit on occurrence of fault currents exceeding a predetermined magnitude, said current-limiting fuse being supported by said base and arranged in alignment with said pole unit, said current-limiting fuse comprising a casing of a melamine-resin-glass-cloth laminate having an outer diameter substantially equal to said predetermined width whereby said casing becomes subject to thermal impairment when said current-limiting fuse is carrying predetermined protracted small overloads; and said pole unit including tripping means sufficiently fast to trip said pole unit on occurrence of said predetermined protracted small overloads prior to thermal impairment of said casing.

2. In combination a base of molded insulating material defining an elongated channel having a predetermined width; a circuit breaker pole unit having a predetermined current-carrying capacity accommodated in said channel; tripping means for said pole unit; a current-limiting fuse having at least said current-carrying capacity adapted to be connected in series with said pole unit in an electric circuit, said current-limiting fuse being supported by said base and arranged substantially in alignment with said pole unit, said current-limiting fuse comprising fuse link means having a plurality of serially related points of reduced cross-sectional area and an additional serially related point having a more reduced cross-sectional area than each of said plurality of points of reduced cross-sectional area, and said current-limiting fuse further comprising a casing of synthetic-resin-glass-cloth laminate having an outer diameter slightly less than said predetermined width whereby said casing becomes subject to thermal impairment upon occurrence of predetermined protracted small overloads; and said pole unit comprising sufficiently fast tripping means to preclude damage to said casing on occurrence of said overloads.

3. In combination a base of molded insulating material defining a plurality of elongated parallel channels of predetermined equal width; a plurality of circuit breaker pole units each having a predetermined current-carrying capacity each accommodated in one of said plurality of channels; a plurality of current-limiting fuses each having at least said predetermined current-carrying capacity and each being adapted to be connected in series with one of said plurality of pole units in an electric circuit for protection of said pole units on occurrence of fault currents exceeding a predetermined magnitude, said plurality of current-limiting fuses being supported by said base and each arranged substantially in alignment with one of said plurality of channels, each of said plurality of current-limiting fuses comprising a casing of synthetic-resin-glass-cloth laminate having an outer diameter slightly less than said predetermined width whereby said casing becomes subject to thermal impairment upon occurrence of predetermined protracted small overloads; and each of said plurality of pole units including a tripping means sufficiently fast to trip said circuit breaker on occurrence of said overloads prior to thermal impairment of said casing of any of said plurality of current-limiting fuses.

4. In combination a base of molded insulating material defining an elongated channel having a predetermined width; a circuit breaker pole unit having a predetermined current-carrying capacity accommodated in said channel; a current-limiting fuse having at least said current-carrying capacity adapted to be connected in series with said pole unit in an electric circuit for protection of said pole unit at the occurrence of fault currents exceeding a predetermined magnitude, said current-limiting fuse being supported by said base, arranged in alignment with said pole unit, and comprising a casing of synthetic-resin-glass-cloth laminate having an outer diameter substantially equal to said predetermined width whereby said casing becomes subject to thermal impairment in accordance with a predetermined insulation-damage time versus current characteristic; and tripping means for said pole unit having a predetermined time-current characteristic

situated below said predetermined insulation-damage time versus current characteristic.

5. In combination a circuit breaker structure comprising a plurality of pole units each having a predetermined current-carrying capacity, and a predetermined interrupting capacity; a plurality of current-limiting fuses each adapted to be connected in series in an electric circuit with one of said plurality of pole units; a common base of insulating material supporting said circuit breaker structure and said plurality of current-limiting fuses; each of said plurality of current-limiting fuses being constructed to have at least the same current-carrying capacity as each of said plurality of pole units and comprising so compact a casing of a melamine-glass-cloth-laminate as to result in a band of relatively small currents which cannot continuously be carried by any of said plurality of current limiting fuses without damage to said casing thereof; each of said plurality of current-limiting fuses being adapted to be the protecting device for one of said plurality of pole units on occurrence of major fault currents exceeding said predetermined interrupting capacity, and each of said plurality of pole units comprising tripping means adapted to protect said casing of one of said plurality of current-limiting fuses from being thermally damaged on occurrence of said relatively small currents inside of said band.

6. In combination a base of molded insulating material defining an elongated channel having a predetermined width; a circuit breaker pole unit having a predetermined current-carrying capacity accommodated in said channel; a current-limiting fuse having at least said current-carrying capacity adapted to be connected in series with said pole unit in an electric circuit for protection of said pole unit on occurrence of major fault currents, said current-limiting fuse being supported by said base and arranged in alignment with said pole unit, said current-limiting fuse having a predetermined time current characteristic and comprising a casing of a synthetic-resin-glass-cloth laminate having an outer diameter substantially equal to said predetermined width of said channel whereby said casing is caused to have an insulation-damage-time versus current temperature characteristic intersecting said time current characteristic; and said pole unit including inverse time current tripping means precluding said casing from ever being subjected to the conditions described by said insulation-damage-time versus current characteristic.

7. A protective device comprising in combination a base of molded insulating material having a plurality of parallel partitions forming an integral part thereof and defining a plurality of parallel channels substantially equal in width; a circuit breaker comprising a plurality of pole units each having a predetermined current-carrying capacity and each arranged in one of said plurality of channels, each of said plurality of pole units comprising a bimetallic overload tripping device having a predetermined tripping characteristic; a plurality of current-limiting back-up fuses for said circuit breaker supported by said base each having at least said current-carrying capacity and each being arranged in alignment with one of said plurality of pole units, a plurality of conductors each adapted to connect one of said plurality of pole units and one of said plurality of current-limiting fuses in series in an electric circuit, each of said plurality of current-limiting fuses having a predetermined time current characteristic and comprising a tubular casing of melamine-glass-cloth-laminate having a diameter substantially equal to said width of each of said plurality of channels whereby said casing is caused to have a danger temperature characteristic intersecting said time current characteristic, and said tripping characteristic of each of said plurality of pole units being adapted to trip said circuit breaker before said casing of any of said plurality of current-limiting fuses can reach the danger temperature of said melamine-glass-cloth-laminate.

8. In combination an automatic switch comprising a pair of cooperating separable contacts having a predetermined current-carrying capacity, a first enclosure housing said automatic switch, conductor means for connecting another device in series with said automatic switch, a current-limiting fuse having at least said predetermined current-carrying capacity connected to said conductor means, a second enclosure housing said current-limiting fuse, said current-limiting fuse comprising a casing of a synthetic-resin-glass-cloth laminate so small in size as to be subject to insulation damage when inside said second enclosure and when carrying currents within a range intermediate a safe current-carrying range and a safe interrupting range, and said automatic switch comprising overload tripping means adapted to trip said automatic switch at the occurrence of currents inside said intermediate current range prior to substantial insulation damage to said casing of said current-limiting fuse.

9. In combination a multipolar automatic switching device comprising a plurality of pole units each having a predetermined current-carrying capacity, a common base supporting said plurality of pole units, barrier means on said base separating said plurality of pole units, a plurality of current-limiting fuses each having at least said predetermined current-carrying capacity and each being arranged on said base in alignment with one of said plurality of pole units, conductor means supported by said base for serially connecting each of said plurality of pole units to one of said plurality of fuses, cover means supported by said base for covering said plurality of pole units and said plurality of fuses, each of said plurality of fuses comprising a casing of synthetic-resin-glass-cloth laminate so small in size as to be subject to insulation damage when covered by said cover means and when carrying currents within a range intermediate a safe current-carrying range and a safe interrupting range of each of said plurality of fuses, and said automatic switching device comprising overload tripping means adapted to trip said automatic switching device at the occurrence of currents inside said intermediate current range prior to substantial insulation damage to said casing of any of said plurality of fuses.

10. In combination a multipolar automatic circuit interrupter comprising a plurality of pole units each having a predetermined width, a predetermined current-carrying capacity and a predetermined interrupting capacity, a plurality of current-limiting fuses each having a current-carrying capacity at least as high as said current-carrying capacity of one of said plurality of pole units and each having an interrupting capacity considerably higher than said interrupting capacity of each of said plurality of pole units, interrupter housing means for housing said automatic circuit interrupter, fuse housing means for housing said plurality of current-limiting fuses, means for serially connecting each of said plurality of pole units to one of said plurality of current-limiting fuses, each of said plurality of current-limiting fuses comprising a substantially tubular casing including an organic insulating material, said casing having a diameter of the same order as said predetermined width of each of said plurality of pole units whereby said casing of each of said plurality of current-limiting fuses inside of said fuse housing means becomes subject to thermal impairment on occurrence of protracted currents considerably less than said interrupting capacity of each of said plurality of current-limiting fuses, and each of said plurality of pole units having time delay tripping means adapted to trip said circuit interrupter in time to preclude thermal impairment of said casing of each of said plurality of current-limiting fuses.

11. In combination a multipolar automatic circuit interrupter comprising a plurality of pole units each having a predetermined width, a predetermined current-carrying capacity and a predetermined interrupting capacity, a plurality of current-limiting fuses each having a current-carrying capacity at least as high as said current-carry-

ing capacity of one of said plurality of pole units and each having an interrupting capacity considerably higher than said interrupting capacity of each of said plurality of pole units, each of said plurality of current-limiting fuses being arranged in alignment with and conductively connected to one of said plurality of pole units, a common frame structure including cover means for accommodating said automatic circuit interrupter and said plurality of current-limiting fuses, each of said plurality of current-limiting fuses including a substantially tubular casing of a synthetic-resin-glass-cloth laminate, said casing having a diameter of the same order as said predetermined width whereby said casing of each of said plurality of current-limiting fuses under said cover means becomes subject to thermal impairment on occurrence of protracted currents considerably less than said interrupting capacity of each of said plurality of current-limiting fuses, and each of said plurality of pole units having time-delay tripping means adapted to trip said circuit interrupter in time to preclude thermal impairment of said casing of each of said plurality of current-limiting fuses.

12. In combination a circuit breaker structure comprising a plurality of pole units each having a predetermined current-carrying capacity and each having a predetermined width; a base of insulating material supporting said plurality of pole units; a plurality of current-limiting fuses having a predetermined blowing time-current characteristic supported by said base each arranged in alignment with one of said plurality of pole units and each adapted to be connected in series in an electric polyphase circuit with one of said plurality of pole units, each of said plurality of current-limiting fuses being constructed to have at least the same current-carrying capacity as each of said plurality of pole units and comprising a casing of a synthetic-resin-glass-cloth laminate having a predetermined width of the same order as said predetermined width of each of said plurality of pole units whereby said casing of each of said plurality of current-limiting fuses becomes subject to such intense heating as to result in a casing-material-damage-time versus current characteristic having a predetermined current-range and situated below said blowing time-current characteristic; and said circuit breaker structure comprising a plurality of automatic overload tripping means each being adapted to have a time-current tripping characteristic including a portion coextensive with said current range of said casing-material-damage-time versus current characteristic and situated below said casing-material-damage-time versus current characteristic.

13. In combination a circuit breaker structure comprising a plurality of pole units each adapted to carry currents up to 600 R.M.S. amperes and each having a predetermined width; a housing of insulating material housing said plurality of pole units; a plurality of current-limiting fuses having a predetermined blowing time-current characteristic arranged inside of said housing each in alignment with one of said plurality of pole units and each adapted to be connected in series in an electric circuit with one of said plurality of pole units, each of said plurality of current-limiting fuses being constructed to have at least the same current-carrying capacity as each of said plurality of pole units and each of said plurality of current-limiting fuses comprising a casing of synthetic-resin-glass-cloth laminate having a predetermined width substantially equal to said predetermined width of each of said plurality of pole units but less than 2.500 inches whereby said casing of each of said plurality of current-limiting fuses becomes subject to such intense heating as to result in a casing-material-damage-time versus current characteristic having a predetermined current range and situated below said blowing time-current characteristic of each of said plurality of current-limiting fuses; and said circuit breaker structure comprising a plurality of automatic overload tripping means each adapted to have a time-current tripping characteristic including a portion coextensive with said predetermined current range of said casing-material-damage-time versus current characteristic and situated below said casing-material-damage-time versus current characteristic.

14. In combination a circuit breaker structure comprising a pole unit having a predetermined current-carrying capacity and having a predetermined width; a frame structure of insulating material supporting said pole unit; a current-limiting fuse having a predetermined blowing time-current characteristic arranged in alignment with said pole unit on said frame structure and adapted to be connected in series in an electric circuit with said pole unit, said current-limiting fuse being constructed to have at least the same current-carrying capacity as said pole unit and said current-limiting fuse comprising a casing including organic insulating material and having a predetermined width substantially equal to said predetermined width of said pole unit whereby said casing becomes subject to such intense heating as to result in a casing-material-damage-time versus current characteristic having a predetermined current range and situated below said blowing time-current characteristic; and said pole unit comprising automatic overload tripping means adapted to have a time-current tripping characteristic including a portion coextensive with said predetermined current range of said casing-material-damage-time versus current characteristic and situated below said casing-material-damage-time versus current characteristic.

References Cited in the file of this patent

UNITED STATES PATENTS

2,140,360	Jennings	Dec. 13, 1938
2,358,215	Darling	Sept. 12, 1944
2,416,951	Prince	Mar. 4, 1947
2,473,196	Dannenberg	June 14, 1949
2,662,140	Kozacka	Dec. 8, 1953
2,800,556	Swain et al.	July 23, 1957
2,809,257	Swain	Oct. 8, 1957
2,843,702	Edmunds	July 15, 1958

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,919,328 December 29, 1959

Frederick J. Kozacka

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 40, for "sructure" read -- structure --; line 72, for "dengerous" read -- dangerous --; column 7, line 70, column 8, lines 6 and 14, after "versus", each occurrence, insert -- current --; same column 8, line 16, for "predetermned" read -- predetermined --; column 10, line 65, for "spring 43 about" read -- spring 44 --; line 66, before "pin" insert -- about --; column 11, line 38, for "l'" read -- le --; column 13, line 42, strike out "temperature".

Signed and sealed this 4th day of October 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents

UNITED STATES PATENT OFFICE

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